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The Effects of Low Volume High-Intensity Interval Training vs. Moderate-Intensity Interval Training With Blood Flow Restriction on Body Composition, Hormone Concentration, and Arterial Elasticity in Overweight and Obese Male Adults

Alexis Lopez

THE EFFECTS OF LOW VOLUME HIGH-INTENSITY INTERVAL TRAINING VS. MODERATE-INTENSITY INTERVAL TRAINING WITH BLOOD FLOW RESTRICTION ON BODY COMPOSITION, HORMONE CONCENTRATION, AND ARTERIAL ELASTICITY IN OVERWEIGHT AND OBESE MALE ADULTS

A Thesis

by

ALEXIS LOPEZ

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ABSTRACT

Lopez, Alexis., The Effects of Low Volume High-Intensity Interval Training vs. Moderate-Intensity Interval Training with Blood Flow Restriction on Body Composition, Hormone Concentration, and Arterial Elasticity in Overweight and Obese Male Adults. Master of Science (MS), August, 2023, 171 pp., 3 tables, 107 figures, references, 72 titles.

PURPOSE: This study compared the effects of HIIT and MIIT+BFR on the adaptations in body composition, salivary hormone concentration, peak oxygen uptake, anaerobic parameters, and arterial elasticity in young overweight and obese male adults.

RESULTS: There was a significant increase in total BMC ($p<0.01$), leg BMC ($p<0.05$), and trunk BMC ($p<0.05$) from baseline in response to HIIT. MIIT+BFR significantly increased LFM/TFM Ratio from baseline ($p<0.01$). HIIT significantly decreased AIx@75 ($p<0.05$) and CI ($p<0.05$). There was a significant increase in ISO 180^{o} Away ($p<0.05$), Thor Begin. ($p<0.01$), and Thor Mid. ($p<0.05$) in response to HIIT. MIIT+BFR had a superior increase in Thor Mid. ($p<0.05$) and significantly increased ISO 180^{o} Toward ($p<0.01$), VO_{2peak} ($p<0.05$), and VO_{2peak}:Time ($p<0.05$). In the last training session, HIIT significantly increased salivary leptin ($p<0.05$), but MIIT+BFR had a superior increase in salivary leptin ($p<0.01$) from pre- to post exercise.

CONCLUSION: HIIT significantly improved total BMC, leg BMC, trunk BMC, and AIx@75 but decreased CI from baseline. HIIT increased quad muscle strength, whereas MIIT+BFR increased hamstring muscle strength. HIIT and MIIT+BFR significantly increased peak torque in Thor Mid and salivary leptin. Only MIIT+BFR significantly improved VO_{2peak}.

DEDICATION

I want to dedicate this accomplishment to my family. This thesis took much more than I thought I had to give. My mother, Dora L. Sanchez, and sister, Kimberly Lopez, were so patient and understanding, but most important, they were supportive. I am grateful for them. My mother and sister had to take on the full responsibility of caring for the house, the bills, and other miscellaneous things. They also cared for me whenever I faced financial trouble. I want to also dedicate this accomplishment to my grandma, Martha Sanchez-Vega, and uncle, Ricardo Sanchez. I did not have a working car for a time due to car troubles, but thanks to my uncle, he lent me his vehicle, so I could continue driving to school. Whenever I ran on a tight schedule and could not find the time to cook a meal for myself, my grandma would ensure I would always find a hot meal at home. I am lucky to have my family. Taking on a big project like this and getting it done did not go in vain. I have learned through the struggle, and now I see things clearly far better than I ever could before. From here on, I can only think of good things for me and my family.

I want to dedicate this endeavor to my father, Silvestre Lopez, whose soul may rest peacefully. My dad did everything he could to ensure I would grow up with a strong mindset and drive. My dad was no doctor or someone with some fancy title. He was a self-employed electrician and an HVAC repairman who cared for the entire family. My dad had his fair share of struggles but did everything he could to keep the family moving forward. Thanks to him, I will do what he raised me to do, achieve a future of my own making. I will make my mark for him and my family. And one day, I will even surpass him. I will make my dad, my mom, and my sister proud.

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CHAPTER I

INTRODUCTION

Obesity is associated with accumulated visceral fat and an increased risk of developing cardiovascular diseases (CVDs) (Zhang et al., 2017). The occurrence of other obesity-related risk factors, such as high blood pressure, diabetes, and dyslipidemia increases an individual's mortality and morbidity rate (Reljic et al., 2020; Tsirigkakis et al., 2021). Excessive body fat increases total blood volume and cardiac output, which causes an elevation in arterial wall stress, smooth muscle cell proliferation, and blood vessel thickness, resulting in arterial stiffness (Cooper et al., 2012). A reduction in central arterial elasticity is another risk factor contributing to the development of CVDs, further increasing mortality rate (Guimaraes et al., 2010; Kawano et al., 2006).

Arterial elasticity is also associated with sedentary lifestyle that induces an imbalance of anabolic and catabolic hormones such as testosterone and cortisol, contributing to the manifestation of health complications (Dote-Montero et al., 2021b). Leptin, an adipocytokine secreted from adipose tissue, is positively correlated with greater body mass index and insulin resistance (Racil et al., 2016b). Fortunately, studies have shown aerobic exercise is a great prescription to induce fat loss, improve hormone concentration, and decrease arterial stiffness while improving arterial elasticity (Zhang et al., 2017; Dote-Montero et al., 2021b; Amani-Shalamzari et al., 2020; Paolucci et al., 2018; Kim et al., 2017; Kawano et al., 2006).

High-intensity interval training (HIIT) is a popular exercise modality used for fat loss, involving brief and intense bouts of exercise separated by resting periods (Reljic et al., 2020). Fat loss is typically accomplished through high volume, long duration, and continuous exercise at a moderate intensity (Zhang et al., 2017). Increasing the exercise intensity from moderate to high intensity leads to a shift in energy sources from free fatty acid and intramuscular triglycerides to blood glucose and muscle glycogen (Zhang et al., 2017). High-intensity exercise reduces the rate of fatty acid mobilization, yet HIIT induces similar metabolic adaptations commonly seen in aerobic training (Zhang et al., 2017). Aerobic exercise training such as walking, running, biking, or swimming does not attract much interest from overweight or obese individuals, regardless of whether this exercise type induces weight loss (Racil et al. 2016b). HIIT is short-duration with repeated bursts of intense exercise such as sprinting and cycling, and it is time-efficient (Zhang et al., 2017; Reljic et al., 2020; Guimaraes et al., 2010). HIIT results in a reduction in plasma leptin concentration, which is associated with a lower body fat percentage (Racil et al., 2016b) and decreased arterial stiffness in hypersensitive individuals (Guimaraes et al., 2010; Ciolac et al., 2010). HIIT has also reduced serum cortisol and increased serum testosterone in physically inactive middle-aged men (Dote-Montero et al., 2021b) and free testosterone in older adults (Hayes et al., 2017). Improvements in testosterone concentration have been speculated to explain the increases in fat-free mass (Hayes et al., 2017) with increased salivary testosterone concentrations being positively correlated with body fat reduction and increases in aerobic capacity in sedentary older men after HIIT (Hayes et al., 2013). However, the effects of HIIT on hormone concentration, arterial elasticity, pulse wave analysis, and pulse wave velocity in overweight and obese young adults are yet to be determined.

Blood flow restriction training (BFR) combined with low- to moderate-intensity aerobic exercise training improves aerobic capacity, body lean mass, and muscular strength (Kim et al., 2016; de Oliveira et al., 2016; Amani-Shalamzari et al., 2019). Studies have shown that intermittent bouts of cycling exercise with BFR induce the early onset of blood lactate concentration in deoxygenated muscles, recruiting higher-order, poorly oxidative muscle fibers, thus causing muscle remodeling and training adaptations (de Oliveira et al., 2016; Corvino, 2017). These training adaptations in response to low-intensity aerobic exercise with BFR can result in increases in isometric strength, which are not seen in high-intensity aerobic exercise (de Oliveira et al., 2016; Kim et al., 2016); furthermore, aerobic capacity and maximal power output have increased in just four weeks of low-intensity interval training with blood occlusion (de Oliveira et al., 2016). Various combinations of occlusion pressure and exercise intensity have been shown to induce significant increases in aerobic and anaerobic parameters and muscle strength (Amani-Shalamzari et al., 2019). In just four weeks of interval training at 60% of the speed of maximal oxygen consumption (vVO_{2max}) or 60-85% of vVO_{2max}, an increasing blood flow restriction pressure of 160 to 240 mmHg, a constant complete BFR pressure of 240 mm Hg, and a constant partial occlusion pressure of 160 mm Hg have increased VO_{2max}, time-to-fatigue, running economy, muscular strength, and peak, average, and minimum power output in physically active collegiate women (Amani-Shalamzari et al., 2019). Increases in aerobic capacity parameters may result from the reduced O_2 delivery in response to BFR, which has been reported to increase pulmonary VO_2 on-kinetics despite a workload 3.5 times less than HIIT (Corvino et al., 2019). In addition, these adaptations can also be seen in high-intensity interval training with BFR, which has demonstrated significant increases in aerobic capacity, running economy, and time-to-fatigue, along with increases in testosterone and decreases in cortisol in futsal athletes (Amani-Shalamzari

et al., 2020). However, the effects of moderate-intensity interval training with BFR (MIIT+BFR) on body composition, hormone concentration, arterial elasticity, pulse wave analysis, and pulse wave velocity in overweight and obese young adults are yet to be identified. Henceforth, this study would provide further evidence to determine if low volume HIIT and MIIT+BFR can induce fat loss, improvements in peak oxygen uptake and average anaerobic power output, hormone concentration, and arterial elasticity in overweight and obese young male adults.

Statement Of The Problem

Adipose tissue (AT) is a multifunctional endocrine organ that secretes adipokines, which contribute to low-grade systemic inflammation, thereby affecting the development of secondary diseases of obesity such as metabolic syndrome, diabetes, hypertension, and atherosclerosis (Schmidt et al., 2015; Tsiotra et al., 2013). In addition, high concentrations of leptin and low-grade inflammation contribute to atherosclerosis and myocardial infarction in obese individuals (Tsiotra et al., 2013). Thus, targeting leptin with an intervention such as exercise could negate their effects while reducing the risk of new-onset diseases. Evidence has shown that moderate-intensity aerobic exercise can improve the systemic inflammation markers in obese individuals (Al-Sharif et al., 2020). However, many overweight and obese individuals report a lack of time as a reason for being unable to engage in exercise (Reljic et al., 2020).

Obesity can elevate cortisol levels due to abnormal regulation of the hypothalamic-pituitary-adrenal (HPA) axis (O'Leary and Hackney, 2014). The excessive release of cortisol is also stimulated due to visceral fat releasing interleukin-6 and tumor necrosis factor-alpha into the circulation, contributing to systemic inflammation. This prolonged stress exposure to elevated cortisol levels is followed by a decrease in the number of glucocorticoid receptors that accentuate adipocyte differentiation in adipose tissue, thus attenuating lipolysis and worsening the obese state

of an individual (O'Leary and Hackney, 2014). Excessive cortisol levels and obesity have an inverse relationship with testosterone concentration in men (O'Leary and Hackney, 2014). High fatty tissue levels can lead to the aromatization of circulating testosterone to elevated circulating estradiol, resulting in low testosterone levels. Testosterone concentrations are also reduced in response to decreased sex hormone-binding globulin and burnout of the HPA axis caused by elevated cortisol levels and adiposity. As previously mentioned, prolonged stress exposure due to high cortisol concentration ultimately burns out the HPA axis, which would increase the sympathetic nervous system and catecholamine release, resulting in a greater increase in the activity of the HPA axis (O'Leary and Hackney, 2014). Chronic exercise is crucial to result in decreases in fat mass and cortisol concentrations, thereby increasing testosterone concentration and regulating the HPA axis.

High body fat levels burden the cardiovascular system as the working heart increases total blood volume and cardiac output. In addition, the arterial blood vessels experience elevations in the arterial intima, smooth muscle growth, and thickness (Cooper et al., 2012). The stress imposed on the heart and blood vessels results in a decrease in arterial elasticity and an increase in arterial stiffness, thus making it difficult for oxygenated blood to reach the working tissues. Arterial elasticity is a noninvasive predictor for the prevalence of CVDs (Cooper et al., 2012). In addition, low cardiorespiratory fitness (CRF) or aerobic capacity is another independent predictor of CVDs and mortality in individuals with high-body body fat (Reljic et al., 2020). Overweight and obese individuals report having no time to exercise, thereby bound to have low CRF levels (Reljic et al., 2020).

HIIT is an effective and time-efficient form of aerobic training (Tsirigkakis et al., 2021). The exercise intensity levels for HIIT are based on VO_{2max}, peak oxygen consumption (VO_{2peak}),

and peak power (W_{peak}), which are commonly assessed from a continuously graded exercise test protocol that measures CRF (Reljic et al., 2020; Zhang et al., 2017; Racil et al. 2016b). Aside from VO_{2max} and VO_{2peak}, power output can also be determined from a 30-second Wingate cycling test. The 30-second Wingate cycling test is commonly used for sprint interval training, a form of anaerobic training that involves training participants at supramaximal intensity for very short-duration sprint cycling bouts against 7.5% of body weight resistance (Whyte et al., 2010; Gibala et al., 2006). Setting the exercise intensity based on the average power output resulting from the 30-second Wingate cycling test would make HIIT a form of anaerobic training instead of aerobic. This leads to the question of the effects of anaerobic interval training with or without BFR on body composition, salivary hormone concentration, peak oxygen uptake, and arterial stiffness in overweight and obese young male adults. In addition, if the exercise training intensity is based on the results from a Wingate anaerobic test, would the interval training with or without BFR induce any increases in muscular size, power, and/or strength?

Purpose

This study compared the effects of two different anaerobic training protocols, which are high-intensity interval training (HIIT) and moderate-intensity interval training with BFR (MIIT+BFR), on the adaptations in body composition, salivary hormone concentration, peak oxygen uptake, average anaerobic power output, and arterial elasticity in young overweight and obese male adults. The study's primary objective was to determine which training protocol results in the best fat loss, salivary hormone concentrations, lean mass, average anaerobic power output, strength, peak oxygen uptake, and arterial elasticity. The secondary outcome of this study was to determine the acute and chronic hormone concentrations of testosterone, cortisol, and leptin in response to one exercise session and after 8 weeks of low-volume exercise training.

Significance

Obesity contributes to developing secondary diseases such as hypertension, asthma, metabolic syndromes, and atherosclerosis (Schmidt et al., 2015). An increase in adipokines such as leptin and an imbalance of testosterone and cortisol levels could be possible mechanisms for developing such diseases in obese individuals (Schmidt et al., 2015; Tsiotra et al., 2013; Hayes et al., 2017). An obese individual may follow the ACSM's guidelines to the standard recommendation of aerobic exercise training, which result in a significant loss in fat mass and low-grade systemic inflammation (Al-Sharif et al., 2020). However, since obese individuals report a lack of time for not being able to engage in this type of exercise (Reljic et al., 2020), the time efficiency of HIIT could improve the concentrations of testosterone, cortisol, and leptin. On the other hand, high-intensity exercise training with blood flow restrictions has been shown to increase muscle mass, strength, aerobic capacity, and testosterone concentrations with decreases in cortisol (Kim et al., 2016; de Oliveira et al., 2016; Amani-Shalamzari et al., 2020). However, the effects of MIIT+BFR on arterial elasticity in obese individuals is still unknown.

Assumptions

The following assumptions are made:

1. The overweight and obese participants performed their exercises to the best of their ability.
2. The overweight and obese participants provided accurate health history and medical information.
3. The overweight and obese participants did not purposely alter their diet to induce fat loss.
4. The overweight and obese participants did not consume any fat loss supplements during the study.

5. The overweight and obese participants did not engage in another training program while volunteering in this study.
6. The overweight and obese participants were at least 8 hours fasted during pre- and post-testing.
7. All testing assessments used provided accurate information for each type of measurement that is valid and reliable.
8. The equipment used was valid and reliable to provide accurate information for each testing session.

Delimitations

The study's delimitations follow:

1. The male participants must have had a body mass index greater than 24.9 to be eligible for this study.
2. Participants had to be sedentary and healthy.
3. The participants were excluded if diagnosed with diseases (e.g., diabetes, heart disease, etc.), musculoskeletal injuries impairing physical performance, history of blood clots, varicose veins, deep vein thrombosis (DVT), or other conditions that would impede venous return.

Limitations

1. Health history and medical information were self-reported.
2. Only male individuals aged 18 to 40 were allowed to participate in the study.
3. Daily diet habits were not changed for this study or monitored.
4. This study recruited overweight and obese male participants and randomly divided them into groups; thus, the subject population might not represent a specific population.

5. The exercise intensity of the training study was based on the results of a 30-second Wingate test instead of a cycling-graded exercise test.
6. The BMI calculation was used to determine if a young male adult volunteer was overweight or obese or not.

Research Questions

The following research questions are addressed:

1. Which training protocol, HIIT or MIIT+BFR, will improve body composition in overweight and obese young male adults?
2. Will low-volume HIIT and MIIT+BFR significantly improve isometric and isokinetic strength in the legs?
3. Will low-volume HIIT and MIIT+BFR significantly improve average anaerobic power output and peak oxygen uptake in overweight and obese males?
4. Which training protocol, HIIT or MIIT+BFR, will induce significant changes in arterial elasticity, pulse wave velocity, and pulse wave analysis in overweight and obese males?
5. Which training protocol, HIIT or MIIT+BFR, will significantly improve salivary hormone concentrations?

Hypothesis

The study is designed to address the following hypothesis:

1. MIIT+BFR will result in similar benefits on body weight, fat, lean, and fat-free mass as HIIT.
2. MIIT+BFR will result in similar strength adaptations as HIIT.
3. MIIT+BFR will result in similar improvements in average anaerobic power output and peak oxygen uptake like HIIT.

4. MIIT+BFR will result in a similar improvement in hemodynamic and cardiovascular parameters as HIIT.
5. MIIT+BFR will result in similar improvements in salivary hormones like HIIT.

Definitions

The following terms are defined as used in this research project:

Cycle Ergometer (Monark 874 E, Sweden): A stationary exercise bicycle that measures the amount of work humans perform. This cycle ergometer was used for the HIIT group.

Electronically Braked Cycle Ergometer (Monark 928 E, Sweden): An electronically braked and stationary exercise bicycle that measures the amount of work humans perform. This cycle ergometer was used for the MIIT+BFR group.

30-Second Wingate Cycling Protocol: A 30-second maximal exercise test was performed on a leg cycle ergometer to determine the average anaerobic power output.

Bruce Protocol: A standard graded exercise test performed on a treadmill. The Bruce protocol is comprised of multiple exercise stages of three minutes each. At each stage, the gradient and speed of the treadmill are elevated to increase the resting metabolic equivalent (MET). After reaching volitional exhaustion, the peak oxygen consumption was calculated.

Resistance Bands: Color-coded elastic bands that become resistive at a given length.

Blood Flow Restriction Cuffs: A 3-cm-wide cuff is placed and inflated around the most proximal region of both arms and legs, compressing and reducing blood flow to the proximal exercising muscles by the KAATSU Master device (KAATSU, Sato Sports Plaza, Tokyo, JAP).

SphygmoCor® Pulse Wave Analyzer (AtCor Medical Pty. Ltd., Sydney Australia): A noninvasive global gold standard technology for assessing the arterial pulse and velocity shape.

HDI/PulseWave CR-2000TM Research Cardiovascular Profiling System (Hypertension Diagnostic, Inc., Eagan, Minnesota, USA): A noninvasive cardiovascular profiling technology that assesses arterial elasticity.

Biodex Isokinetic Dynamometer: A computer-assisted leg extension machine used to assess muscle strength, power, endurance, etc. This device was used to administer the Thorstensson Test of Fatigability, Maximal Voluntary Contraction (MVC), and Isokinetic Unilateral tests.

Thorstensson Test of Fatigability: A test that correlates the amount of muscle power produced at a fixed rate of speed over fifty repetitions performed during leg extension. In other words, it provided the fatigue index of fast-twitch muscle fibers.

Dual-Energy X-Ray Absorptiometry (DXA): DXA (GE Lunar Prodigy, enCORE software version 6.70.021; GE Healthcare, Madison WI) is a scanner that measured body composition and provide measures of whole-body and regional fat mass, muscle mass, and bone mass.

Anthropometric Measures: Height, weight, body mass index (BMI), heart rate, and blood pressure.

Venous Return Questionnaire: Answering “yes” to any question excluded the subject from the study. The Principal Investigator, a Certified Clinical Exercise Physiologist, interpreted this questionnaire.

Health Screening Questionnaire: Parts 1 and 3 of the questionnaire were used to get background information from the participants. Part 2 assessed if the participant qualifies for the study. If any participant answers "yes" to questions 15, 16, and 17, they were excluded from the study. If the participant provided more than 3 answers to question 18, they were excluded from this study.

Physical Activity Readiness Questionnaire (PAR-Q): A simple self-screening tool used to determine the safety or possible risks of exercising based on their health history, current symptoms, and risk factors.

Borg's RPE Scale: (Rating of Perceived Exertion): A scale that measures physical activity intensity level. Perceived exertion is how hard you feel like your body is working.

Summary

HIIT is a time-efficient exercise modality that can result in weight loss in overweight and obese individuals (Zhang et al., 2017). Therefore, this study aimed to improve the concentration of specific hormone concentrations, body composition, peak oxygen uptake, average anaerobic power out, and arterial elasticity in overweight and obese participants. These variables were also assessed for moderate-intensity interval training with blood flow restriction. The salivary concentrations of leptin, testosterone, and cortisol were assessed after one exercise session and 8-weeks of low-volume training. Hence, the literature review relevant to this study was used to identify the essential characteristics of an exercise program fit to improve overweight and obese individuals' physical abilities, cardiovascular profile, and hormone concentrations.

CHAPTER II

REVIEW OF LITERATURE

This study compared the effects of two different anaerobic training protocols, which are high-intensity interval training (HIIT) and moderate-intensity interval training with BFR (MIIT+BFR), on the adaptations in body composition, salivary hormone concentration, peak oxygen uptake, average anaerobic power output, and arterial elasticity in young overweight and obese male adults. The study's primary objective was to determine which training protocol results in the best fat loss, salivary hormone concentrations, lean mass, average anaerobic power output, strength, peak oxygen uptake, and arterial elasticity. The secondary outcome of this study was to determine the acute and chronic hormone concentrations of testosterone, cortisol, and leptin in response to one exercise session and after 8 weeks of low-volume exercise training.

Introduction

Obesity can lead to premature morbidity and mortality as accumulated visceral fat and low-grade systemic inflammation are diseases that are related to cardiometabolic risk factors (Reljic et al., 2020; Tsirigkakis et al., 2021). Moreover, obesity can reduce arterial elasticity and testosterone concentration due to obese individuals living a sedentary lifestyle involving little physical activity (Cooper et al., 2012; Dote-Montero et al., 2021b). Achieving weight loss is a challenge for most people who are overweight or obese. Obese individuals claim lack of time as the main barrier to participating in physical activity (Reljic et al., 2020). High-intensity interval training (HIIT) is a

time-efficient exercise methodology involving short-bouts of physical activity at a high to a maximal intensity that results in weight loss along with decreased leptin levels (Zhang et al., 2017; Racil et al., 2016b). In addition, HIIT is another form of vigorous exercise training that could reduce arterial stiffness, cortisol concentrations, and improve testosterone levels (Guimaraes et al., 2010; Ciolac et al., 2010; Dote-Montero et al., 2021b). However, HIIT could be too vigorous for some obese individuals. They could feel discouraged from engaging in physical activity; thus, the application of BFR to moderate-intensity interval training could be another alternative to induce fat loss, improve hormone concentrations, and decrease arterial stiffness. Furthermore, one of the benefits of combining BFR with exercise training is that it enables the individual to exercise at a low-to-moderate intensity and produce an improved aerobic capacity, muscle hypertrophy, and strength (Kim et al., 2016; de Oliveira et al., 2016; Amani-Shalamzari et al., 2020).

Since the intensity of this research training study will be based on the average power output resulting from a 30-second Wingate cycling protocol, it is essential to know how anaerobic training affects arterial elasticity, body composition, and hormone concentration. Resistance training or weightlifting is another form of anaerobic training (Ozaki et al., 2013; Kawano et al., 2006). Previous research has demonstrated that chronic resistance training can decrease carotid arterial compliance (Ozaki et al., 2013; Kawano et al., 2006). However, what are the effects of anaerobic training when the training intensity is based on 40-60% or 80-100% of average power output (W_{avg}) on hemodynamics, arterial elasticity, body composition, and hormone concentration in overweight and obese young male adults? The 30-second Wingate cycling protocol is commonly used for sprint interval training (SIT), a particular form of very high-intensity and very low-duration exercise training, which involves 4-6 repeated 30-second “all-out” cycling sprints against the resistance of 7.5% of body weight interspersed by 4-minutes of rest (Whyte et al., 2010; Gibala

et al., 2006). On the contrary, the exercise protocols for this training study are bike interval training at a fixed cadence of 60 revolutions per minute at an intensity level of 40-60% W_{avg} with BFR or 80-100% W_{avg} for 8 bouts of 60-seconds of cycling or 16 bouts per 30-seconds of cycling, respectively.

This review includes the following topics: The Chronic Effects of HIIT in the Obese Population, The Chronic Effects of HIIT in Young and Older Populations, The Chronic Effects of HIIT on Arterial Elasticity, The Acute Effects of Interval Exercise with BFR, The Chronic Effects of Interval Training with BFR, The Chronic Effects of Interval Training with BFR vs. HIIT, The Effects of Resistance Training on Arterial Compliance, The Effects of Sprint Interval Training.

The Chronic Effects of HIIT in the Obese Population

A study by Racil et al. (2016b) demonstrated that 12 weeks of combined plyometrics (P) and HIIT resulted in greater reductions in leptin concentrations in obese adolescent female participants. Twenty-one obese female participants were subjected to HIIT, and 25 partook in HIIT+P. The training programs lasted 12 weeks, with three sessions per week. The HIIT program included two training blocks separated by 4-minutes of passive recovery. Each block consisted of six-eight 30-second bouts of running at 100% velocity at VO_{2peak} (vVO_{2peak}) with 30-seconds of active recovery running at 50% vVO_{2peak}. The HIIT+P program followed the same format as the other experimental group but with two plyometric training blocks preceding the high-intensity interval exercises. The two plyometric blocks consisted of three different plyometric exercises executed for 15-seconds followed by 15-seconds of passive recovery totaling 2 minutes per exercise. The plyometric blocks were separated by 1-minute passive recovery, and each exercise was separated by 30-seconds. After 12 weeks of training, both HIIT and HIIT+P groups demonstrated significant decreases in body mass by -3.8 ± 3.9% vs. -2.0± 1.0%, BMI Z-score by

-15.9 ± 4.8% vs. -9.6± 2.6%, and body fat percentage by -7.1 ± 1.7% vs. -7.2± 1.8%, respectively. However, HIIT+P significantly increased lean body mass by 3.0 ± 1.7%. The plasma leptin concentrations were significantly reduced in response to both experimental groups. HIIT+P induced greater reductions in plasma leptin concentration by 23.8 ± 5.8% compared to only HIIT, which induced a 14.0 ± 5.4% decrease. Furthermore, both HIIT and HIIT+P significantly increased VO_{2peak} by 7.0 ± 2.2% vs. 9.5± 3.0% and vVO_{2peak} by 10.9 ± 4.8% vs. 11.7± 6.0%, respectively.

In another study by Racil et al. (2016a), obese female adolescents were subjected to 12 weeks of moderate-intensity interval training (MOIT) or HIIT. The participants from both protocols had to perform three weekly sessions, and each session consisted of 3 bouts of 4-8 minutes of interval running. In other words, 15 seconds of running followed by 15 seconds of active recovery until completing 4-8 minutes of exercise per bout. Three minutes of passive recovery separated each bout. The intensity of the MOIT protocol was set at 80% maximal aerobic speed (MAS), followed by an active recovery at 50% MAS. In contrast, the participants in the HIIT program had to run at 100% MAS followed by an active recovery workload at 50% MAS. After 12 weeks of interval training, both groups demonstrated significant improvements in body mass, body fat percentage, BMI Z-score, systolic and diastolic blood pressure, VO_{2max}, and resting heart rate. In addition, both HIIT and MOIT significantly decreased blood leptin concentrations by -22.31% ± 6.58% and -23.20 ± 10.18%, respectively. The percent changes in systolic and diastolic blood pressure for HIIT were -4.46 ± 3.32% and -7.17 ± 3.86%, respectively, and -3.48 ± 1.23% and -5.79 ± 3.35% in MOIT, respectively. Body mass and body fat percentage changes were superior in HIIT by -3.70 ± 1.0% and -9.60 ± 2.26%, respectively, vs. -1.98 ± 1.12% and -8.24 ± 1.78% in MOIT, respectively. Blood leptin levels were associated with body fat percentage in HIIT and VO_{2max} in MOIT.

Gerosa-Neto et al. (2019) demonstrated that six weeks of HIIT did not induce any changes in body composition, visceral fat, or leptin concentrations in sedentary obese men. Thirteen participants were subjected to HIIT, and they exercised 3 days a week for 6-weeks. The HIIT protocol consisted of ten 1-minute bouts at 100% VO_{2max} with 1-minute of passive rest between repetitions. After 6-weeks of training, there was a main effect of time which VO_{2max} significantly increased by 10%. The mean change in VO_{2max} for HIIT was 2.86 ml/kg/min. Arterial systolic blood pressure significantly decreased with HIIT inducing a mean change of -6.62 mm Hg. Unfortunately, after 6-weeks of training, the participants showed no significant changes in body composition, visceral and subcutaneous fat, or leptin concentrations in response to HIIT. Diastolic blood pressure did change by -3.99 mm Hg but not significantly. Six weeks of HIIT intervention was not enough to make any changes in body composition or leptin concentrations.

A study by Kong et al. (2016) determined that five weeks of HIIT had no effect on total body weight, fat mass or systemic hormones but significantly improved VO_{2peak} and W_{peak} on overweight and obese young females. Ten female participants were subjected to HIIT. The HIIT program was executed for 4 exercise sessions per week for 5 weeks total. The participants performed 60 repetitions of 8 seconds of cycling at 90% VO_{2peak} interspersed with 12 seconds of passive recovery. In addition, the initial resistance of the HIIT protocol was 1.0 kg, and the resistance increased by increments of 0.5 kg per completing 2 sessions until reaching 0.05 × body weight. After 5 weeks of interval training, HIIT had significantly improved VO_{2peak} and W_{peak} by inducing a 7.9% and 13.8% increase, respectively. HIIT demonstrated no changes in body weight, total fat mass, and total body fatness. Serum levels of testosterone, cortisol, and leptin were unchanged. Furthermore, there was no significant correlation among the tested variables.

In a randomized controlled study by Zhang et al. (2017) demonstrated that 12-weeks of HIIT resulted in positive changes on whole-body fat, abdominal visceral fat, and abdominal subcutaneous fat in young adult and obese Chinese women without any changes in dietary intake. The HIIT protocol involved 4-minute cycling exercise bouts at an intensity of 90% of maximal oxygen consumption (VO_{2max}) with 3-minutes of resting per bout. The participants had to exercise 3-4 days per week while achieving 200-300 kJ of work per session. After the 12 weeks of HIIT, there was a significant reduction in body mass and body fat percentage. There were significant reductions in the postintervention measurements of whole-body fat mass and the fat mass of the android, gynoid, and trunk regions. A reduction in cross sectional abdominal visceral fat area (AVFA) was discovered, and the abdominal subcutaneous fat area (ASFA) was significantly reduced postintervention. In addition, aerobic fitness significantly increased. The participants attained more than 10% reductions in whole-body and regional fat mass, abdominal visceral fat, and abdominal subcutaneous fat in response to 12-weeks of HIIT.

A study by Reljic et al. (2020) determined that low-volume HIIT improved cardiometabolic health in individuals with severe obesity. Thirty severely obese participants with two additional cardiometabolic risk markers completed this study. In addition, the participants received nutritional counseling to promote weight loss. The HIIT protocol was executed for two sessions per week for 12 weeks total, and it consisted of five 1-minute cycling bouts at an 80-95% HR_{max} separated by a 1-minute low-intensity recovery. After the 12 weeks of intervention, the obese participants significantly reduced body weight and body fat mass with a small loss of body water. The participants lost an average of -5.3 kg of body weight with a body fat mass reduction of -4.7 kg and a loss of body water -0.4 L. The HIIT intervention improved absolute VO_{2max} by 270 mL, relative VO_{2max} by 3.5 mL/kg/min, maximal power output (W_{max}) by 24 W, and relative W_{max} by

0.3 W/kg. Moreover, the HIIT program significantly reduced systolic blood pressure by -12 mmHg, lowered diastolic blood pressure by -10 mmHg, and decreased mean arterial blood pressure by -11 mmHg.

Tsirigkakis et al. (2021) demonstrated similar effects of a 10 second and a 60-second bout, with both bouts matched for the workload on regional body composition in obese men without any changes in dietary intake. Sixteen obese male participants completed this study as they were divided into two equal groups. One group performed 48 bouts of 10 seconds each with 15 seconds of active recovery, whereas the second group performed 8 bouts of 60 seconds each with 90 seconds of active recovery. Both groups cycled at 100% of peak power output (W_{peak}) with an active recovery at 15% W_{peak}. Both groups performed 3 sessions, separated by 48 hours, per week for 8 weeks. After 8 weeks of training, there was no significant main effect of group or group × time interaction for mean power output and energy expenditure during the last training session. Still, both groups significantly increased mean power values from the first to the last training session. Peak oxygen consumption (VO_{2peak}) and W_{peak} increased by 20.0 ± 7.2% and 18.3 ± 6.6%, respectively, due to a significant main effect of time for both groups. Although there was no significant main effect of group or group × time interaction on anthropometric and body composition measurements, there was a main effect of time on body fat; thereby, both groups decreased total and segmental fat mass. Moreover, both groups resulted in an increase in leg lean body mass by 0.82 ± 0.55 kg.

In a study by Smith-Ryan et al. (2015), three weeks of HIIT had no significant effect on body composition or VO_{2peak} on overweight and obese men. Twenty-five participants were subjected to 9 sessions of two types of HIIT programs. One group had to perform 10 bouts of 1 minute of cycling (1MIN-HIIT) at 90% W_{peak} interspersed with 1 minute of rest periods. Whereas

the second group had to execute five bouts of 2 minutes of cycling (2MIN-HIIT) at fluctuating intensities ranging from 80% to 100% VO_{2peak} per session. Both of these training programs had no effect on fat mass or body fat percentage, but 2MIN-HIIT and 1MIN-HIIT induced an increase of 2.1 kg and 1.7 kg in lean mass, respectively, without a significant effect.

The Chronic Effects of HIIT in Young and Older Populations

A study by Hayes et al. (2017) demonstrated that six weeks of HIIT induced an increase in serum concentrations of total testosterone and free testosterone in sedentary older males. The participants had to complete nine sessions of HIIT with each session consisting of six 30-second bouts of sprint cycling at 40% W_{peak} interspersed by 3 minutes of active recovery. However, the six weeks of HIIT were preceded by 6 weeks of precondition training which was 150 minutes per week of moderate intensity of aerobic exercise. Results demonstrated a significant increase of total testosterone after the 6 weeks of preconditioning and remained significantly elevated after HIIT compared to baseline values. Whereas there no was significant increase in free testosterone after preconditioning training, yet there was a significant increase in free testosterone levels after HIIT compared to baseline values. Cortisol levels were unchanged from baseline values to post preconditioning training to post HIIT.

Herbert et al. (2017) applied the same training program seen in the Hayes et al. (2017) study in male master athletes. Serum concentrations of total testosterone, free-testosterone, and cortisol were compared after six weeks of high-volume aerobic training followed by six weeks of low-volume HIIT. There were no changes in absolute or relative W_{peak}, total testosterone, free testosterone, or testosterone to cortisol ratio but there was a moderate decrease in cortisol after six weeks of aerobic training. However, after six weeks of HIIT, there was a significant increase in

absolute and relative W_{peak} and a small increase in free testosterone with a large increase in cortisol, which resulted in a moderate decrease in testosterone to cortisol ratio.

The Chronic Effects of HIIT on Arterial Elasticity

A study by Kim et al. (2017) demonstrated that HIIT had no effect on common carotid artery compliance and arterial stiffness in sedentary older adults. A total of 14 participants from 55 to 79 years of age were subjected to HIIT. The participants performed on an all-extremity non-weight-bearing air-braked ergometer for four days per week for 8 weeks total. The HIIT program consisted of a 10-minute warm-up at 70% peak heart rate (HR_{peak}), four 4-minute bouts at 90% of HR_{peak} separated by three 3-minute bouts of active recovery at 70% of HR_{peak}, ending with a 5-minute cool-down at 70% HR_{peak}, thus totaling 40 minutes. After 8 weeks of training, HIIT did not induce any changes in common carotid artery compliance and arterial stiffness. HIIT significantly improved VO_{2peak} and time to exhaustion during the maximal exercise test. Anthropometric measures such as body weight and BMI remained unchanged.

A study by Guimaraes et al. (2010) determined that 40 minutes of interval training resulted in a significant decrease in arterial stiffness in hypertensive individuals. Sixteen hypertensive participants were subjected to interval training (IT). The participants exercised three times per week for 16 weeks. Each exercise session consisted of a 10-minute warm-up of stretching exercises, 40 minutes of exercise training, 20 minutes of submaximal strength training, and a 10-minute cool-down. The IT protocol consisted of alternating bouts of 2-minute of running at 50% HRR and 1-minute running at 80% HRR until totaling 40-minutes of exercise on a treadmill. After 16 weeks of training, the mean 24-hour ambulatory blood pressure monitoring (ABPM) and daytime diastolic blood pressure values significantly decreased. Interval training significantly decreased carotid to femoral pulse wave velocity (cfPWV). However, IT had no effect on BMI.

Another study by Ciolac et al. (2010) demonstrated that interval training improved the hemodynamic, metabolic, and hormonal status of young normotensive women with a high familial risk for hypertension. Eleven young normotensive women with hypertensive parents were subjected to aerobic IT (AIT). The participants trained three times a week for 16 weeks. Each exercise session consisted of a 5-minute warm-up, 40-minutes of exercise training, and 15-minutes of calisthenics. The AIT group performed 2-minutes of walking at 50-60% VO_{2max} with alternating bouts of 1-minute walking or running at 80-90% VO_{2max} until completing 40-minutes of exercise. After 16 weeks of training, anthropometric measures did not change significantly. AIT significantly reduced aortic pulse wave velocity (PWV) and significantly improved VO_{2max}. Heart rate did not change significantly in response to AIT, but the participants significantly improved their blood pressure response to exercise. Lastly, AIT significantly reduced 24-hour ambulatory blood pressure.

The Acute Effects of Interval Exercise with BFR

A study by Corvino et al. (2017) subjected twelve male participants with a mean age of 23 ± 2 years, body mass of 75 ± 7 kg, and body height of 177.7 ± 7 cm to three different trials that consisted of two sets of five 2-minute bouts with a 1-minute recovery between bouts and 5-minutes of rest between sets. A cadence during the exercise sets was maintained at 70 rpm. The HIIT trial started off at 105% W_{peak}, which decreased by 5% after every 30 seconds until completing 2-minutes of exercise. During the intermittent BFR trial at 30%W_{peak}, the cuff belts were placed proximally on both legs with intermittent cuff inflations at an average pressure of 149 ± 16 mm Hg during exercising bouts and deflated to 0 mm Hg during resting intervals. As for the continuous BFR trial at 30% W_{peak}, the cuff pressure was inflated at average of 103 ± 14 mm Hg, which was 80% of the participants' passive occlusion pressure, throughout the entire 35 minutes of the

exercise session. Ventilation (V_E) and VO_2 increased significantly in response to HIIT at 105%-90% W_{peak} as a single bout of high intensity exercise induced the greatest effects compared to the other trials. The V_E values were significantly greater 156 ± 34 L· min^{-1} in the 2nd set than 137 ± 35 L· min^{-1} in the 1st set in response to acute HIIT.

The Chronic Effects of Interval Training with BFR

This study by Amani-Shalamzari et al. (2019) aimed to determine the effects of various combinations of occlusion pressure and exercise intensity in physically active collegiate women. Thirty-two active collegiate women between the ages of 18-30 were divided into four equal groups: increasing BFR pressure with constant exercise intensity (IP-CE); constant partial BFR pressure with increasing exercise intensity (CP_P-IE); constant complete BFR pressure with increasing exercise intensity (CP_C-IE); increasing BFR pressure with increasing exercise intensity (IP-IE). All participants had to exercise 3 sessions per week for 4 weeks. The training protocol for the IP-CE, CP_P-IE, and CP_C-IE groups were compromised of ten bouts of 2-minutes of treadmill running with BFR interspersed by 1-minute of recovery without BFR. Whereas the IP-IE group did 10-5 bouts of the same duration volume. The final pressure for the partial BFR pressure was ∼50% estimated arterial occlusion from the thigh circumference and complete occlusion pressure was proportional to the thigh circumference as well. BFR pressure increased by 30 mm Hg per week for IP-CE and IP-IE groups whereas the cuff pressure remained constant throughout the 4 weeks for the CP_P-IE and CP_C-IE groups. The baseline exercise intensity for all groups was set at 60% vVO_{2max}, which increased throughout for 4 weeks of training finishing at 85% vVO_{2max} for CP_P-IE and IP-IE groups. After 4 weeks of training, VO_{2max} increased significantly in all groups from pre-to-post training. VO_{2max} increased by 9.6 ± 2.0% in the IP-CE group, 11.2 ± 5.5% for CPP-IE, 14.8 ± 4.9% in CPC-IE, and the IP-IE group improved by 8.4 ± 2.4%. Moreover, running

economy (RE) decreased significantly from pre-to-post training for IP-CE but not for IP-IE. There were significant differences in vVO_{2max} and RE between the CP_C-IE group with IP-CE and IP-IE groups, thereby producing superior effects. Time-to-fatigue (TTF) increased significantly in all groups, 22.1 ± 5.4% in the IP-CE group, 18.2 ± 9.9% for CPP-IE, 30.3 ± 7.6% in CPC-IE, and the IP-IE group improved by 21.3 ± 8.5%. The vVO_{2max} also increased significantly in all groups. vVO_{2max} increased by 14.6 ± 6.9% in the IP-CE group, 12.4 ± 9.7% for CPP-IE, 18.3 ± 2.9% in CPC-IE, and the IP-IE group improved by 15.9 ± 6.8%. The W_{peak} increased significantly in all groups with 21.3 ± 5.5% in the IP-CE group, 17.5 ± 9.7% for CPP -IE, 28.1 ± 4.3% in CPC -IE, and the IP-IE group improved by 13.5 ± 10.0%. W_{avg} showed a significant increase in all groups from pre-training to post-training with 15.1 ± 6.8% in the IP-CE group, 10.3 ± 6.1% for CPP-IE, 22.6 ± 4.9% in CPC-IE, and the IP-IE group improved by 13.9 ± 8.6%. The W_{min} increased significantly in all groups with 4.9 ± 2.7% in the IP-CE group, 6.9 ± 3.9% for CPP-IE, 16.9 ± 9.2% in CPC-IE, and the IP-IE improved by 7.4 ± 3.6%. Muscle strength increased significantly in all groups with an 18.8 ± 7.9% in the IP-CE group, 20.3 ± 6.3% for CPP-IE, 31.0 ± 6.2% in CPC-IE, and the IP-IE group improved by 20.5 ± 2.7%. The CP_C-IE group had superior improvements in anaerobic parameters and muscle strength as there was a significant difference between CP_C-IE with the other groups. RPE was greater in the CPC-IE group as values were noted as “very hard” than in the other groups which reported “hard” values during all training sessions. Mean heart rate was higher in the CPC-IE group than in the other groups during all training session.

The Chronic Effects of Interval Training with BFR vs. HIIT

A this study by Amani-Shalamzari et al. (2020) aimed to determine the effects of BFR in combination with small-sided game (SSG) training on the long and short-duration exercise capacities of futsal players. The twelve participants had a mean age of 23 ± 2 years, a bodyweight

of 67.5 ± 6.8 kg, body height of 1.74 ± 0.05 m, BMI of 22.2 ± 2.0 kg/m^2, and at least five years of experience in futsal, and they were equally divided into a non-BFR group and a BFR group. The HIIT program was 3 weeks consisting of ten sessions separated by 48 hours of 3-a-side SSG on a 20 × 20 m hard surface pitch. Each session included four 3-minute bouts of high-intensity physical activity separated by 2-minute resting periods. Bouts would increase by 2 per completing 3 sessions except for the 10th session, which was completed at the same intensity as the 1st for physiological comparisons. Cuff pressure was inflated to 110% of each leg's individual systolic blood pressure on the upper thigs during training and was deflated during the 2-minute passive recovery periods. The cuff pressure would progressively increase by 10% per 2 training sessions. Both BFR and non-BFR groups significantly increased VO_{2max} and vVO_{2max}, but between-group differences were not significant. Although VO_{2max} similarly increased in both groups, RE significantly increased with a ~22% reduction in submaximal oxygen cost, and TTF increased by 7% with BFR. Moreover, W_{avg}, W_{peak}, and minimum power output (W_{min}) increased significantly in response to the BFR group. Whereas the non-BFR group only improved peak power. RPE and HR were significantly greater in the BFR group than the non-BFR group throughout the length of the study. Testosterone and cortisol levels increased significantly in response to both groups' first training sessions, but testosterone levels only increased at the last training session. BFR training induced a slight increase in resting testosterone, resulting in a significant increase in the resting testosterone to cortisol ratio.

A study by de Oliveira et al. (2016) determined the effects of low-intensity interval training (LIIT) with intermittent BFR on parameters of aerobic fitness and maximal isometric knee extension strength. The secondary purpose of the study was to compare the magnitude of training-induced changes between LIIT + BFR and HIIT. The third purpose was to determine if a

combination of HIIT and LIIT + BFR in a random order could result in aerobic fitness improvements like HIIT and induce similar strength gains, as seen with BFR training. This study subjected 37 young adults with ages of 23.8 ± 4 years, and they were divided into four training groups: 10 = HIIT, 10 = LIIT + BFR, 10 = combined HIIT and LIIT + BFR, and 7 = LIIT without BFR. The training program for all groups consisted of three training sessions per week on a stationary ergometer for 4 weeks. Each exercise session consisted of 2 sets of 5-8 repetitions, with each repetition lasting 2-minutes and interspersed by 1-minute of passive recovery. The rest interval between sets was 3-minutes of active recovery at 30% W_{max} followed by 2-minutes of passive recovery. The LIIT and LIIT + BFR groups performed each training session at 30% W_{max}, and the pressure cuffs were placed on the proximal portion of the thigh with cuff pressure inflated at 140-200 mm Hg during each repetition. The HIIT group performed each repetition at 110% W_{max} with a 5% decrease in intensity every 30 seconds. The combined HIIT and LIIT + BFR group alternated the sets of LIIT + BFR and HIIT in random order for every exercise session. After 4 weeks of training, body mass and body fat percentage remained unchanged for all training programs. The VO_{2max} significantly increased with a significant main effect for time by 9.2 ± 6.5% for the HIIT, 5.6 ± 4.2% in LIIT + BFR, and 6.5 ± 5.5% in response to combined HIIT and LIIT + BFR groups. W_{max} significantly increased by 15.0 ± 4.5% for the HIIT, 11.7 ± 4.7% in LIIT + BFR, and 10.9 ± 4.5% in response to combined HIIT and LIIT + BFR groups. Isometric strength significantly increased only for LIIT + BFR group by 11%, with a significant two-way interaction for group × time. Isometric strength decreased by -0.7 ± 9.9% and -3.5 ± 6.8% in the HIIT and combined HIIT and LIIT + BFR groups, respectively.

Corvino et al. (2019) aimed to determine the effect of 4-weeks of low-intensity endurance intermittent BFR training on moderate-intensity pulmonary oxygen uptake (VO_{2p}), carbon dioxide

output (VCO_{2p}), and V_E on kinetics compared with HIIT. Seventeen recreationally active young adults completed the study. Nine participants were assigned to HIIT and eight performed BFR training. All participants were instructed to maintain a cycling cadence of 70 rpm. The participants had to exercise three days per week. Each intervention consisted of two sets of five-to-eight 2-minute cycling bouts. Each bout was interspersed by 1-minute passive rest, and the sets were separated by 3-minutes of active recovery at 30% W_{peak} followed by 2-minutes of passive rest. The BFR group had to train at 30% W_{peak}, whereas the HIIT group had begun each repetition at 110% W_{peak} with a progressive 5% decrease every 30 seconds. The BFR group exercised with an inflated cuff pressure of 140-200 mm Hg during the 2-minute repetitions and deflated during the 1-minute rest. Peak lactate and peak heart rate were lower in BFR than in HIIT. The time constant VO_2 was reduced in BFR and HIIT with no differences between interventions. The effect size for the time constant VO_2 in BFR was moderate, whereas the effect size was large for HIIT. The time constant values for both VCO_{2p} and V_{Ep} were significantly reduced after HIIT but did not reach significance for BFR. The effect size (ES) for the time constant for VCO_{2p} was moderate for BFR and very large for HIIT, and the ES for the time constant for V_{Ep} was moderate for both BFR and HIIT. These results demonstrate that endurance BFR training induced a faster VO_2 on-kinetics, the same as HIIT. Endurance BFR training speeded VO_{2p} on-kinetics by 24 ± 19% despite the performance of 3.5 times less work than the HIIT group, which speeded VO_2 on-kinetics by 34 ± 18%.

The Effects of Resistance Training on Arterial Compliance

In a study by Kawano et al. (2006), four months of full-body resistance training at moderate intensity has been shown to reduce carotid arterial compliance by 20%. The young male participants performed three sets of 14-16 repetitions at 50% of 1-RM with 2 minutes of recovery between six exercises and sets for three days per week, leading to a decrease in arterial compliance.

They also experienced an increase in the left ventricular mass index and relative wall thickness, which correlate with arterial stiffness (Kawano et al., 2006). In fact, the negative effects of resistance training can occur much sooner with less workload demand per week. Ozaki et al. (2013) had nine young men experience a 21% decrease in carotid arterial compliance after six weeks of high-intensity resistance training. The participants were subjected to three sets of ten repetitions of free-weight flat bench press at 75% of 1-RM with 2-3 minutes of rest between sets for three days per week for 6 weeks total. The reduction in carotid arterial compliance was correlated with a training-induced elevation in systolic arterial pressure during training sessions (Ozaki et al., 2013).

The Effects of Sprint Interval Training

Whyte et al. (2010) found that two weeks of sprint interval training significantly increased VO_{2max} and W_{avg}, reducing systolic blood pressure in young overweight and obese sedentary men. Ten men were subjected to six sessions of 4-6 "all-out" 30-second of cycling sprints interspersed by 4.5 minutes of active rest at 30 W. The braking force was kept at 0.065 kg per kg of fat-free mass for 30 seconds for each session. After two weeks, VO_{2max} and W_{avg} increased by 8.4% and 3.6%, respectively, and systolic pressure improved by 4.7% (Whyte et al., 2010). The muscular performance also significantly increased in a different study by Gibala et al. (2006), where eight physically active men were subjected to six sessions of 4-6 "all-out" 30-second of cycling sprints interspersed by 4-minutes of active rest at 30 W. The breaking force for this training study was at a resistance equivalent to 7.5% of their body weight (Gibala et al., 2006). After two weeks of SIT, the time required to complete a 750kJ cycling test decreased significantly by 10.1% with a corresponding increase in W_{avg} from 212 ± 17 W to 234 ± 16 W. The time required to complete a 50kJ cycling test decreased by 4.1% W, significantly increasing W_{avg} from 435 ± 23 W to 453 ±

25 W (Gibala et al., 2006). Both studies by Whyte et al. (2010) and Gibala et al. (2006) demonstrated rapid improvements in maximal oxygen uptake, mean power output, muscular performance, and systolic blood pressure in just 2 weeks of SIT.

Summary

Different formats of HIIT result in significantly high concentrations of testosterone while significantly reducing leptin and cortisol levels. A HIIT training volume equal to or less than six weeks with a training frequency of three to four days per week does not appear to affect body composition and systemic hormones. Training volumes of 12 weeks of HIIT, two days or three-four per week, resulted in significant changes in body composition, power output, oxygen consumption, and hemodynamics in healthy or sedentary individuals. Improvements seen in body composition, hemodynamics, oxygen uptake, and arterial elasticity depend heavily on the intensity and duration of the HIIT protocol. Moreover, changes in arterial stiffness depend on the type of HIIT prescribed. Running interval training can significantly increase arterial elasticity, but not non-weight-bearing air-braked ergometer interval training. Three to four weeks of bike interval training with various methods of BFR can significantly increase VO_{2max}, vVO_{2max}, TTF, W_{avg}, and muscle strength. Differences between HIIT and interval training with BFR are minimal regarding changes in oxygen uptake and vVO_{2max}. However, interval training with BFR can lead to significant improvements in running economy and TTF and superior increases in testosterone and muscle strength. Regardless, superior effects in response to interval training with BFR depend on the frequency, exercise type, duration, volume, and BFR pressure level. Nonetheless, the effect of bike interval training with BFR on arterial elasticity is yet to be determined.

CHAPTER III

METHODS

This study compared the effects of two different anaerobic training protocols, which are high-intensity interval training (HIIT) and moderate-intensity interval training with BFR (MIIT+BFR), on the adaptations in body composition, salivary hormone concentration, peak oxygen uptake, average anaerobic power output, and arterial elasticity in young overweight and obese male adults. The study's primary objective was to determine which training protocol results in the best fat loss, salivary hormone concentrations, lean mass, average anaerobic power output, strength, peak oxygen uptake, and arterial elasticity. The secondary outcome of this study was to determine the acute and chronic hormone concentrations of testosterone, cortisol, and leptin in response to one exercise session and after 8 weeks of low-volume exercise training.

This chapter presents and discusses the methods and procedures used to conduct the study. Before initiating the study, the Institutional Review Board approved the research protocol at the University of Texas Rio Grande Valley.

Study Population

Twenty-four male participants between the ages of 18 to 40 and with a BMI greater than 24.9 were recruited for this study. The participants were randomly assigned into two equal groups. The first group performed HIIT on a bike ergometer, followed by 3 circuits of upper-body resistance band exercises. The second group executed MIIT+BFR on an electronically braked

cycle ergometer, followed by the same volume of circuit training. The total duration of interval training for the HIIT group was 24 minutes, whereas the interval training lasted for 18 minutes in the MIIT+BFR group. Each pre- and post-testing session for both protocols lasted about an hour and 30 minutes. Depending on the group assigned, the total time commitment was about 18 to 21 hours throughout the study.

Recruitment

Participants were recruited by handing out fliers to the public and word-by-mouth. Any overweight and obese male participant that liked to voluntarily participate in this study was scheduled for an interview to be screened for inclusion and exclusion criteria to determine their eligibility for the study. Eligible overweight and obese male participants were taken through the study design aspects and signed an informed consent document. Participation in this study was entirely voluntary; thus, participants were allowed to withdraw at any time.

Inclusion Criteria

1. Participants had to be between the ages of 18 to 40.
2. Participants must have had a BMI greater than 24.9.

Exclusion Criteria

1. Participants were diagnosed with central nervous system disorders, cardiovascular and metabolic diseases, or musculoskeletal injuries.
2. Participants have had a history of blood clots, varicose veins, deep vein thrombosis (DVT), or other conditions that would impede venous return.

Questionnaires

These questionnaires were filled by the participants who liked to volunteer in the study when coming into their interview and were used to determine eligibility to enter. The questionnaires were provided by the interviewer.

1. Venous Return Questionnaire: A “yes” or “no” questionnaire that determined if the participant had any cardiovascular disease that may affect the venous return. Answering “yes” to any question excluded the subject from the study.
2. Health Screening Questionnaire: Parts 1 and 3 of the questionnaire were used to get background information from the participants. Part 2 assessed if the participant qualified for the study. If any participant answered “yes” to questions 15, 16, and 17, they were excluded from the study. If the participant provided more than 3 answers to question 18, they were excluded from this study.
3. Physical Activity Readiness Questionnaire (PAR-Q): A simple self-screening tool used to determine the safety or possible risks of exercising based on their health history, current symptoms, and risk factors.

Instrumentation

The following instruments were utilized to complete the study. Each instrument was conducted under the supervision of trained personnel and investigators.

Blood Flow Restriction

3-cm-wide cuffs were placed and inflated around the most proximal region of both legs, compressing and reducing blood flow to the proximal exercising muscles by the KAATSU Master device (KAATSU, Sato Sports Plaza, Tokyo, JAP). Initial cuff pressure was between 35-45 mm Hg for both legs. The final cuff pressure was determined by multiplying brachial systolic blood

pressure by 1.44. However, cuff pressure would be first set at 120 mm Hg for 30 seconds and released for 10 seconds. Cuff pressure would increase by every 20 mm Hg while holding for 30 seconds and releasing for 10 seconds per pressure until the calculated pressure was reached.

Capillary Refill Time (CRT)

This measurement assesses the time it takes the capillary bed on the skin surface of the vastus medialis to regain its color after pressure has been applied for three seconds.

Body Mass Index (BMI)

This assessed the body mass based on the participant's height and weight. BMI was calculated by dividing the mass (kg) by height (m^2). Height was measured by a wall stadiometer to the nearest 0.5 centimeters, and weight was measured by a digital weight scale (DC-430U Dual Frequency Total Body Composition Analyzer, Tanita, Tokyo, Japan) to the nearest 0.1 kilograms.

Hydration Status

The hydration status of the participants was measured by using the SPER Scientific Clinical Urine Refractometer (PAL-10S Urine Specific Gravity Refractometer, Atago, Tokyo, Japan), which is a device that requires 3 drops of urine placed on its lens.

Dual-Energy X-Ray Absorptiometry (DXA)

DXA (GE Lunar Prodigy, enCORE software version 6.70.021; GE Healthcare, Madison WI) is one of the most accurate methods for measuring body composition. This device is considered the gold standard for bone-mineral density assessment. The participants lay comfortably in a supine position with their bodies linearly aligned on the device until the DXA scan was complete.

HDI/PulseWave CR-2000TM Research Cardiovascular Profiling System

The HDI/PulseWave CR-2000TM Research Cardiovascular Profiling System (Hypertension Diagnostic, Inc., Eagan, Minnesota, USA) device was used to determine the hemodynamic parameters (Brachial Systolic and Diastolic Pressure, Pulse Pressure, Pulse Rate, Systemic Vascular Resistance, and Cardiac Output) and the elasticity index of the large artery and small artery derived from the radial artery. The participants laid still, silent, and comfortably in a supine position with their arms supinated and slightly abducted and legs unbent and separated. The sensor was placed on the radial artery near the right-hand wrist, and the blood pressure cuff was placed on the left arm region. After 5-minutes of laying still and silent, the hemodynamic parameters and the large and small arterial elasticity index values were assessed until two values with less than 5-10% difference were obtained.

SphygmoCor® Pulse Wave Analyzer

Pulse wave velocity (PWV) and pulse wave analysis (PWA) was measured by SphygmoCor® Pulse Wave Analyzer (AtCor Medical Pty. Ltd., Sydney Australia). SphygmoCor assessment is considered the gold standard for both PWV and PWA. PWV is a measurement used to assess central arterial elasticity. The participants laid still, silent, and comfortably in a supine position with their arms supinated and slightly abducted and legs unbent and separated. A brachial blood pressure cuff was placed on the right arm region with pure skin contact, and a thigh blood pressure cuff was located on the uppermost region of the right thigh. A pen-like sensor was placed on the right carotid artery to determine PWV. PWA and PWV were assessed subsequently and not simultaneously. After 5-minutes of laying still and silent, PWA and PWV were assessed until two values with less than 5-10% difference were obtained.

30-Second Wingate Test

The Wingate involves 30-seconds of maximal exercise against the resistance of 7.5% of total body weight (TBW) applied on the flywheel of a leg-cycle ergometer (Monark, 874E, Sweden). This test was used to determine the average anaerobic power output sustained throughout the entire 30-seconds. The formula to calculate average power is as follows: Work Rate = Resistance (kg) × 6 meters (m) × revolutions per minute (RPM). Resistance is the resistance applied to the flywheel (kg). The 6 meters is the distance covered in one revolution of the flywheel, and the RPM is the revolutions completed within the 30-seconds. The average power output was recorded as work rate ($kg \bullet m \bullet min^{-1}$), watts (W), and relative average power output (W/kg). The participants performed a 5-minute warm-up comprised of cycling at a normal pace with a resistance of 2% TBW, including three 5-second sprint cycles against the resistance of 3.7% TBW at the 2:00, 3:00, and 4:00 minute mark. After a 3-minute rest period, the participants performed the 30-second maximal exercise, which was preceded by three seconds of "all out" cycling with no resistance until dropping the weight tray holding the 7.5% TBW resistance on the flywheel, and the participants continued to pedal with maximum effort for the duration of the test. The participants' RPM was video recorded from the moment of dropping the weight tray holding 7.5% TBW until completing the 30 seconds of "all out" cycling. Afterwards, the video recording was played in slow motion to count each revolution completed within the 30-seconds of cycling. The intensity of the training protocols was based on the average power output calculated from the 30-second Wingate cycling protocol.

The Biodex Multi-Joint System – Pro 4

A computer-assisted machine used to assess the muscle torque produced during a 5-second leg isometric contraction or at a fixed rate of speed for 10 repetitions of leg extensions and leg

curls. This device was also used to administer the Thorstensson Test of Fatigability, Maximal Voluntary Contraction (MVC), and Isokinetic Unilateral tests.

Thorstensson Test of Fatigability

A test that correlates the amount of muscle torque produced at a fixed rate of speed of 180°/500° per second over fifty repetitions of leg extension. This test is also used to estimate the fast-twitch (FT) fiber percentage from the percent decline in the average peak torque values of the first three repetitions and the last three reps of the test. The following equation calculates for FT: FT% = [(% Decline) – 5.2] / 0.90. The equation for % decline follows %Decline = [(PT at 1-3) – (PT at 48-50)] / [PT at 1-3)] × 100. The formula to calculate the percentage of slow-twitch (ST) fibers follows ST% = 100 – FT%. (Thorstensson and Karlsson, 1976).

Bruce Protocol

A standard graded exercise test performed on a treadmill to determine the participants' aerobic capacity. The Bruce protocol is comprised of multiple exercise stages of three minutes each. At each stage, the gradient and speed of the treadmill were elevated to increase the resting metabolic equivalent (MET). After reaching volitional exhaustion, the peak oxygen consumption was calculated. The maximal heart rate was also recorded immediately after reaching volitional fatigue. A two-minute and thirty-second warm-up at 3.0 miles per hour (mph) with 0% grade inclination was administered before the test, and a 5–10-minute cooldown followed the completion of the protocol. The following equation was used to calculate the participants' aerobic capacity: $14.76 - (1.38 \times \text{Time}) + (0.451 \times \text{Time}^2) - (0.012 \times \text{Time}^3)$.

Enzyme Immunoassay (EIA) Kit

A biochemical technique used for the quantitative measurement of salivary testosterone, cortisol, and leptin, separately. Saliva samples were collected before and immediately after the first and last training sessions.

Table 1. Bruce Protocol

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

Research Design

This study required 21 sessions to be completed in the Neuromuscular Performance Laboratory, room #216, located in the Vocation Trades Shop M-1 building. The sessions were scheduled at least 48 hours apart, and the participants had to complete 2 sessions per week. The 1st session involved filling out questionnaires, reviewing inclusion and exclusion criteria, signing informed consent, and determining their BMI, which was calculated from their height and body weight measurements. In the 2nd session, the eligible participants had to walk into the laboratory at least 8 hours fasted and hydrated for pre-testing baseline values. Upon arrival, the hydration levels were assessed by a Clinical Urine Refractometer from the urine samples obtained from the participants. If the participants were not hydrated, in other words, the hydration status was not below 1.010, they would continue to drink water and recollect urine samples in 20-minute intervals until hydration levels were adequate. Next, the participants underwent a DXA scan for baseline body composition assessment. Later, their baseline hemodynamic parameters and large and small arterial elasticity indexes were recorded via HDI/PulseWave CR-2000TM Research Cardiovascular Profiling System. After working with the HDI/PulseWave, the participants

remained lying down. Their baseline values for pulse wave analysis and pulse wave velocity were measured sequentially via SphygmoCor® CPV Pulse Wave Analyzer. Finally, the participants performed a 30-second Wingate protocol after doing a five-minute cycling warm-up with three five-second cycling sprints at varying resistances. This session took approximately 90 minutes to complete. The 3rd visit assessed other pre-testing baseline values, and urine samples were also collected to determine adequate hydration levels before testing. The participant performed the following exercise test protocols on the right leg on the Biodex Dynamometer; two five-second maximal isometric quadriceps contractions at a knee joint angle of 60°, a ten-repetition isokinetic knee contraction of leg extension and leg curls at 60° per second, a ten-repetition isokinetic knee contraction of leg extension and leg curls at 180° per second, and the Thorstensson Test of Fatigability. The participants performed a 5-minute cycling warm-up on a bike ergometer with a resistance of 1.0 kg and a cadence of 60 beats per minute before performing these exercise protocols. Then, the participants had to perform the Bruce protocol on a treadmill. Before the graded exercise test, the participants did a two-minute and 30-second warm-up on the treadmill at a speed of 3 mph and an inclination grade of 0%. The participant's heart rate and RPE scores were monitored and recorded 15 seconds before completing each stage. The maximum heart rate was recorded until the participant had reached volitional fatigue. After the Bruce protocol, the participants performed a five-minute cool-down at 2.5 mph with a 0% inclination grade. This session took approximately an hour to complete. In the 4^{th} session, regardless of HIIT or MIIT + BFR followed by light-moderate resistance band exercises, the first exercise session was performed in the morning under 8-hour fasted and hydrated conditions. Before beginning any exercise, fasting saliva samples were collected in a saliva sample collection kit via the passive drool method to determine the salivary baseline values of testosterone, cortisol, and leptin.

Immediately after completing the first exercise session, fasting saliva samples were re-collected via the passive drool method. During sessions 5 to 18, the participants and the researcher had the luxury of agreeing on time schedules that were most convenient to complete the exercise sessions. The 19th session, the last training session, had to be completed under hydrated and 8-hour fasting conditions in the morning. Fasting saliva samples were recollected immediately before and after the last training session with the same saliva sample collection kit via the passive drool method to determine any changes in salivary concentration of testosterone, cortisol, and leptin. Each participant was scheduled to complete sessions 20 and 21 under the same conditions and order of variable testing as sessions 2 and 3. These sessions were also scheduled at least 48 hours apart.

Exercise Protocols

The following procedures are specified for the training sessions. Participants were randomly assigned to one of the two groups performing one designed anaerobic training protocol for 8 weeks, 2 times a week. Every session was conducted under the supervision of the trained personnel and investigators.

High-Intensity Interval Training

The HIIT group participated in high-intensity anaerobic training sessions. Participants attended the training room and performed the specified routine two times a week with at least 48 hours of rest between sessions. HIIT began with the participant warming up by cycling with a resistance of 1.0 kg for five minutes on a bike ergometer (Monark 874, Sweden). Then, they performed the training routine of 16 bouts of 30-seconds of leg cycling at an intensity of 80-100% W_{avg} interspersed by 45 seconds of passive rest. The exercise-to-rest ratio of the HIIT program was a 1:1.5 ratio. However, the participants were given a 15-second warm-up before each bout; the resistance applied on the flywheel would gradually increase to the target resistance. Moreover,

the participants had to strictly petal at 60 RPM per cycling bout. After completing the leg cycling bouts, the participants had a cool down for three minutes while cycling on the bike ergometer with 1.0 kg resistance and then passively rested for two minutes. Next, they performed three circuits consisting of four upper body resistance band exercises at a light-to-moderate resistance for 10-20 repetitions per exercise. Each circuit was interspersed with 60 seconds of passive rest. If the intensity of the cycling bouts becomes less vigorous for the participants, the intensity was subsequently increased from 80% W_{avg} to 85%, 90%, 95%, and 100% of the participant's average anaerobic power output. Thus, they kept performing at a vigorous level. The Borg's RPE scale assessed the protocol's intensity level by having the participants rate their perceived exertion during training. As for the resistance band exercises, the participants started performing three circuits compromised of light-moderate resistance-band bicep curls, overhead press, chest press, and finally, band pull-apart. The participants performed 10 repetitions per resistance-band exercise, totaling 40 repetitions per circuit. As the participants' rate of perceived exertion for the resistance band exercises improved throughout the study, the number of repetitions was subsequently increased from 10 to 15 to 20 reps per exercise, totaling 60 to 80 reps, respectively.

Moderate-Intensity Interval Training with Blood Flow Restriction

The MIIT+BFR group participated in moderate-intensity anaerobic blood flow restriction training sessions. Participants attended the training room and performed the specified routine two times a week with at least 48 hours of rest between sessions. MIIT+BFR protocol began with the participant warming up by cycling with a resistance of 1.0 kg for five minutes on an electronically braked cycle ergometer (Monark 928 E, Sweden). Then, they performed the training routine, which consisted of eight bouts of 60 seconds of leg cycling at an intensity of 40-60% W_{avg} with continuous BFR at 160-260 mm Hg on the proximal regions of both legs during exercise. The

exercise-to-rest ratio of the MIIT+BFR was a 1:1 ratio. However, the participants were given a 15-second warm-up before each bout; the resistance applied on the flywheel would gradually increase to the target resistance. Moreover, the participants had to strictly petal at 60 RPM per cycling bout. After completing the leg cycling bouts, the participants had a cool down for three minutes while cycling on the bike ergometer with 1.0 kg resistance and then passively rested for two minutes. The exercise intensity would subsequently change from 40% W_{avg} to 45%, 50%, 55%, and 60% of the participant's average anaerobic power output when the participants' perceived exertion rate improved per training session. The Borg's RPE scale assessed the protocol's intensity level by having the participants rate their perceived exertion during training. In addition, the applied restriction pressure set on the upper region of the thighs was determined by the capillary refill time (CRT). The CRT was determined by pressing the thumb onto the vastus medialis muscle for three seconds. If the blanched white color of the surface of the skin regained its normal color within two to three seconds, then the final pressure was set for each exercise session. Next, they performed three circuits consisting of four upper body resistance band exercises at a light-to-moderate resistance for 10-20 repetitions per exercise. Each circuit was interspersed with 60 seconds of passive rest. The resistance band exercises were performed without BFR. The participants performed bicep curls, overhead press, chest press, and finally, band pull-apart. The participants performed 10 repetitions per resistance-band exercise, totaling 40 repetitions per circuit. As the participants' rate of perceived exertion for the resistance band exercises improved throughout the study, the number of repetitions was subsequently increased from 10 to 15 to 20 reps per exercise, totaling 60 to 80 reps, respectively.

Data Analysis

One-way analysis of variance (ANOVA) was used to test baseline differences between groups and percent (%) changes from pre- to post-training. Percent changes were calculated using the following formula: (post – pre)/pre x 100. When there were no significant differences between groups at baseline, a two-way repeated-measures ANOVA was used to test differences between pre-and post-exercise test values (condition (MIIT+BFR vs. HIIT) x time (pre vs. post)). When ANOVA with repeated measures detected a significant difference, post hoc analyses using the Bonferroni test were used to determine which groups differ from each other. When homogeneity assumption was violated, Kruskal-Wallis, a non-parametric test, was used to analyze differences from pre-to post-training between groups. Analysis of covariance (ANCOVA) was used when there were significant differences between groups at baseline. ANCOVA results were reported for ejection duration, force decline %, fast twitch (FT), slow twitch (ST). All data were expressed as means ± SE in the text, figures, and tables. An alpha of 0.05 was used to determine statistical significance and data were analyzed using SPSS for Windows (IBM Corporation, New York, USA).

Summary

This study focused on improving body composition, salivary hormone concentration, average anaerobic power output, peak oxygen uptake, and arterial elasticity in overweight and obese young male adults. The anaerobic training protocols consisted of bike training followed by upper-body resistance band exercises. One group performed HIIT, and the other group performed MIIT+BFR. Both primary and secondary measures were evaluated in response to 8-weeks of anaerobic training for each of the two exercise protocols.

CHAPTER IV

RESULTS

This study compared the effects of two different anaerobic training protocols, which are high-intensity interval training (HIIT) and moderate-intensity interval training with BFR (MIIT+BFR), on the adaptations in body composition, salivary hormone concentration, peak oxygen uptake, average anaerobic power output, and arterial elasticity in young overweight and obese male adults. The study's primary objective was to determine which training protocol results in the best fat loss, salivary hormone concentrations, lean mass, average anaerobic power output, strength, peak oxygen uptake, and arterial elasticity. The secondary outcome of this study was to determine the acute and chronic hormone concentrations of testosterone, cortisol, and leptin in response to one exercise session and after 8 weeks of low-volume exercise training.

Subject Characteristics

36 participants were recruited to participate in the study, but only 24 subjects completed all 21 sessions (age = 23.1 ± 0.7 yr.). The participants were randomized in a counterbalance study design. Table 2 displays the study population baseline anthropometric measurements. The subjects were recruited from the University of Texas Rio Grande Valley in Brownsville, TX.

Table 2. Anthropometric Data

Variables	Overall (n = 24)	HIIT (n = 12)	MIIT+BFR (n = 12)
Age (yr.)	23.1 ± 0.7	23.7 ± 1.0	22.6 ± 1.1
Height (cm)	174.6 ± 1.4	174.4 ± 2.0	174.8 ± 2.0
Weight (kg)	100.5 ± 4.5	101.4 ± 7.9	99.5 ± 4.7
BMI (kg/m^2)	32.9 ± 1.2	33.2 ± 2.3	32.5 ± 1.1
Brachial SBP (mm Hg)	125.9 ± 1.8	123.5 ± 2.5	128.3 ± 2.5
Brachial DBP (mm Hg)	74.2 ± 1.6	72.0 ± 1.8	76.4 ± 2.5

Values are reported as mean ± SE.

Body Composition

Table 3 displays the effects of HIIT and MIIT+BFR on whole body composition from pre- to post-training. One-way ANOVA found no significant baseline differences between groups for all variables. Two-way ANOVA with repeated measures found a significant time main effect for Total Fat-Free Mass ($p = 0.04$), Total Bone Mineral Content (BMC) ($p = 0.01$), Leg Lean Mass ($p = 0.04$), Leg BMC ($p = 0.02$), Trunk BMC ($p = 0.03$), Lean Gynoid Mass ($p = 0.05$), and Gynoid BMC ($p = 0.02$). There was also a condition*time interaction for Leg Fat Mass to Total Fat Mass Ratio ($p = 0.02$).

Table 3. Whole Body Composition Results

	MIIT+BFR (n = 12)		HIIT (n = 12)	
Variables	PRE	POST	PRE	POST
Total Mass (kg)	99.9 ± 4.6	100.0 ± 4.6	100.9 ± 7.6	102.2 ± 7.5
Total Lean Mass (g)	63,598.9 ± 2,975.7	63,909.6 ± 3,046.8	62,607.9 ± 3,212.3	63,526.2 ± 3,166.3
Total Fat Free Mass (g)	67,251.2 ± 3,359.6	67,809.4 ± 3,394.0	65,360.7 ± 3,587.2	66,486.8 ± 3,564.0
Total Fat Mass (g)	33,134.5 ± 2,954.1	32,871.6 ± 2,859.1	35,084.0 ± 5,159.1	35,440.4 ± 4,939.0
Total Region Fat Percent (%)	32.8 ± 2.3	32.6 ± 2.2	33.1 ± 2.6	33.1 ± 2.4
Total BMC (g)	3,166.4 ± 142.7	3,173.1 ± 146.8	3,202.8 ± 131.0	3,228.4 ± 133.9
Total Tissue Mass (g)	96,733.5 ± 4,541.5	96,781.1 ± 4,503.0	97,692.1 ± 7,504.8	98,966.5 ± 7,430.2

Values are reported as mean ± SE.

Figure 1 displays the changes in body weight from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

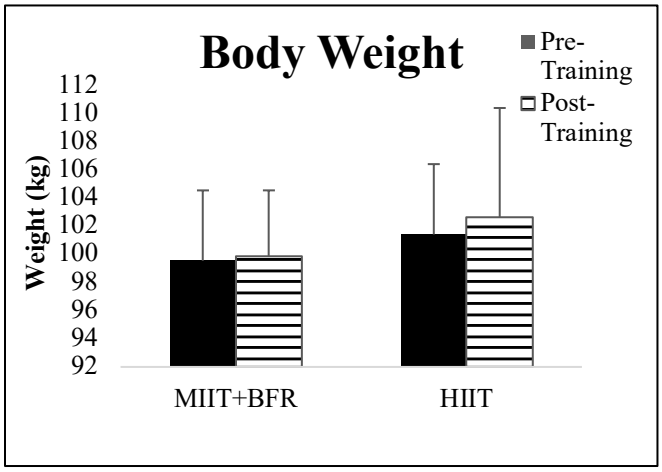


Figure 1. Body Weight

Figure 2 displays the changes in body mass index from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

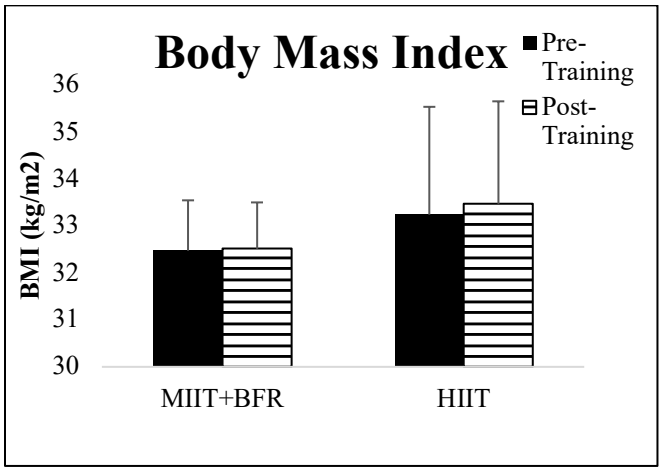


Figure 2. Body Mass Index

Figure 3 displays the changes in total mass measured by DXA from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

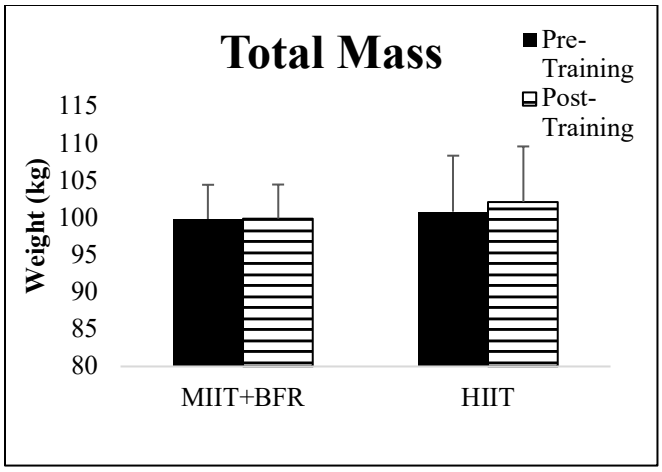


Figure 3. Total Mass

Figure 4 displays the changes in total lean mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

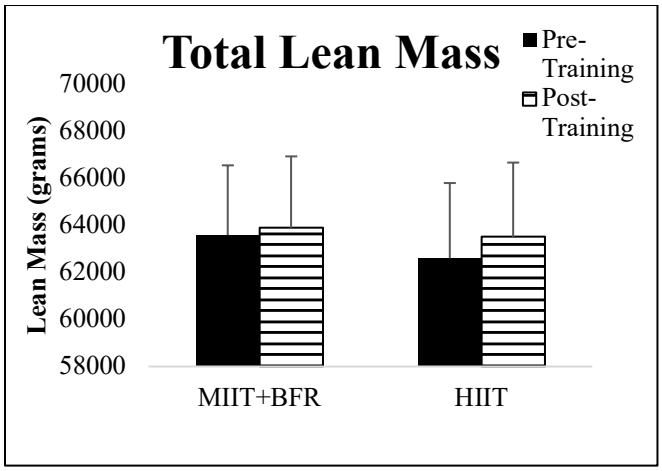


Figure 4. Total Lean Mass

Figure 5 displays the changes in total fat-free mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a significance for a time main effect (66,306.0 ± 2,457.4 vs. 67,148.1 ± 2,460.8 g, $p = 0.04$) from

pre- to post-training; however, follow-up analysis test showed a trend for HIIT ($p = 0.06$) but not for MIIT+BFR ($p > 0.05$). There was no significant condition main effect nor a time*condition interaction.

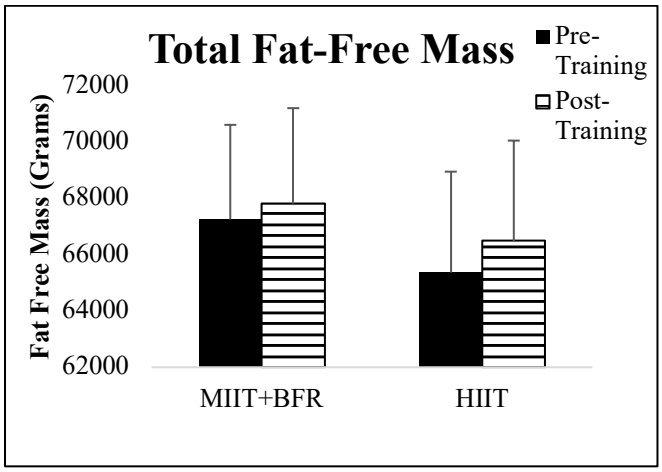


Figure 5. Total Fat-Free Mass

Figure 6 displays the changes in total fat mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p>0.05$).

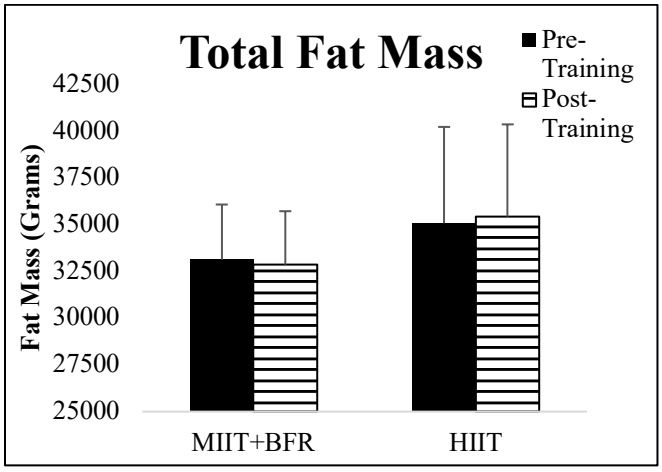


Figure 6. Total Fat Mass

Figure 7 displays the changes in total region percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

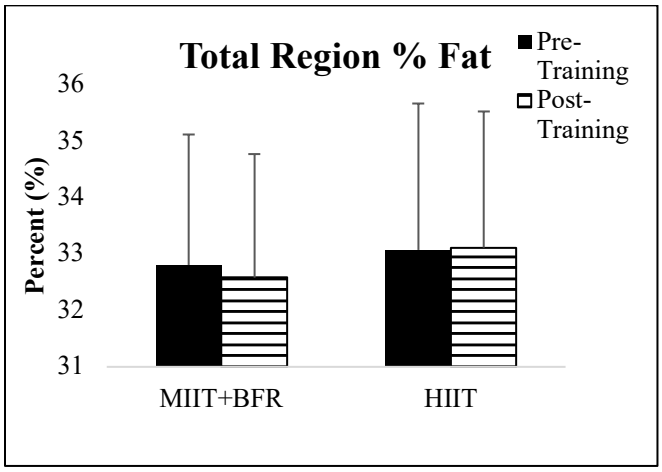


Figure 7. Total Region % Fat

Figure 8 displays the changes in the android region percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

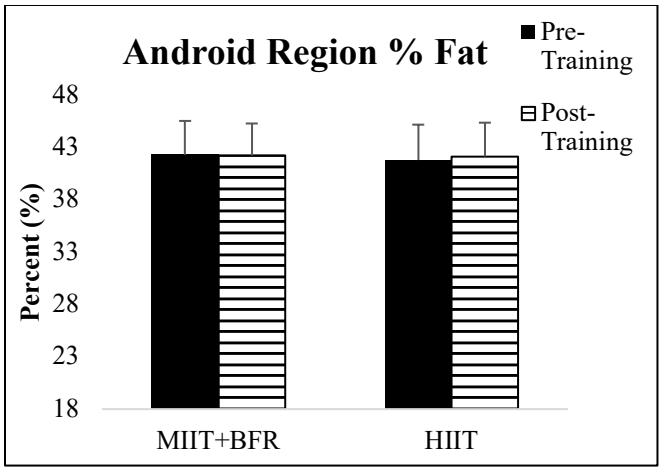


Figure 8. Android Region % Fat

Figure 9 displays the changes in the gynoid region percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

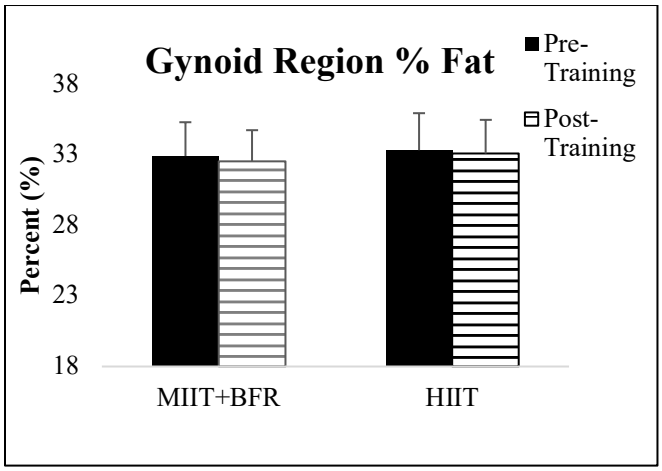
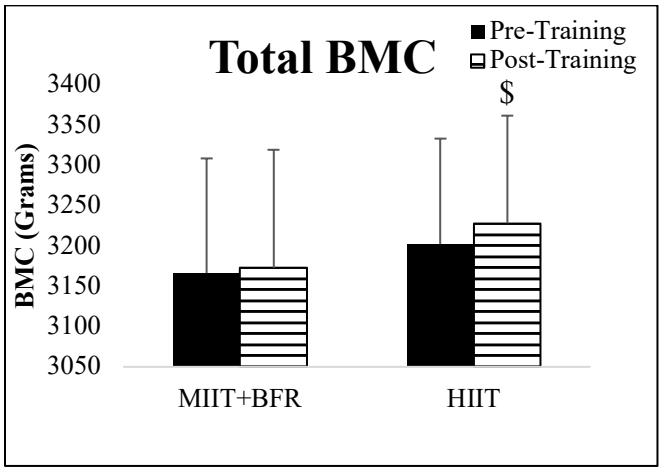


Figure 9. Gynoid Region % Fat

Figure 10 displays the changes in total bone mineral content (BMC) from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a significance for a time main effect (3,184.6 ± 96.9 vs. 3,200.8 ± 99.3 g, $p = 0.01$) from

pre- to post-training. There was a trend for a condition*time interaction (BFR: 3,166.4 ± 137.0 g vs. 3,173.1 ± 140.5 g; HIIT: 3,202.8 ± 137.0 g vs. 3,228.4 ± 140.5 g, p = 0.08) from pre- to post-training. A follow-up analysis test determined that HIIT significantly increased total BMC from baseline (p = 0.002). There was no significant condition main effect.



$Significantly different (p < 0.01) from baseline.
Values reported as mean ± SE.

Figure 10. Total Bone Mineral Content (BMC)

Figure 11 displays the changes in relative skeletal muscle index (RSMI) from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance (p > 0.05). Two-way ANOVA with repeated measures found a trend for a time main effect (10.0 ± 0.3 vs. 10.1 ± 0.3 kg/m^2, p = 0.06). However, follow-up analysis test lost the trend. There was no significance for condition main effect or condition*time interaction.

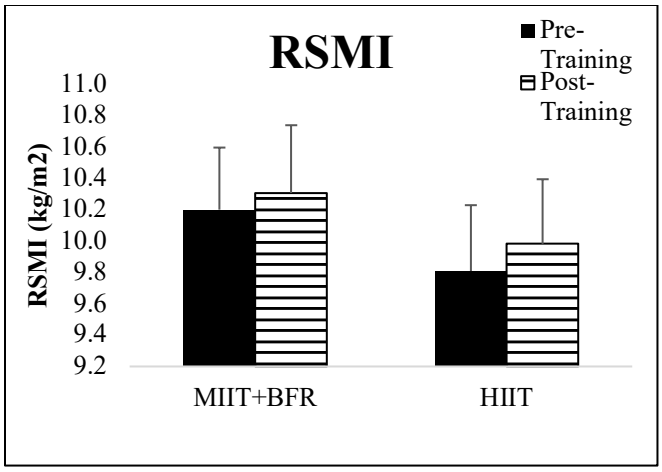


Figure 11. RSMI

Figure 12 displays the changes in leg region percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

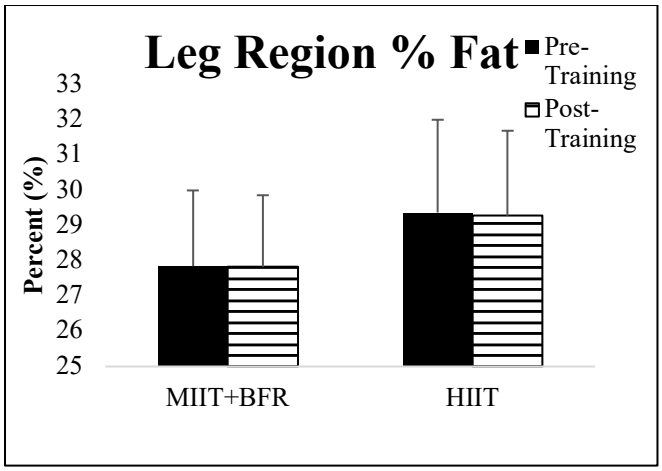


Figure 12. Leg Region % Fat

Figure 13 displays the changes in leg total mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

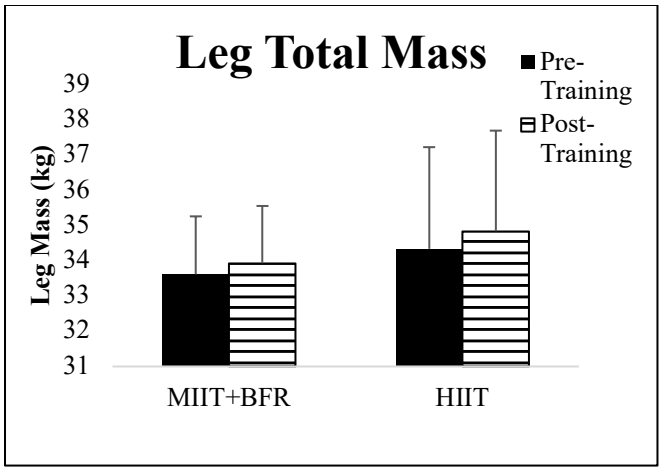


Figure 13. Leg Total Mass

Figure 14 displays the changes in leg fat mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

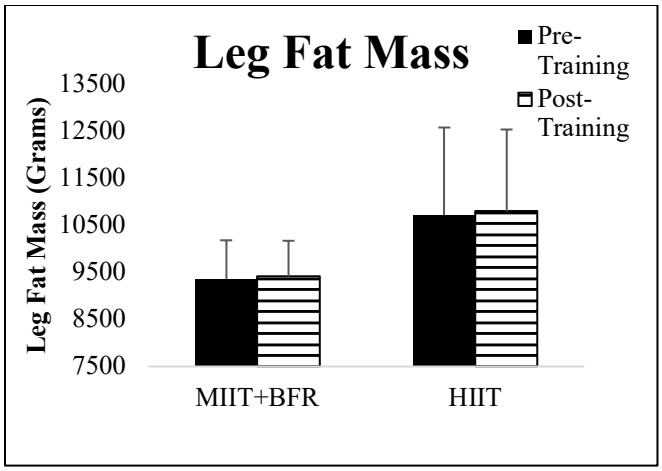


Figure 14. Leg Fat Mass

Figure 15 displays the changes in lean leg mass (LLM) from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a significance for a time main effect (22,705.3 ± 943.6 vs. 23,060.1 ± 958.3 g, $p = 0.04$) from pre-

to post-training; however, follow-up analysis test showed a trend for HIIT ($p = 0.07$) but not for MIIT+BFR ($p > 0.05$). There was no significance for a condition main effect, nor was there a condition*time interaction.

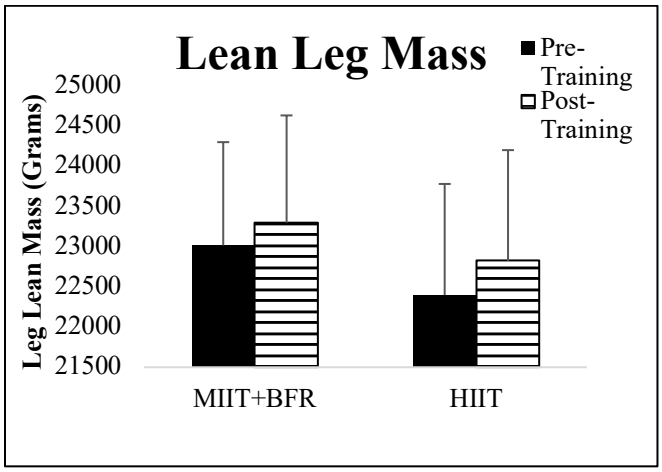
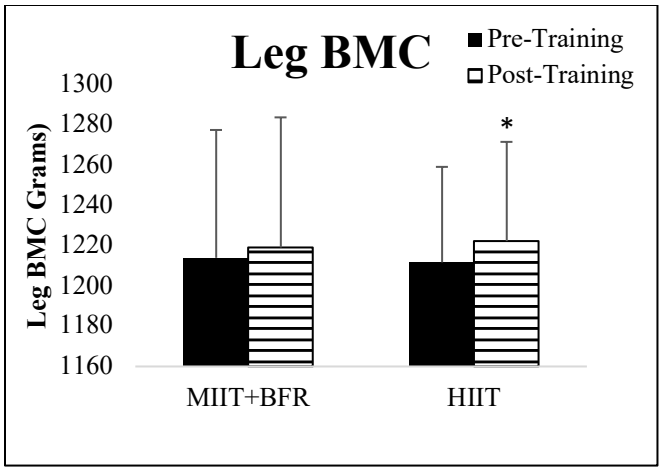


Figure 15. Lean Leg Mass

Figure 16 displays the changes in leg bone mineral content from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a significance for a time main effect (1,212.9 ± 39.7 vs. 1,220.8 ± 40.7 g, $p = 0.02$) from pre- to post-training. A follow-up analysis test determined that HIIT significantly increased post-values from baseline ($p = 0.02$). There was no significant condition main effect nor a condition*time interaction.



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

Figure 16. Leg Bone Mineral Content (BMC)

Figure 17 displays the changes in leg tissue mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

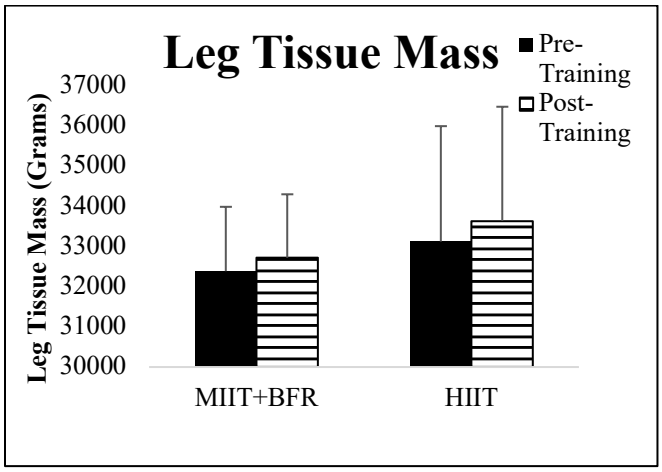


Figure 17. Leg Tissue Mass

Figure 18 displays the changes in trunk region percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for

homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

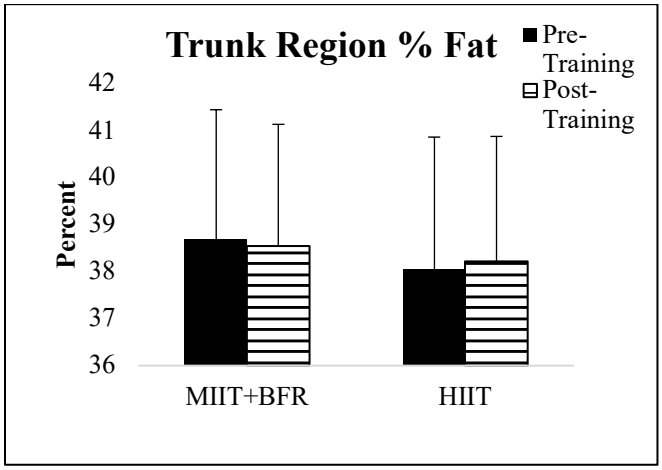


Figure 18. Trunk Region % Fat

Figure 19 displays the changes in trunk total mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

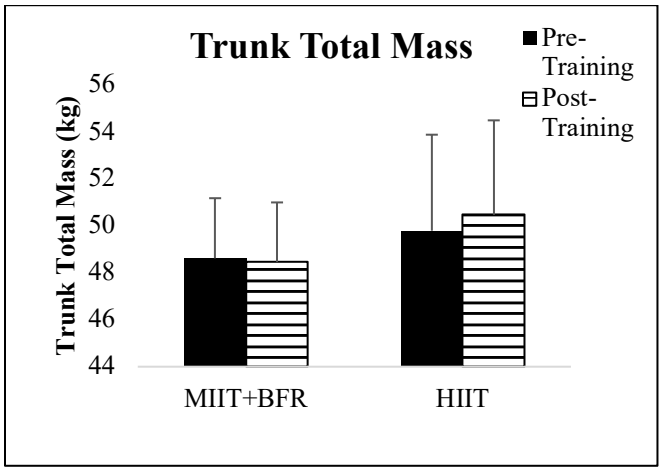


Figure 19. Trunk Total Mass

Figure 20 displays the changes in trunk fat mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

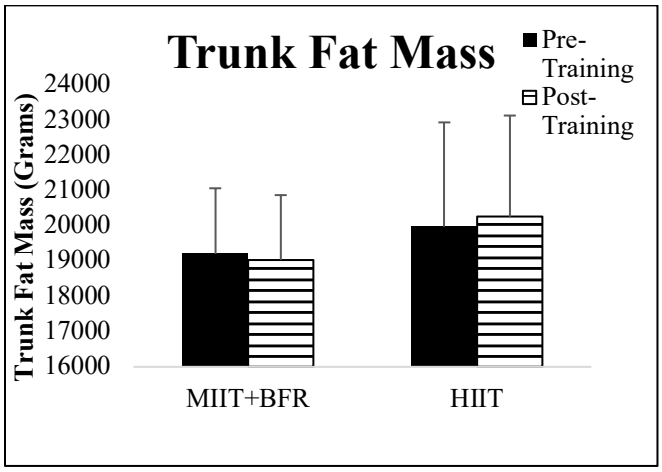


Figure 20. Trunk Fat Mass

Figure 21 displays the changes in trunk lean mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

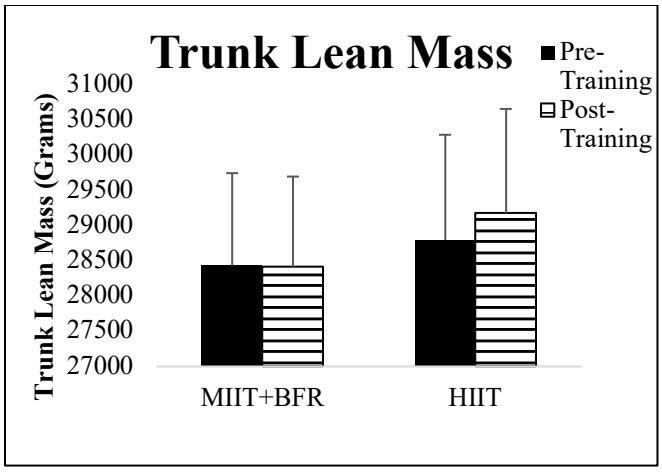
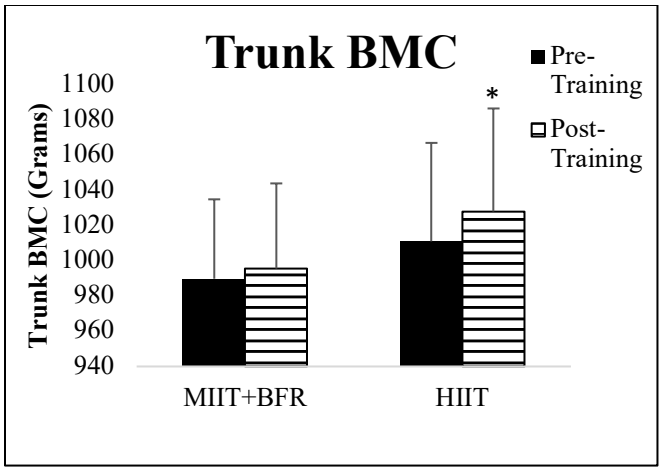


Figure 21. Trunk Lean Mass

Figure 22 displays the changes in trunk bone mineral content from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a significance for a time main effect (1,000.5 ± 36.0 vs. 1,011.9 ± 38.0 g, $p = 0.03$) from pre- to post-training. A follow-up analysis test determined that HIIT significantly increased post-values from baseline ($p = 0.02$). There was no significant condition main effect nor a condition*time interaction.



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

Figure 22. Trunk Bone Mineral Content (BMC)

Figure 23 displays the changes in trunk tissue mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

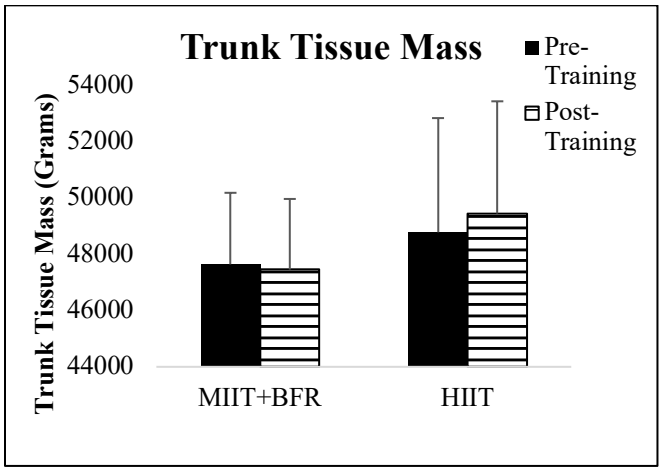


Figure 23. Trunk Tissue Mass

Figure 24 displays the changes in arm region percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

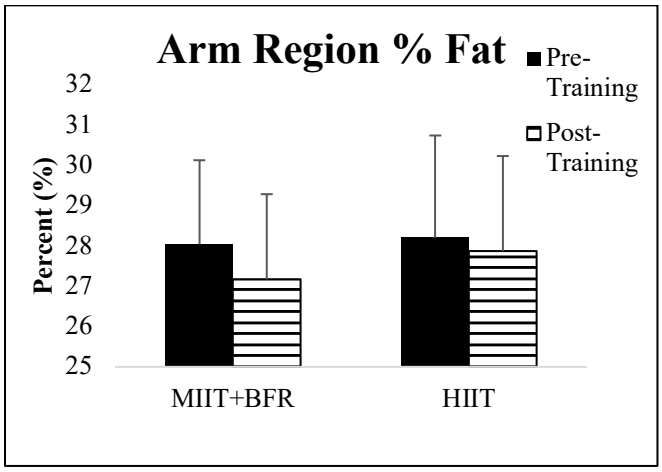


Figure 24. Arm Region % Fat

Figure 25 displays the changes in arm tissue mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

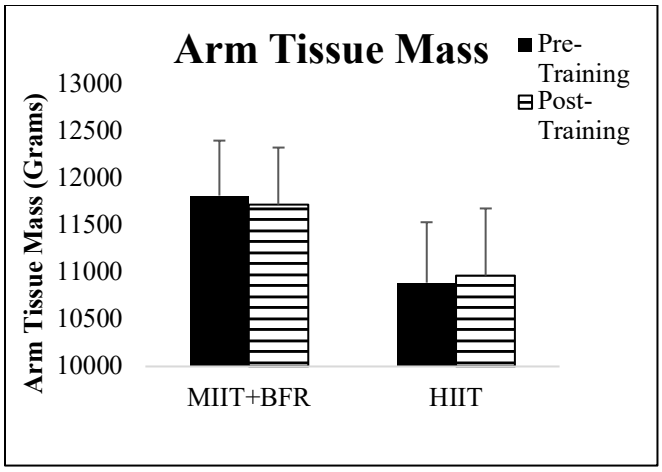


Figure 25. Arm Tissue Mass

Figure 26 displays the changes in arm fat mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

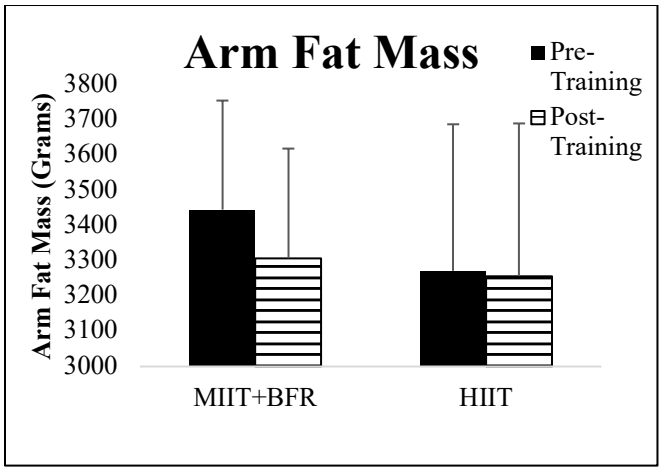


Figure 26. Arm Fat Mass

Figure 27 displays the changes in arm lean mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

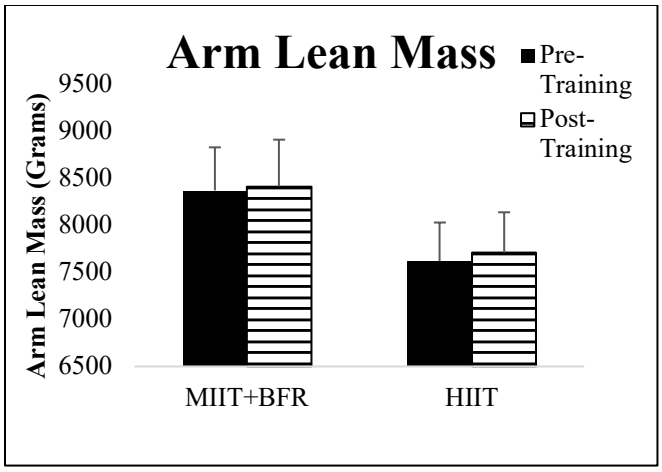


Figure 27. Arm Lean Mass

Figure 28 displays the changes in arm bone mineral content from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

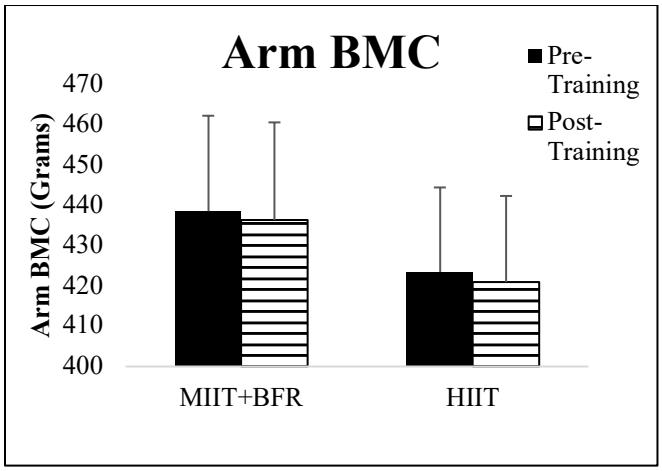


Figure 28. Arm Bone Mineral Content (BMC)

Figure 29 displays the changes in arm total mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

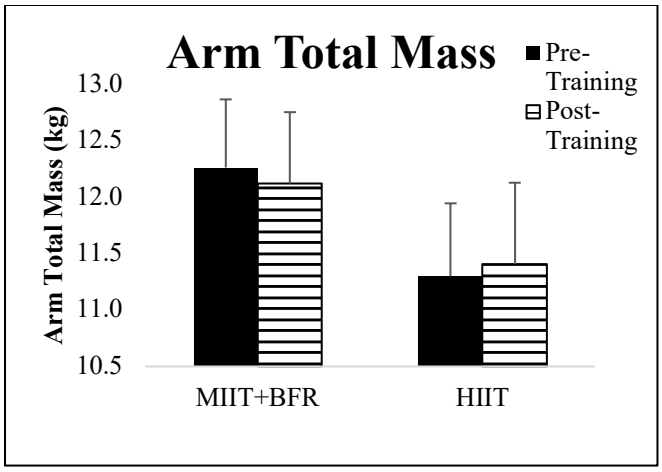


Figure 29. Arm Total Mass

Figure 30 displays the changes in android region percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

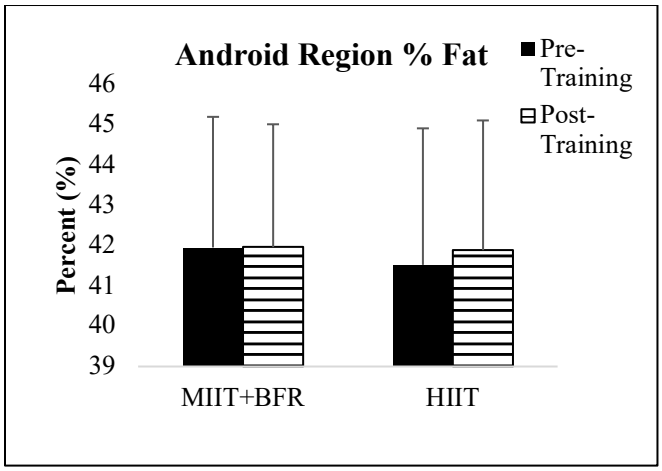


Figure 30. Android Region % Fat

Figure 31 displays the changes in android tissue mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

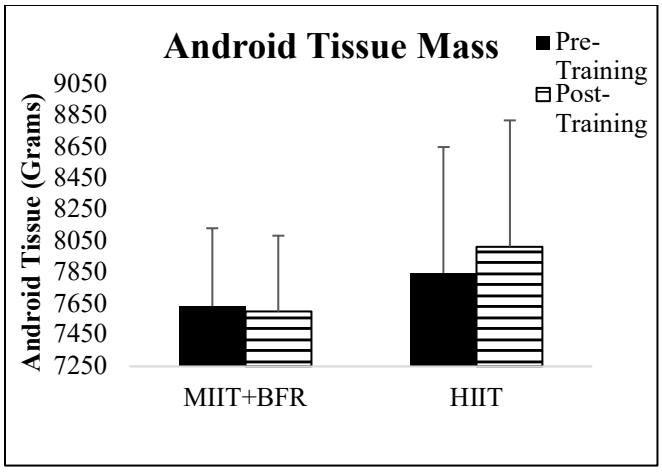


Figure 31. Android Tissue Mass

Figure 32 displays the changes in android fat mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

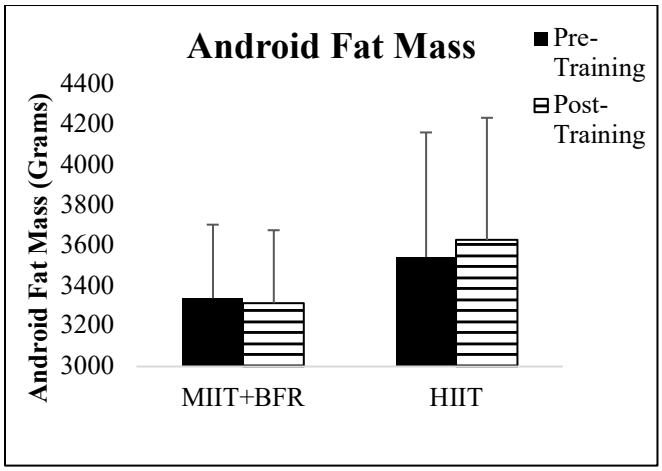


Figure 32. Android Fat Mass

Figure 33 displays the changes in android lean mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

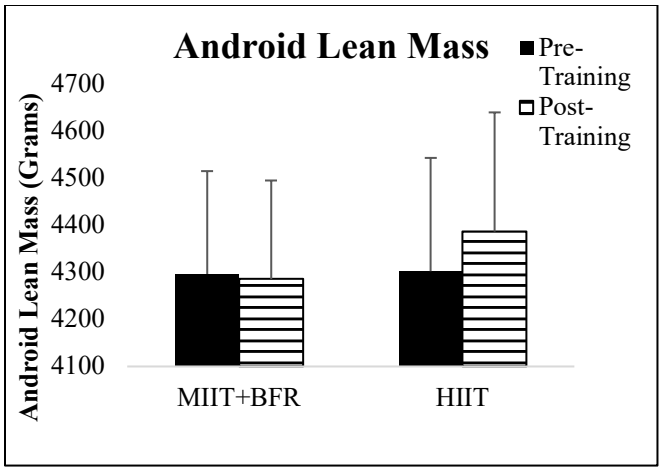


Figure 33. Android Lean Mass

Figure 34 displays the changes in android bone mineral content from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance ($p>0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

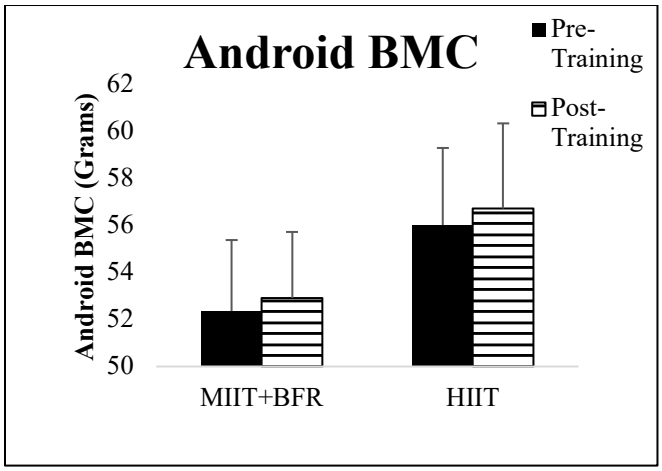


Figure 34. Android Bone Mineral Content (BMC)

Figure 35 displays the changes in android total mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

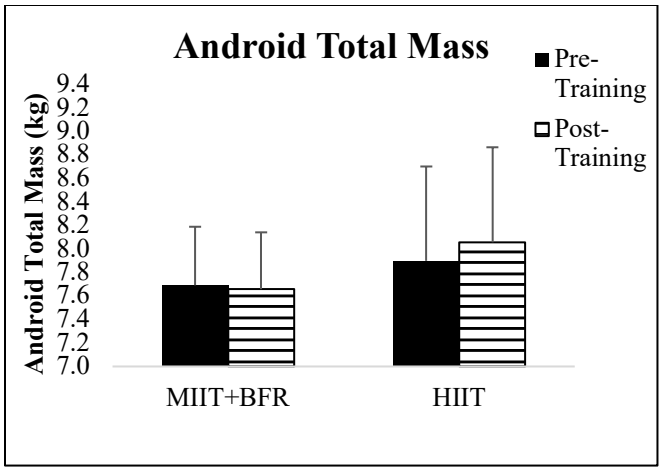


Figure 35. Android Total Mass

Figure 36 displays the changes in gynoid region percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's Test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

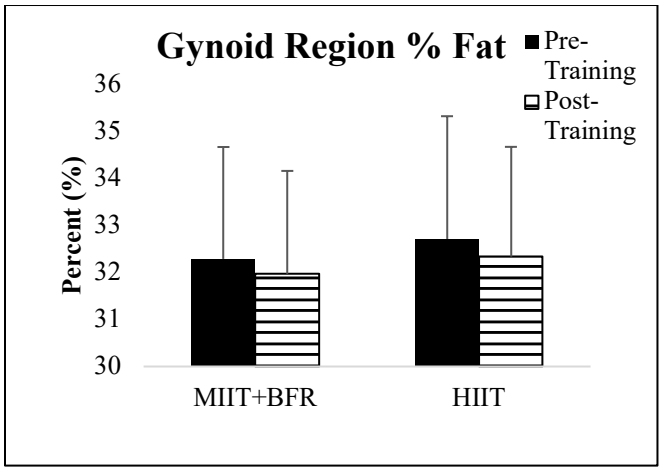


Figure 36. Gynoid Region % Fat

Figure 37 displays the changes in gynoid tissue mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

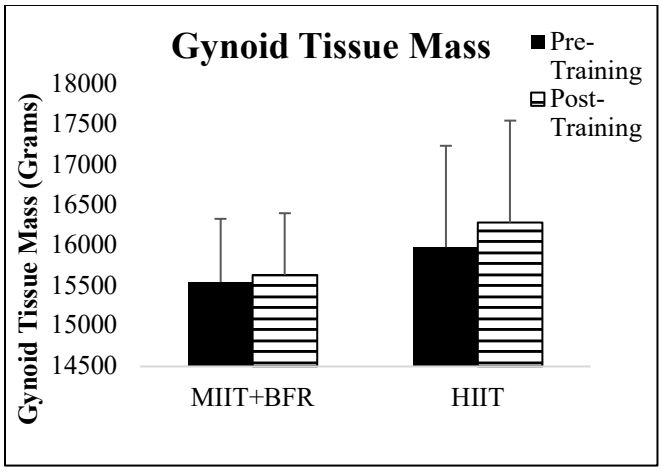


Figure 37. Gynoid Tissue Mass

Figure 38 displays the changes in gynoid fat mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

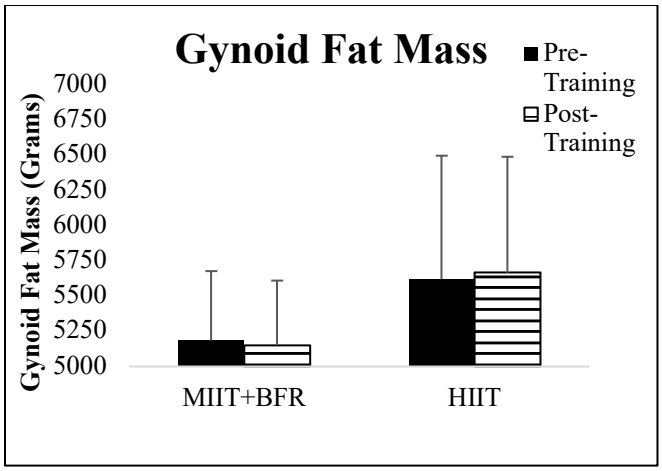


Figure 38. Gynoid Fat Mass

Figure 39 displays the changes in lean gynoid mass (LGM) from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a significance for a time main effect (10,363.3 ± 383.9 vs. 10,552.2 ± 386.7 g, $p = 0.05$) from pre-

to post-training; however, follow-up analysis test showed a trend for HIIT ($p = 0.06$) but not for MIIT+BFR ($p < 0.05$). There was no significance for a condition main effect, nor was there a condition*time interaction.

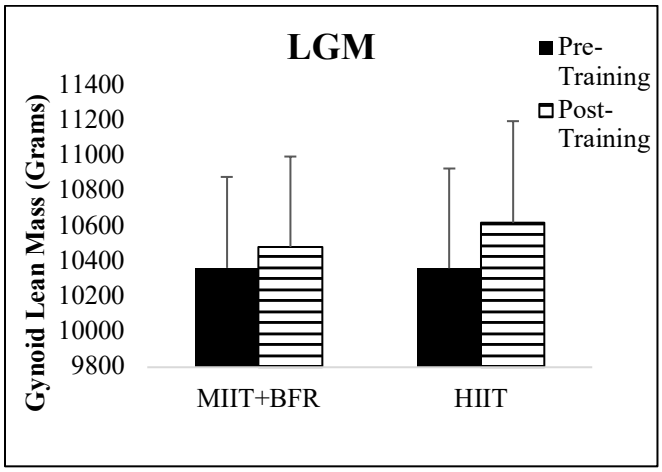


Figure 39. Lean Gynoid Mass (LGM)

Figure 40 displays the changes in gynoid bone mineral content from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a significance for a time main effect (320.6 ± 11.1 vs. 325.0 ± 11.8 g, $p = 0.02$) from pre- to post-training; however, follow-up analysis test showed a trend for HIIT ($p = 0.07$) and for MIIT+BFR ($p = 0.09$). There was no significant condition main effect nor a condition*time interaction.

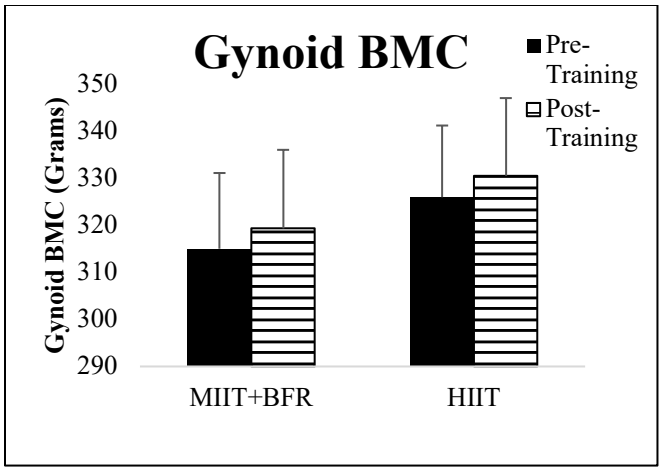


Figure 40. Gynoid Bone Mineral Content (BMC)

Figure 41 displays the changes in gynoid total mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

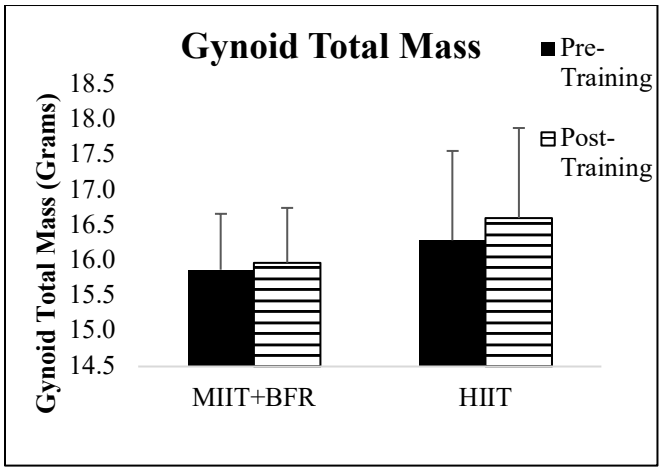


Figure 41. Gynoid Total Mass

Figure 42 displays the changes in total tissue mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

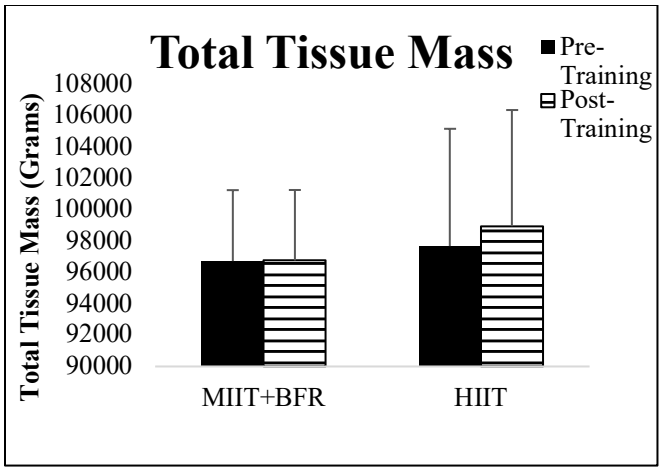


Figure 42. Total Tissue Mass

Figure 43 displays the changes in trunk fat mass (FM) to total FM ratio from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

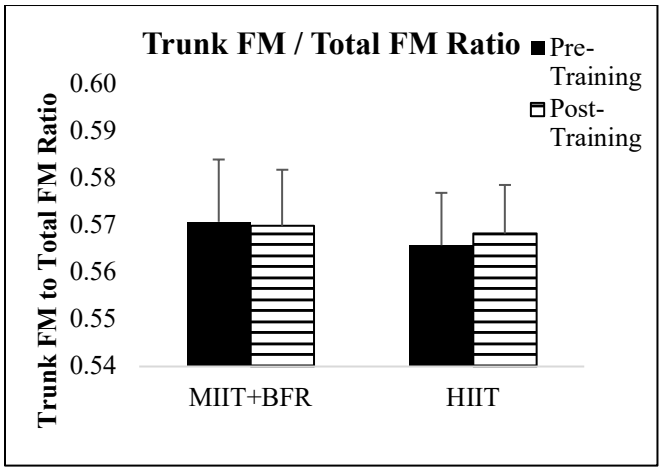
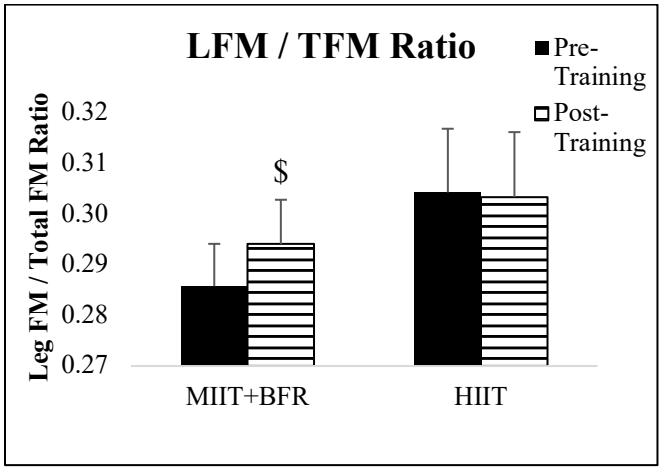


Figure 43. Trunk Fat Mass (FM) / Total FM Ratio

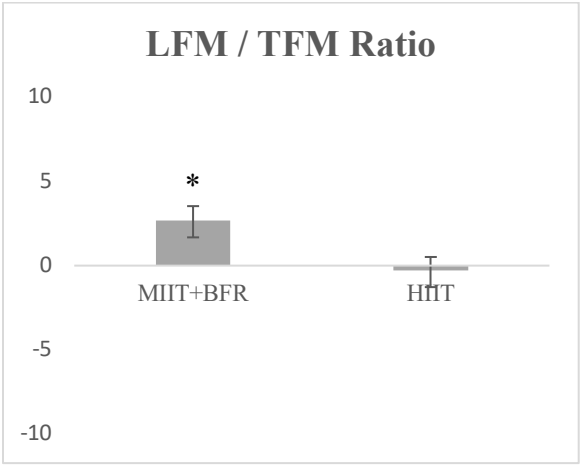
Figure 44 displays the changes in leg fat mass (LFM) to total FM (TFM) ratio from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a trend for a time main effect (0.29 ± 0.01 vs. 0.30 ± 0.01, $p = 0.06$) and a

condition*time interaction (BFR: 0.28 ± 0.01 vs. 0.29 ± 0.01; HIIT: 0.30 ± 0.01 vs. 0.30 ± 0.01, p = 0.002) from pre- to post-training. A follow-up analysis test determined that MIIT+BFR significantly increased post-values from baseline (p = 0.005). Figure 45 displays each condition's percent change from pre to post. One-way ANOVA found a significant percent change between conditions (p = 0.02). The percent changes for HIIT, and MIIT+BFR were -0.3% and 2.7%, respectively.



$Significantly different (p < 0.01) from baseline.
Values reported as mean ± SE.

Figure 44. LFM / TFM Ratio



*Significantly different (p < 0.05) from baseline.

Figure 45. Percent Change in LFM/TFM Ratio

Figure 46 displays the changes in limb fat mass (FM) to trunk FM ratio from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

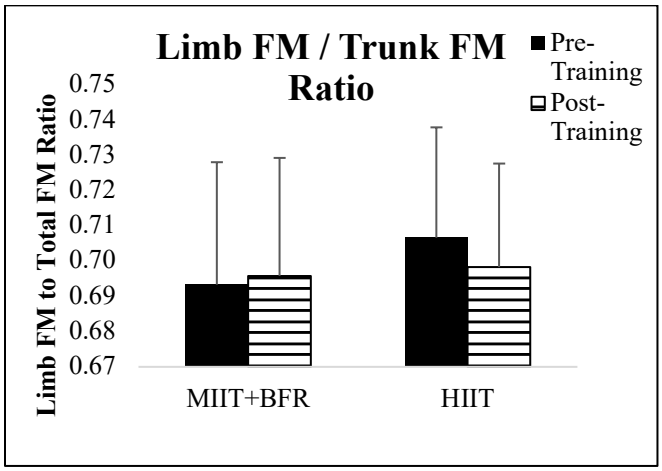


Figure 46. Limb FM / Trunk FM Ratio

Figure 47 displays the changes in estimate visceral adipose tissue (VAT) mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

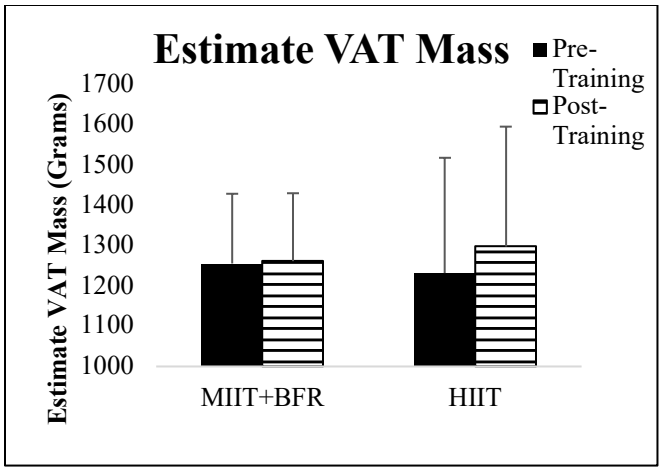


Figure 47. Estimate Visceral Adipose Tissue (VAT) Mass

Figure 48 displays the changes in visceral adipose tissue (VAT) volume from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

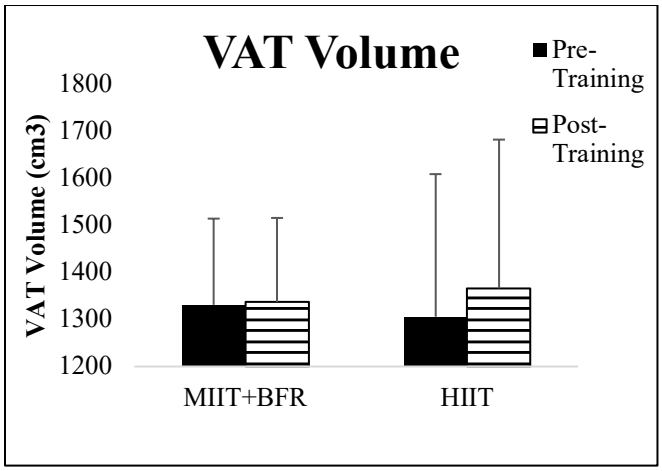


Figure 48. Visceral Adipose Tissue (VAT) Volume

Figure 49 displays the changes in resting metabolic rate from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

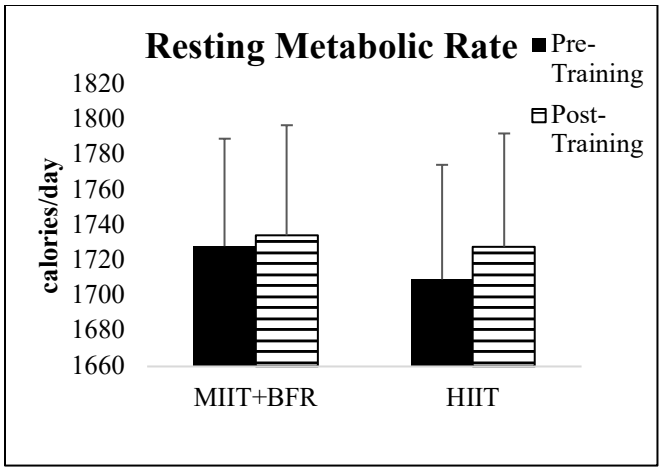


Figure 49. Resting Metabolic Rate

Cardiovascular Parameters

Figure 50 displays the changes in pulse wave velocity from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

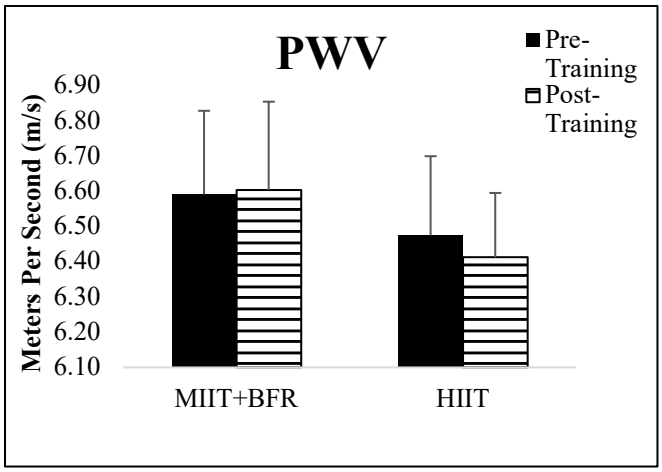


Figure 50. Pulse Wave Velocity (PWV)

Figure 51 displays the changes in aortic systolic blood pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

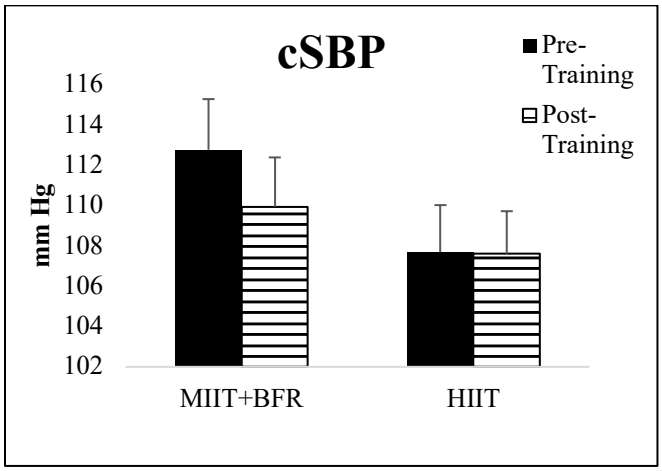


Figure 51. Aortic Systolic Blood Pressure (cSBP)

Figure 52 displays the changes in aortic diastolic blood pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

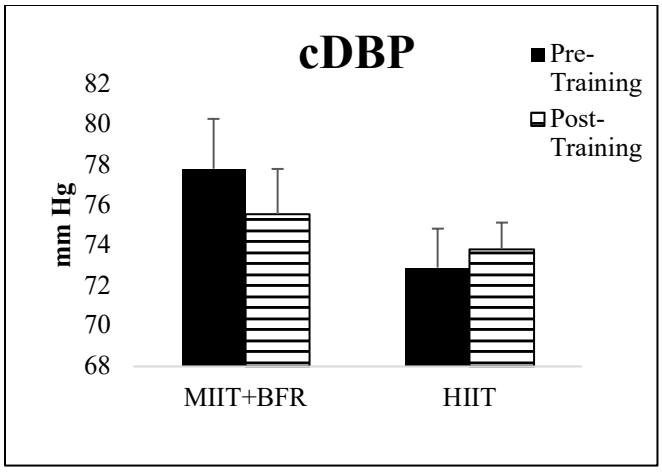


Figure 52. Aortic Diastolic Blood Pressure (cDBP)

Figure 53 displays the changes in aortic pulse pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

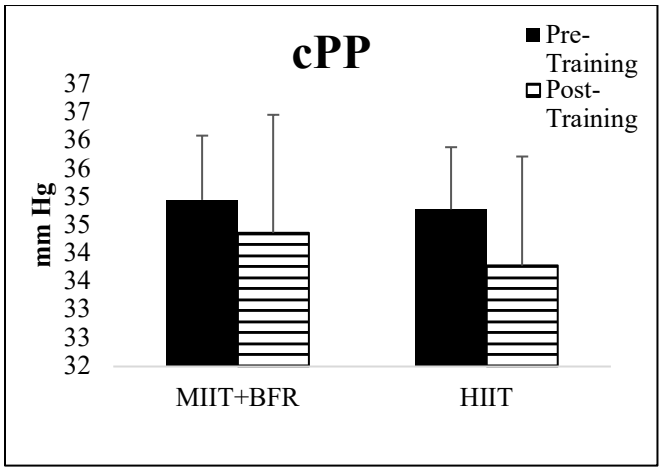


Figure 53. Aortic Pulse Pressure (cPP)

Figure 54 displays the changes in aortic mean arterial pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

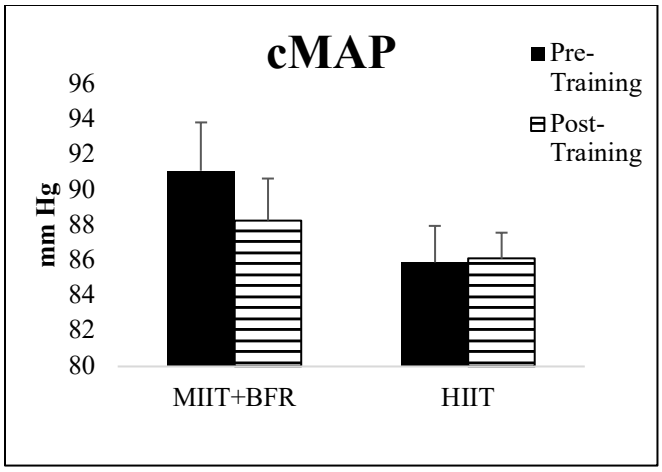


Figure 54. Aortic Mean Arterial Pressure (cMAP)

Figure 55 displays the changes in aortic heart rate from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

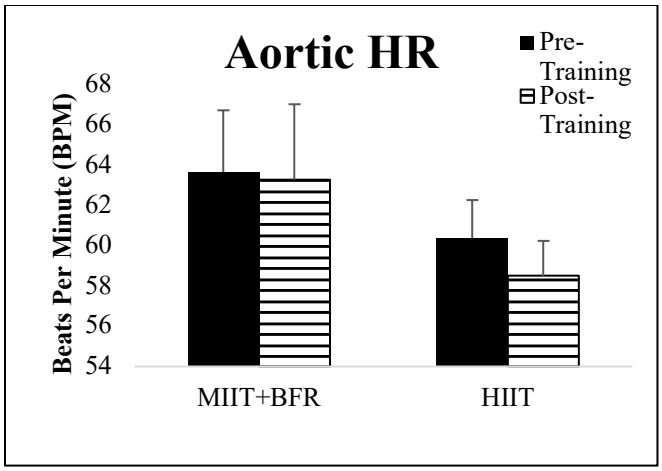


Figure 55. Aortic Heart Rate (HR)

Figure 56 displays the changes in brachial systolic blood pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

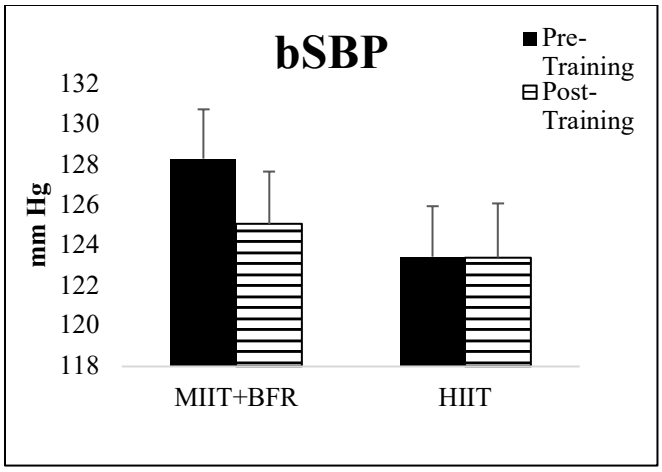


Figure 56. Brachial Systolic Blood Pressure (bSBP)

Figure 57 displays the changes in brachial diastolic blood pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

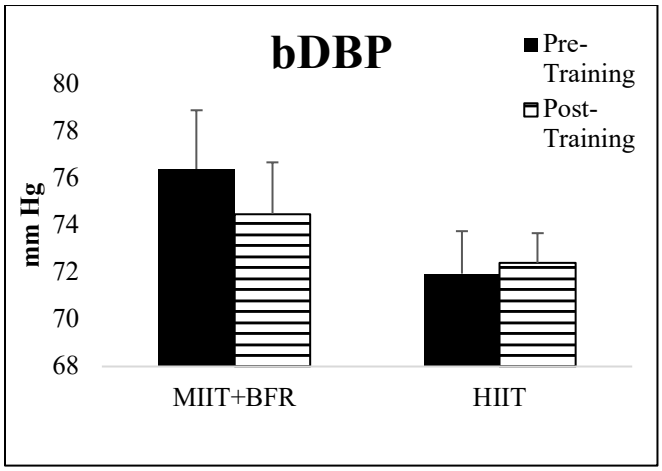


Figure 57. Brachial Diastolic Blood Pressure (bDBP)

Figure 58 displays the changes in augmentation index % from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

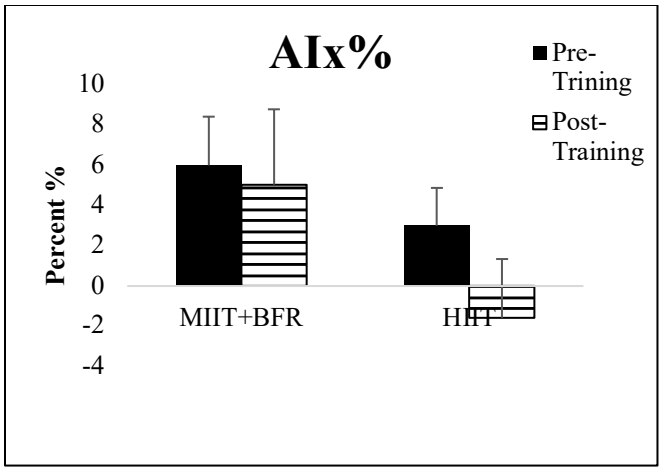
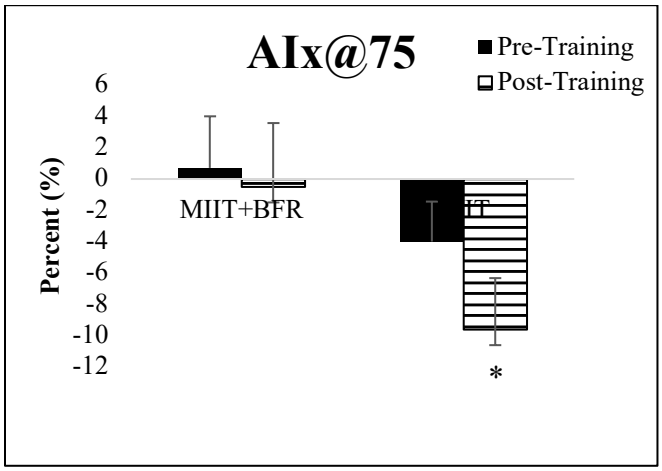


Figure 58. Augmentation Index % (AIx%)

Figure 59 displays the changes in the augmentation index @ 75 beats per minute (AIx@75) from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significant condition main effect nor a condition*time interaction; however, there was a significant decrease over time (-4.0 ± 2.6% vs. -9.6 ± 3.3%, $p = 0.03$) in response to HIIT from pre- to post-training.



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

Figure 59. Augmentation Index @ 75 (AIx@75)

Figure 60 displays the changes in heart rate, period from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

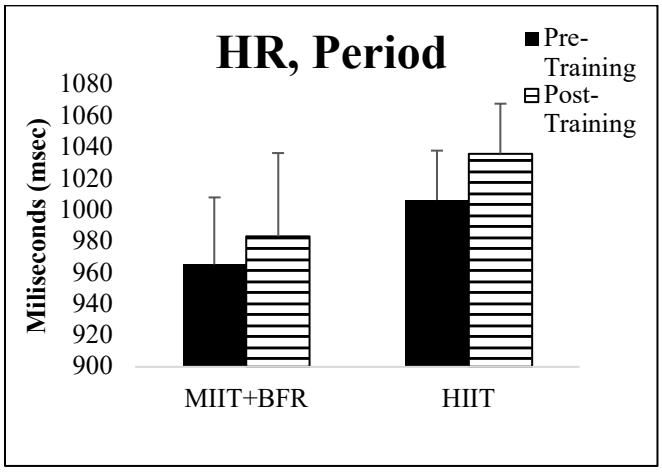


Figure 60. Heart Rate (HR), Period

Figure 61 displays the changes in ejection duration from pre- to post-training. One-way ANOVA found a significant baseline difference between groups ($p = 0.02$). However, analysis of covariance (ANCOVA) found no significant differences between baseline values ($p > 0.05$).

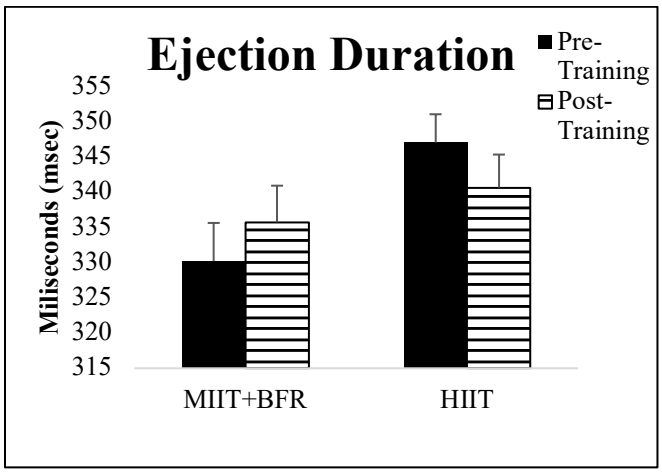


Figure 61. Ejection Duration

Figure 62 displays the changes in aortic T2 from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

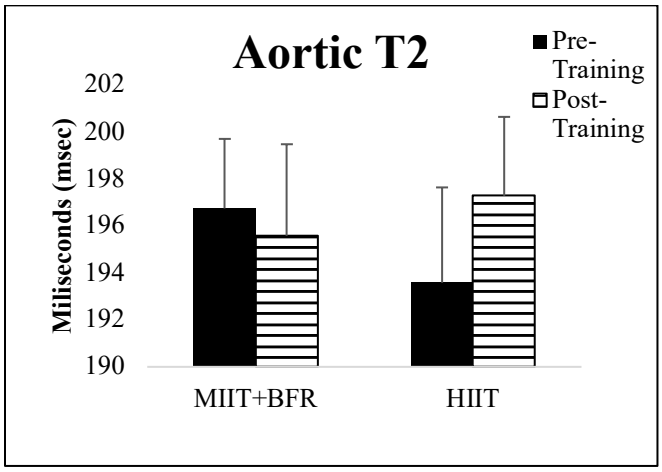


Figure 62. Aortic T2

Figure 63 displays the changes in P1 Height from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

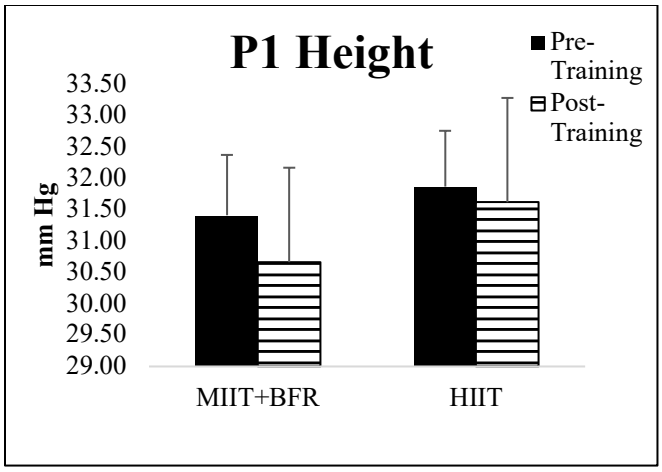


Figure 63. P1 Height

Figure 64 displays the changes in aortic augmentation pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

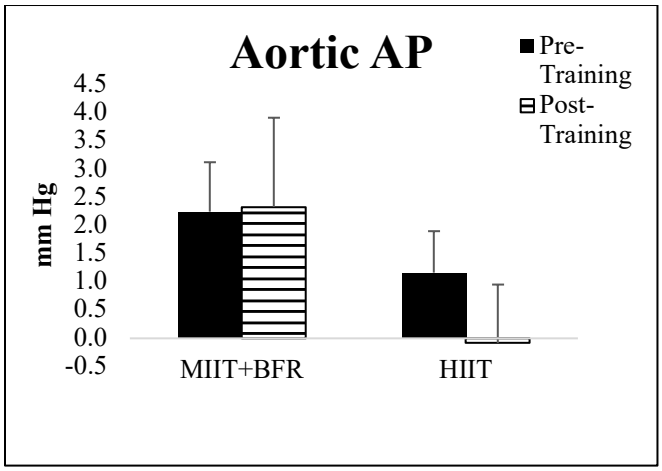


Figure 64. Aortic Augmentation Pressure (AP)

Figure 65 displays the changes in Buckberg SEVR% from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

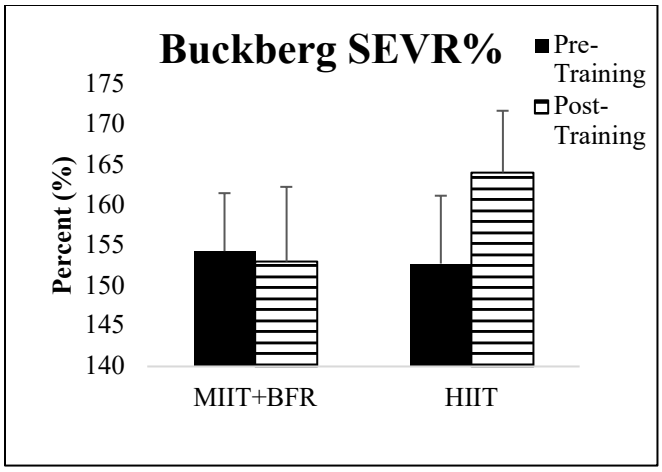


Figure 65. Buckberg SEVR%

Figure 66 displays the changes in end-systolic pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a trend for a condition*time interaction (BFR: 97.3 ± 3.1 vs. 94.8 ± 2.5 mm Hg; HIIT: 90.8 ± 3.1 vs. 92.3 ± 2.5 mm Hg, $p = 0.09$) from pre- to post-training. However, a follow-up analysis test no longer found a trend in end-systolic pressure for HITT ($p > 0.05$) and MIIT+BFR ($p > 0.05$).

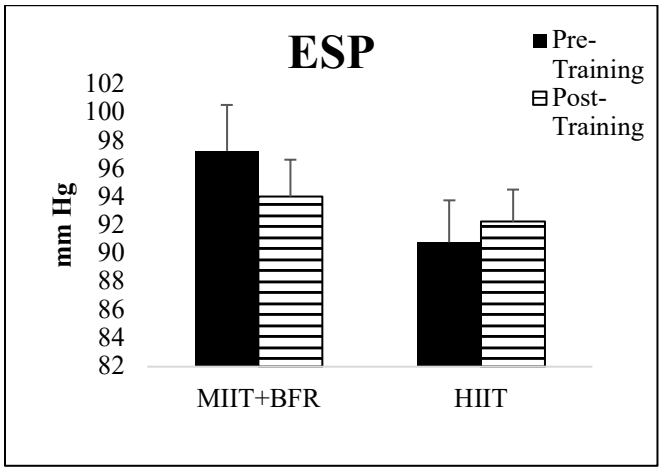


Figure 66. End-Systolic Pressure (ESP)

Figure 67 displays the changes in forward pulse height from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

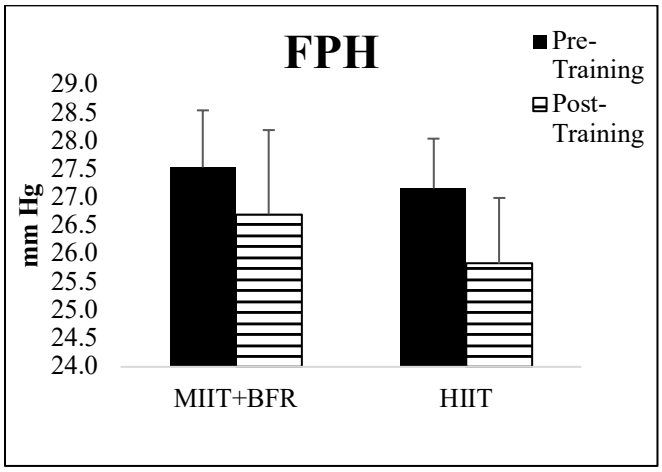


Figure 67. Forward Pulse Height (FPH)

Figure 68 displays the changes in reflected pulse height from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

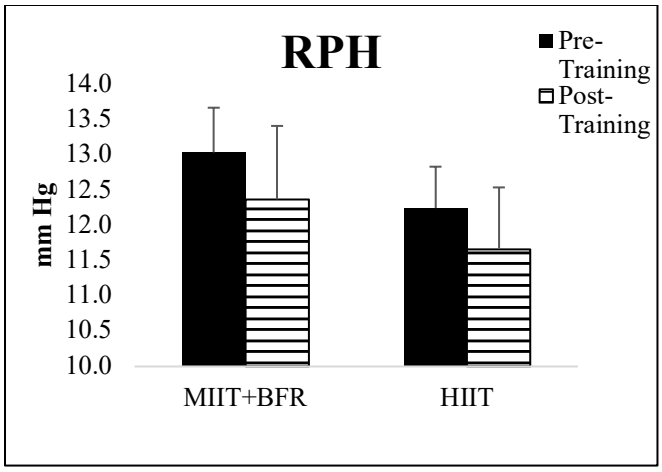


Figure 68. Reflected Pulse Height (RPH)

Figure 69 displays the changes in reflection magnitude from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

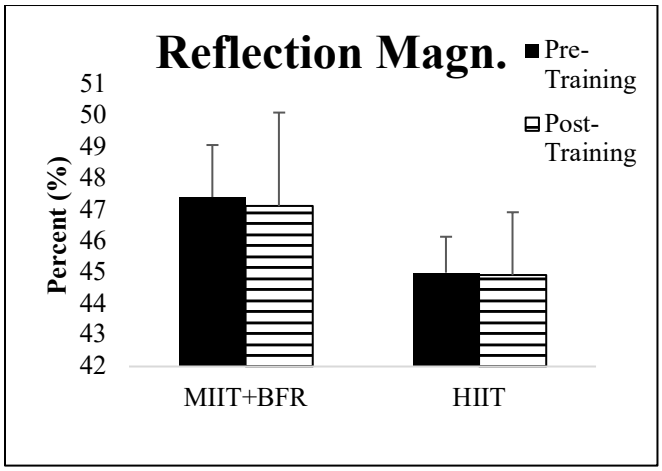


Figure 69. Reflection Magnitude (Magn.)

Anaerobic Measurements

Figure 70 displays the changes in work rate from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significant condition

main effect nor a condition*time interaction; however, there was a trend for a time main effect for HIIT ($p = 0.06$) from pre- to post-training but not for MIIT+BFR ($p < 0.05$).

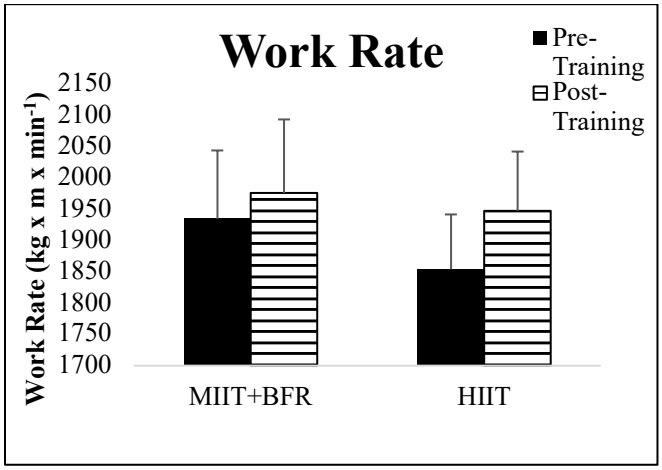


Figure 70. Work Rate

Figure 71 displays the changes in average anaerobic power output (W_{avg}) from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significant condition main effect nor a condition*time interaction; however, there was a trend for a time main effect for HIIT ($p = 0.06$) from pre- to post-training but not for MIIT+BFR ($p < 0.05$).

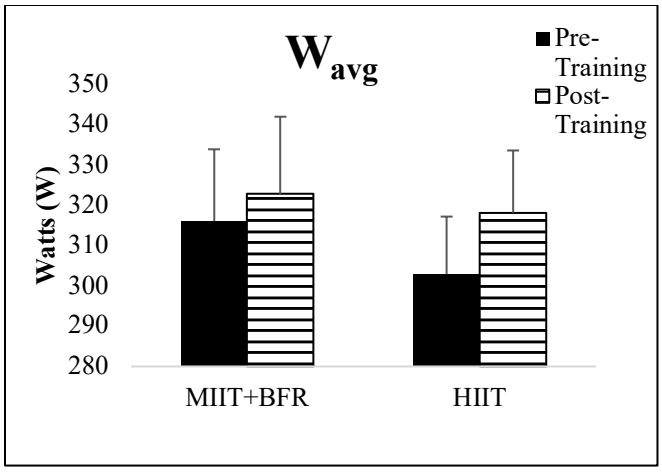


Figure 71. Average Anaerobic Power Output (W_{avg})

Figure 72 displays the changes in relative average power output from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

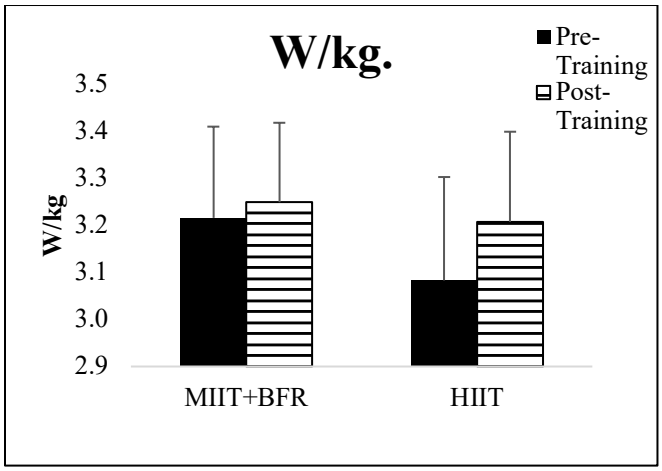


Figure 72. Relative Average Power Output (W/kg.)

Strength Measurements

Figure 73 displays the changes in maximal voluntary contraction from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no

significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

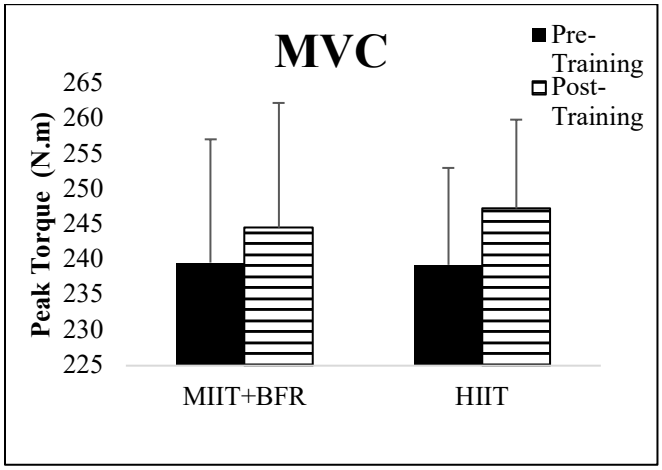
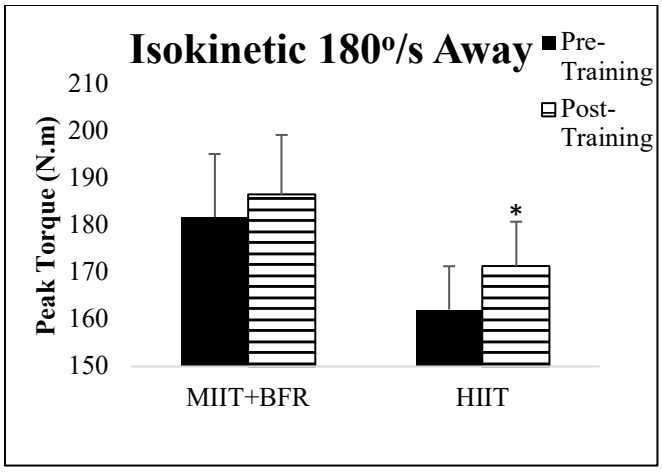


Figure 73. Maximal Voluntary Contraction (MVC)

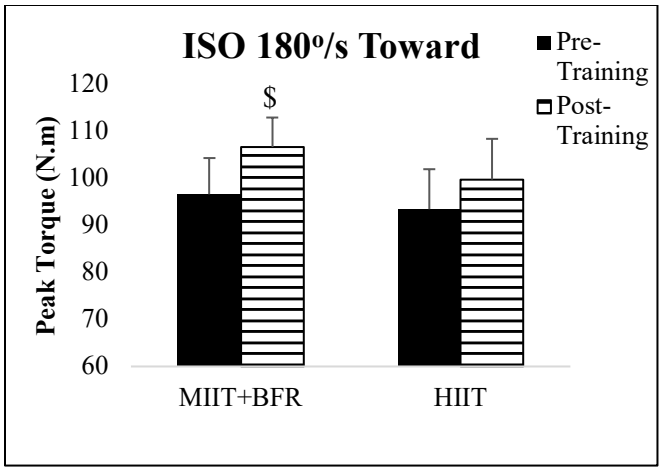
Figure 74 displays the changes in isokinetic (ISO) 180°/s away from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a significance for a time main effect (172.0 ± 8.2 vs. 179.0 ± 7.9 N·m, $p = 0.01$) pre- to post-training. A follow-up analysis test determined that HIIT significantly increased post-values from baseline ($p = 0.02$). There was no significance for a condition main effect or a condition*time interaction.



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

Figure 74. Isokinetic (ISO) 180º/s Away

Figure 75 displays the changes in isokinetic 180°/s toward from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a significance for a time main effect (95.1 ± 5.8 vs. 103.3 ± 5.03 N·m, $p = 0.002$) from pre- to post-training. A follow-up analysis test determined that MIIT+BFR significantly increased post-values from baseline ($p = 0.006$), and there was a trend for a time main effect for HIIT ($p = 0.07$) from pre- to post-training. There was no significance for a condition main effect or a condition*time interaction.



$Significantly different ($p < 0.01$) from baseline.
Values reported as mean ± SE.

Figure 75. Isokinetic (ISO) 180º/s Toward

Figure 76 displays the changes in isokinetic 60°/s away from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

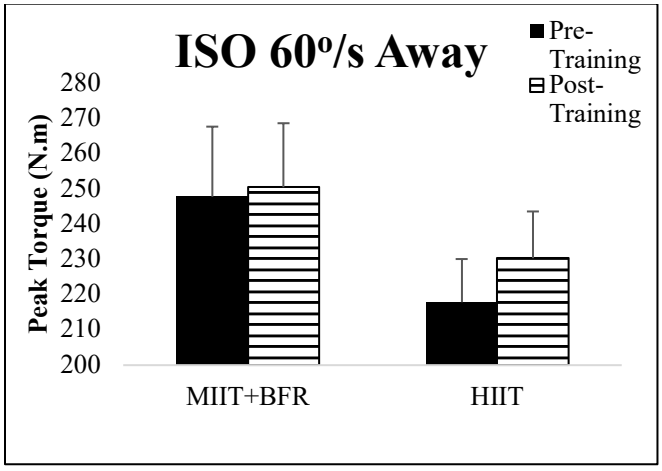


Figure 76. Isokinetic (ISO) 60º/s Away

Figure 77 displays the changes in isokinetic 60°/s toward from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

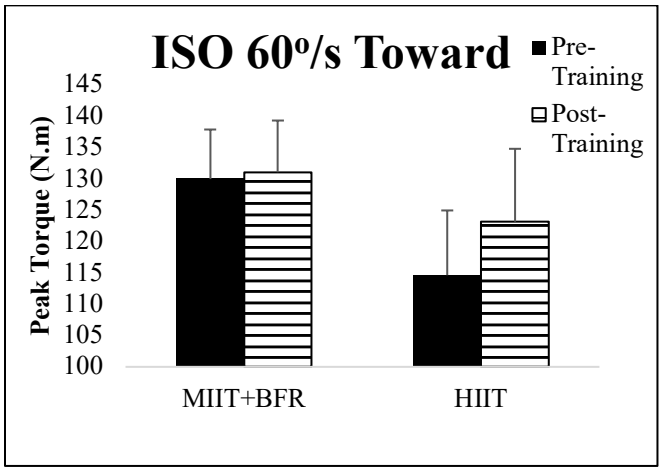
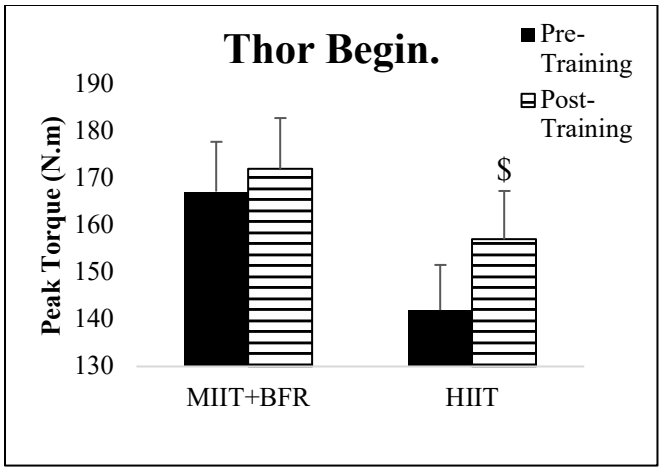


Figure 77. Isokinetic (ISO) 60º/s Toward

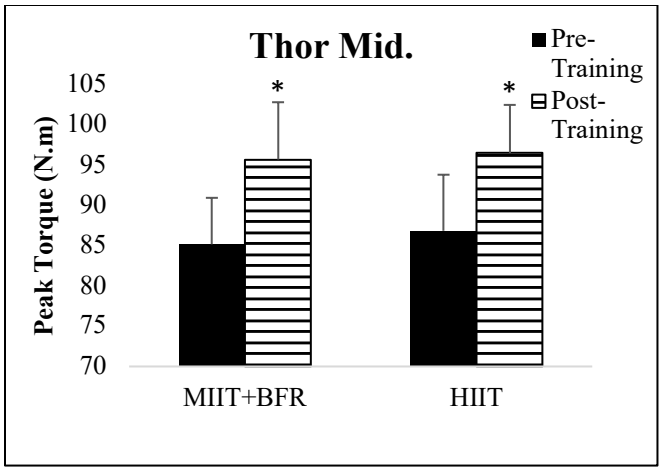
Figure 78 displays the changes in the first repetitions of the Thorstensson Test of Fatiguability from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a significance for a time main effect (154.6 ± 7.2 vs. 164.6 ± 7.5 N·m, $p = 0.01$) from pre- to post-training; however, a follow-up analysis test determined that HIIT significantly increased post-values from baseline ($p = 0.005$). There was no significance for a condition main effect or a condition*time interaction.



[$]Significantly different ($p < 0.01$) from baseline.
Values reported as mean ± SE.

Figure 78. Thorstensson (Thor) Beginning (Begin.)

Figure 79 displays the changes in the repetitions 24, 25, and 26 of the Thorstensson Test of Fatiguability from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a significance for a time main effect (86.0 ± 4.5 vs. 96.1 ± 4.7 N·m, $p = 0.003$) from pre- to post-training; however, a follow-up analysis test determined that HIIT significantly increased post-values ($p = 0.03$) from baseline, but MIIT+BFR induced a superior increase ($p = 0.02$) from baseline. There was no significance for a condition main effect or a condition*time interaction.



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

Figure 79. Thorstensson (Thor) Middle (Mid.)

Figure 80 displays the changes in the last three repetitions of the Thorstensson test of Fatiguability from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

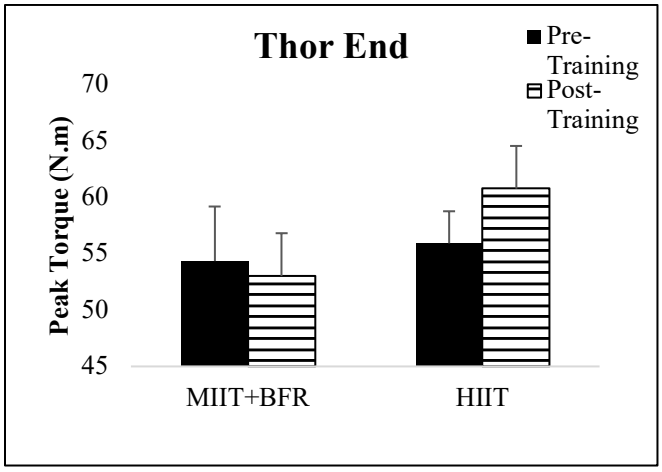


Figure 80. Thorstensson (Thor) End

Figure 81 displays the changes in the % decline of the Thorstensson Test of Fatiguability from pre- to post-training. One-way ANOVA found a significant baseline difference between groups ($p = 0.05$). However, analysis of covariance (ANCOVA) found no significant differences between conditions for baseline values ($p > 0.05$).

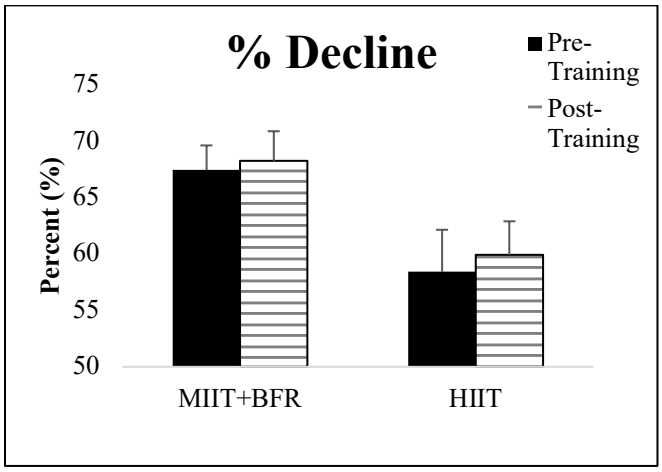


Figure 81. % Decline

Figure 82 displays the changes in the fast-twitch (FT) muscle fiber percentage from pre- to post-training. One-way ANOVA found a significant baseline difference between groups ($p = 0.05$). However, analysis of covariance (ANCOVA) found no significant differences between conditions for baseline values ($p > 0.05$).

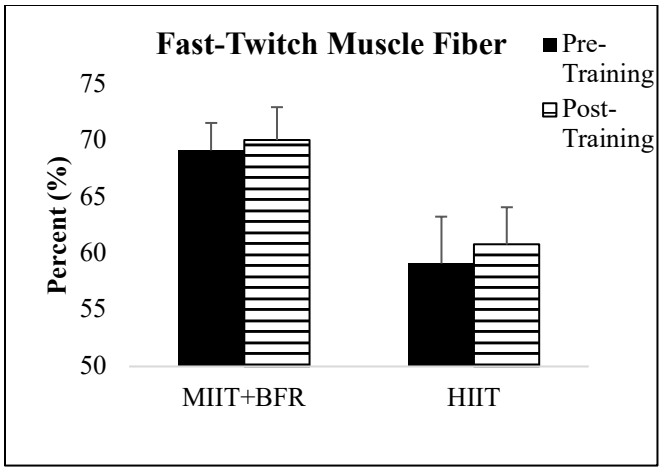


Figure 82. Fast-Twitch Muscle Fiber

Figure 83 displays the changes in the slow-twitch (ST) muscle fiber percentage from pre- to post-training. One-way ANOVA found a significant baseline difference between groups ($p = 0.05$). However, analysis of covariance (ANCOVA) found no significant differences between conditions for baseline values ($p > 0.05$).

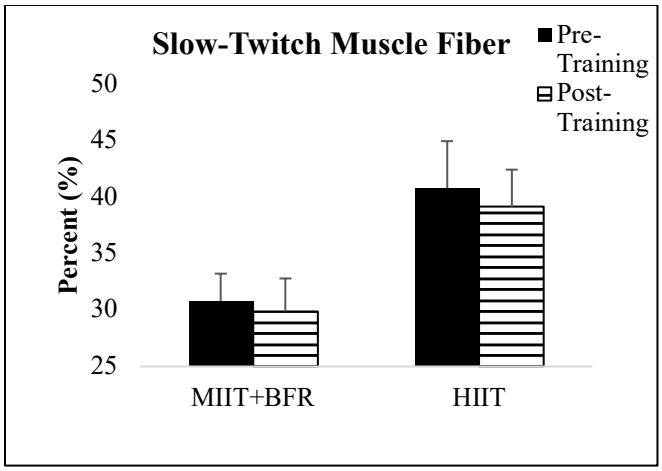


Figure 83. Slow-Twitch Muscle Fiber

Hemodynamic Responses

Figure 84 displays the changes in HDI systolic blood pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no

significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

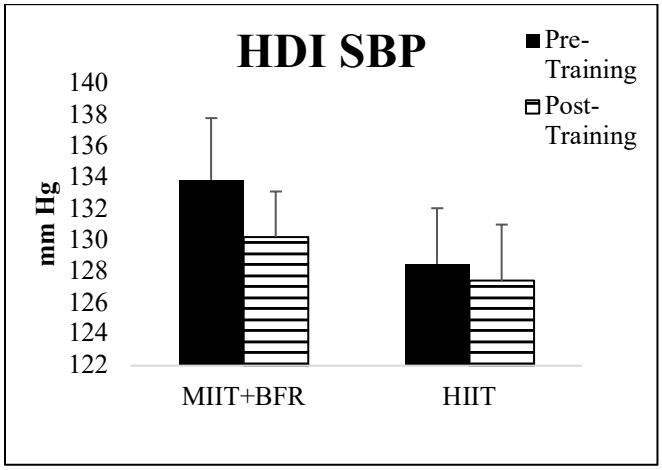


Figure 84. HDI Systolic Blood Pressure (HDI SBP)

Figure 85 displays the changes in HDI diastolic blood pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

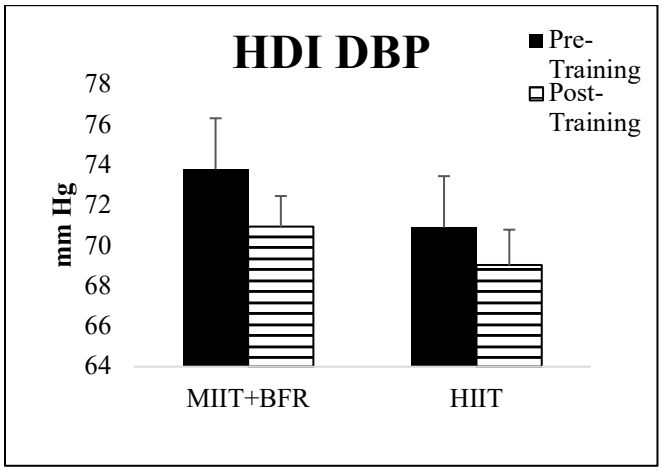


Figure 85. HDI Diastolic Blood Pressure (HDI DBP)

Figure 86 displays the changes in HDI mean arterial pressure (MAP) from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no

significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a trend for a time main effect (93.4 ± 2.1 vs. 90.3 ± 1.4 mm Hg, $p = 0.07$); however, a follow-up analysis test lost the trend. There was no significance for a condition main effect, nor was there a condition*time interaction.

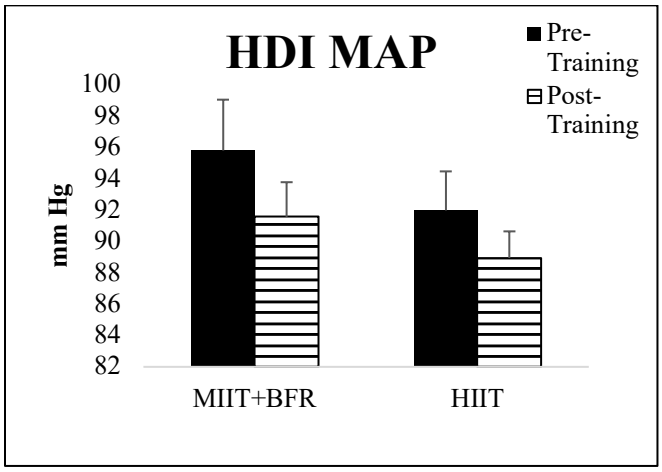


Figure 86. HDI Mean Arterial Pressure (HDI MAP)

Figure 87 displays the changes in HDI pulse pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

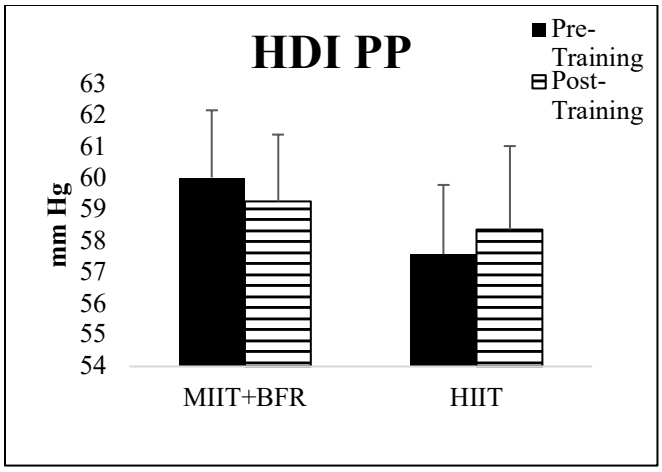


Figure 87. HDI Pulse Pressure (HDI PP)

Figure 88 displays the changes in HDI heart rate from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

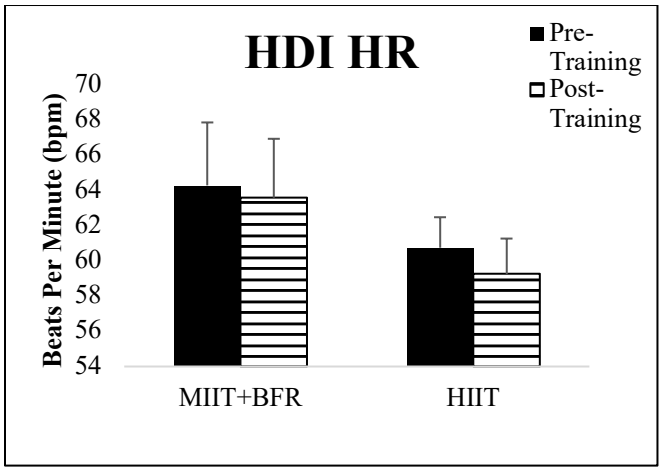


Figure 88. HDI Heart Rate (HDI HR)

Figure 89 displays the changes in cardiac ejection time from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

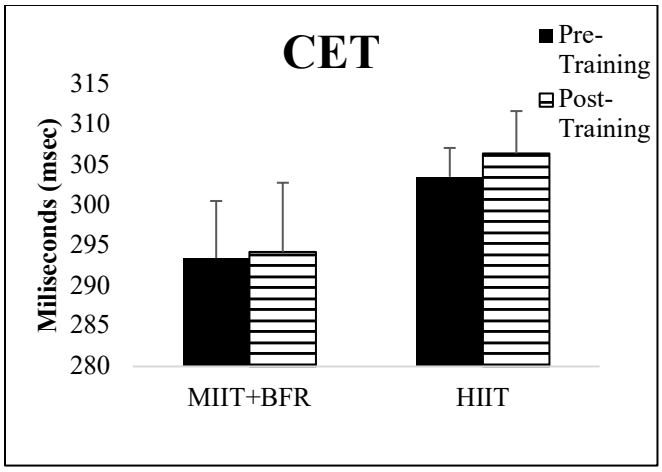


Figure 89. Cardiac Ejection Time (CET)

Figure 90 displays the changes in stroke volume from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

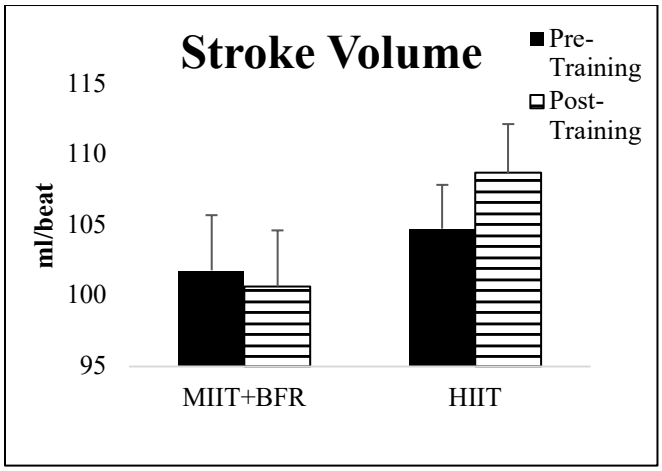


Figure 90. Stroke Volume

Figure 91 displays the changes in stroke volume index from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected a significance for homogeneity of variance ($p < 0.05$); therefore, a Kruskal-Wallis test was used. However, no significant differences between conditions were detected ($p > 0.05$).

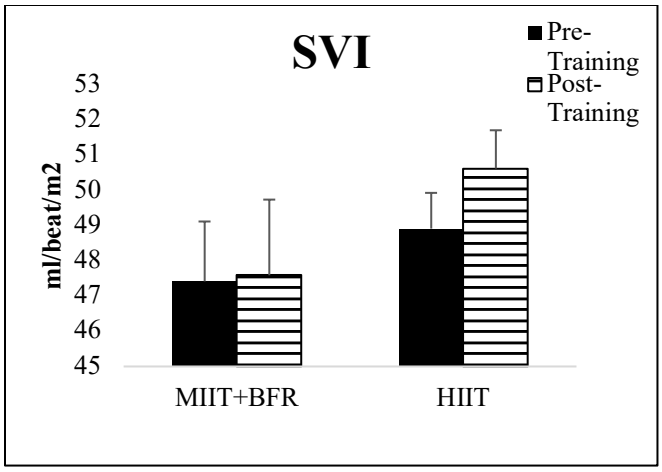


Figure 91. Stroke Volume Index (SVI)

Figure 92 displays the changes in cardiac output from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

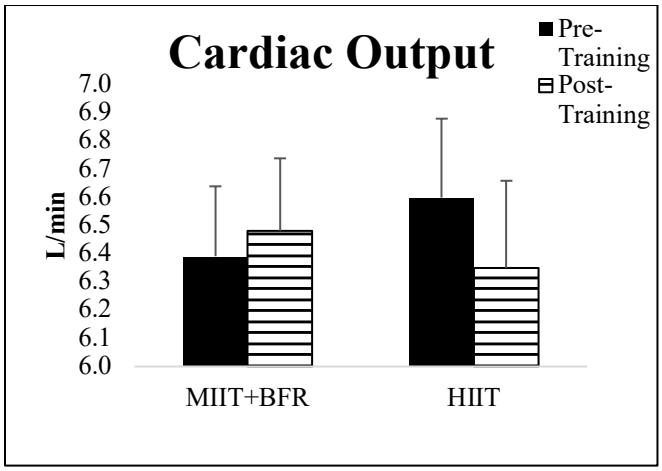
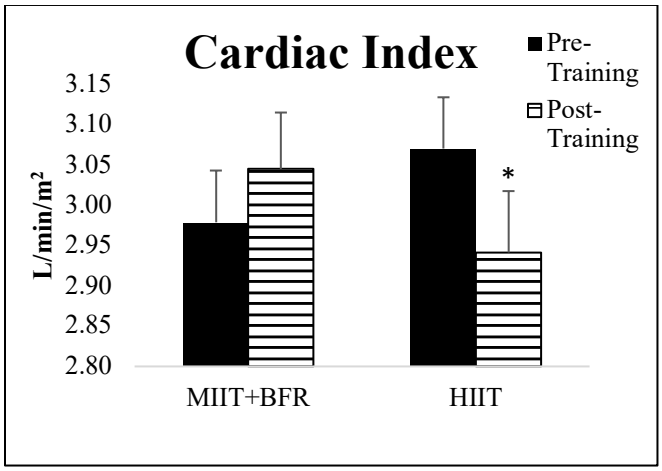


Figure 92. Cardiac Output

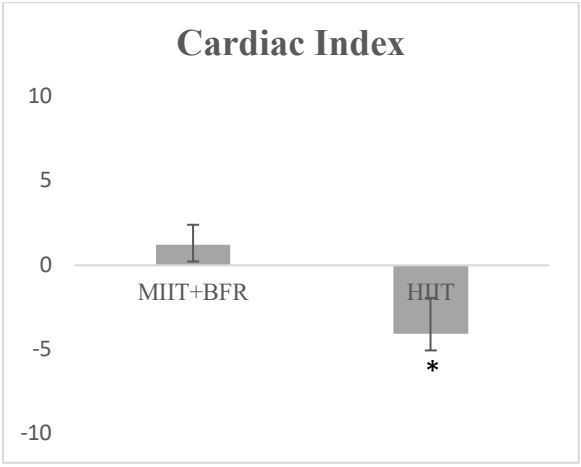
Figure 93 displays the changes in cardiac index from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a condition*time interaction (BFR: 3.01 ± 0.07 vs. 3.05 ± 0.08 L/min/m^2; HIIT: 3.07 ± 0.06 vs. 2.94

± 0.07 L/min/m^2, p = 0.04) from pre- to post-training; however, a follow-up analysis test determined that HIIT significantly changed the post-values from baseline (p = 0.03). Figure 94 displays each condition's percent change from pre to post. One-way ANOVA found significance in the percent change between conditions (p = 0.05). The percent changes for HIIT and MIIT+BFR were -4.1% and 1.2%, respectively.



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

Figure 93. Cardiac Index



*Significantly different (p < 0.05) from baseline.

Figure 94. Percent Change in Cardiac Index

Figure 95 displays the changes in large arterial elasticity index from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

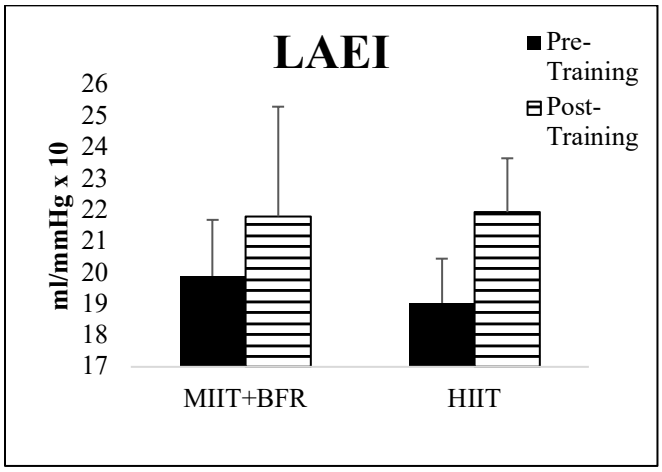


Figure 95. Large Arterial Elasticity Index (LAEI)

Figure 96 displays the changes in small arterial elasticity index from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

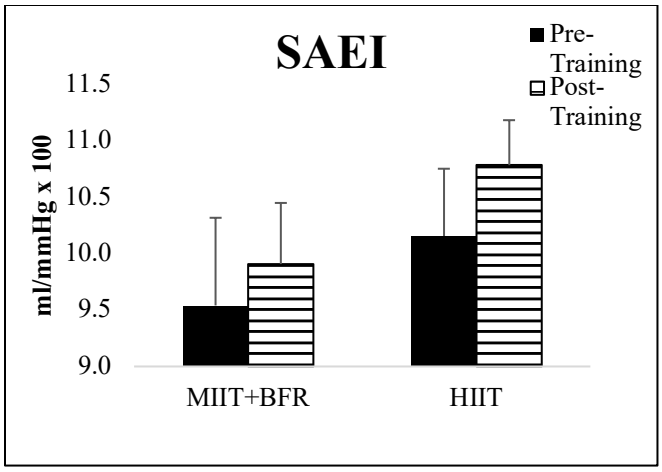


Figure 96. Small Arterial Elasticity Index (SAEI)

Figure 97 displays the changes in systemic vascular resistance from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

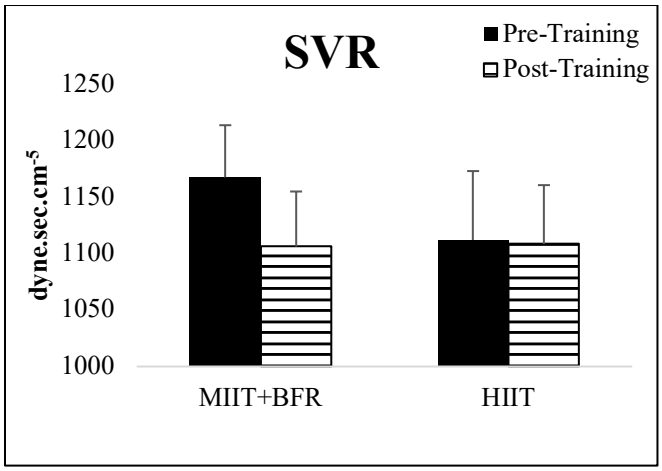


Figure 97. Systemic Vascular Resistance (SVR)

Figure 98 displays the changes in total vascular impedance from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for condition or time main effect or condition*time interaction.

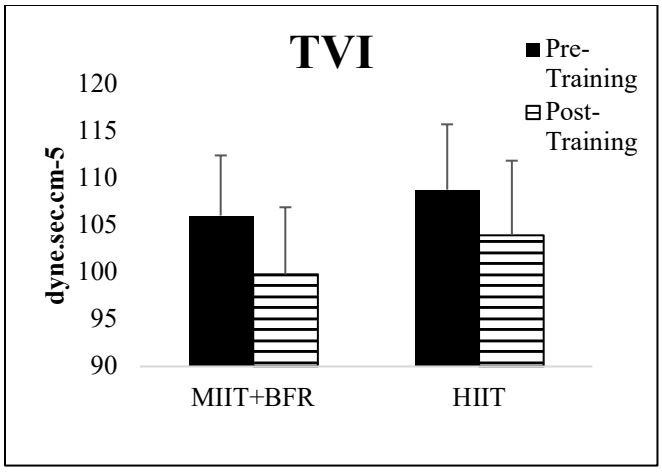
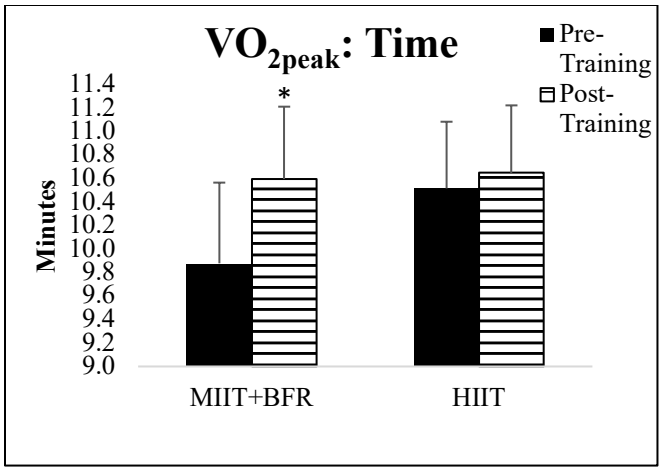


Figure 98. Total Vascular Impedance (TVI)

Cardiorespiratory Fitness

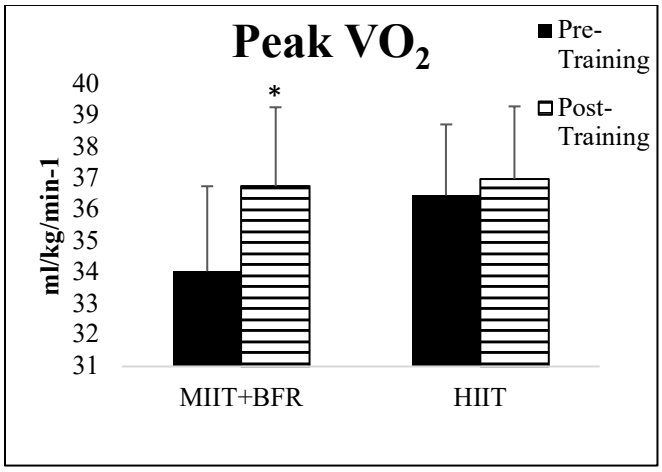
Figure 99 displays the changes in time to reach peak oxygen uptake (VO_{2peak}) from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a significance for a time main effect (10.2 ± 0.4 vs. 10.6 ± 0.4 min, $p = 0.01$) and a trend for a condition*time interaction (BFR: 9.9 ± 0.6 vs. 10.6 ± 0.6 min; HIIT: 10.5 ± 0.6 vs. 10.7 ± 0.6 min, $p = 0.06$) from pre- to post-training. A follow-up analysis test determined that MIIT+BFR significantly increased post-values from baseline ($p = 0.02$) but not for HIIT ($p > 0.05$). There was no significance for a condition main effect.



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

Figure 99. VO_{2peak}:Time

Figure 100 displays the changes in peak oxygen uptake (VO_2) from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p>0.05$). Two-way ANOVA with repeated measures found a significance for a time main effect (35.3 ± 1.7 vs. 36.9 ± 1.7 ml/kg/min-1, $p = 0.01$) and a trend for a condition*time interaction (BFR: 34.0 ± 2.5 vs. 36.8 ± 2.4 ml/kg/min-1; HIIT: 36.5 ± 2.5 vs. 37.0 ± 2.4 ml/kg/min-1, $p = 0.06$) from pre- to post-training. There was no significance for a condition main effect. A follow-up analysis test determined that MIIT+BFR significantly increased post-values from baseline ($p = 0.02$) but not HIIT ($p>0.05$).



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

Figure 100. Peak VO_2

Figure 101 displays the changes in peak heart rate from pre- to post-training. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). There was no significance for a condition main effect or a condition*time interaction. Two-way ANOVA with repeated measures found a significance for a time main effect (191.7 ± 2.9 vs. 194.8 ± 1.8 bpm, $p = 0.06$) from pre- to post-training; however, a follow-up analysis test found a trend for MIIT+BFR ($p = 0.07$) but not for HIIT ($p > 0.05$).

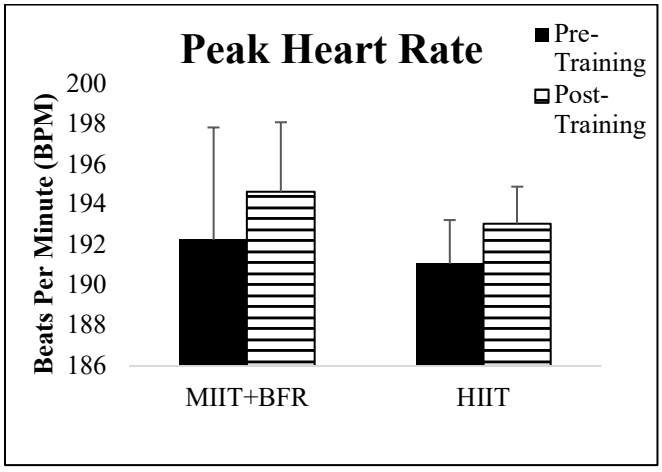


Figure 101. Peak Heart Rate

Hormone Response

Figure 102 displays the changes in salivary cortisol concentration in response to the first training session. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for a condition or a time main effect ($p > 0.05$), nor was there a condition*time interaction ($p > 0.05$).

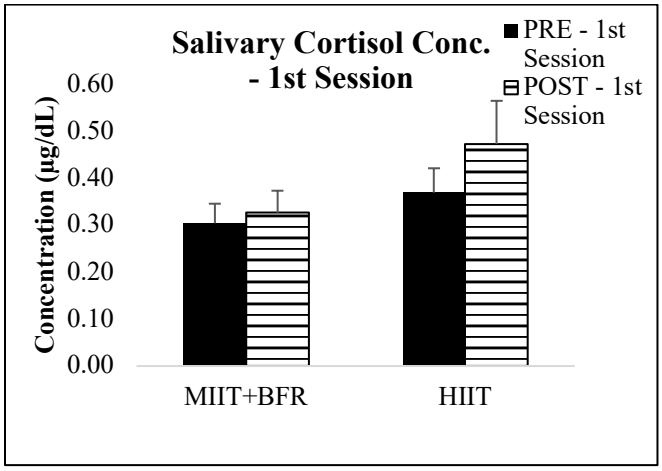


Figure 102. Salivary Cortisol Concentration (Conc.) – 1st Session

Figure 103 displays the changes in salivary cortisol concentration in response to the last training session. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for a condition main effect, nor was there a condition*time interaction. There was a significance for a time main effect ($p = 0.03$), but a follow-up analysis test lost the significance ($p > 0.05$).

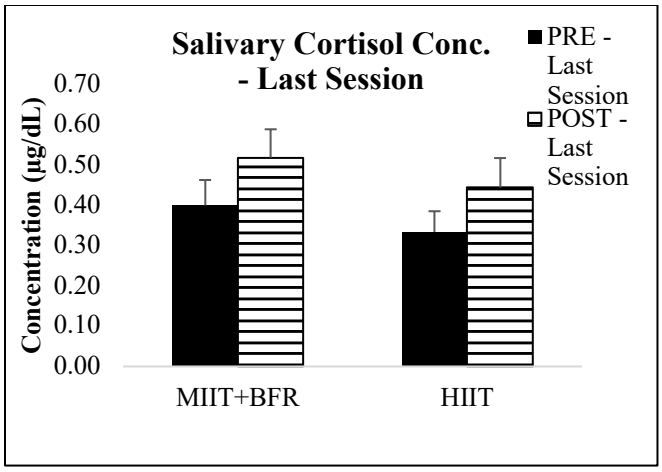


Figure 103. Salivary Cortisol Concentration (Conc.) – Last Session

Figure 104 displays the changes in salivary testosterone concentration in response to the first training session. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for a condition or a time main effect ($p > 0.05$), nor was there a condition*time interaction ($p > 0.05$).

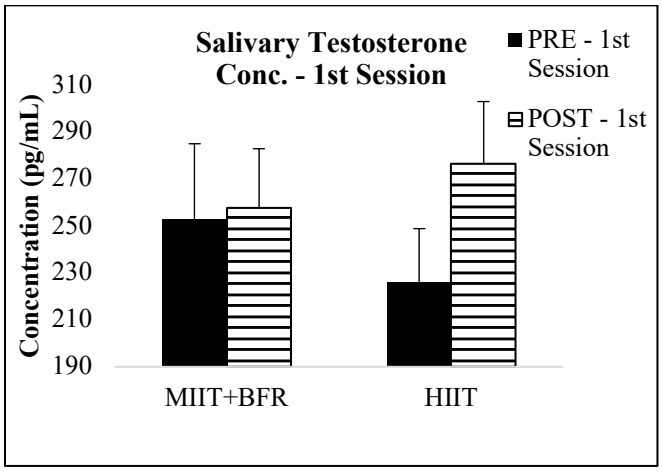


Figure 104. Salivary Testosterone Concentration (Conc.) – 1st Session

Figure 105 displays the changes in salivary testosterone concentration in response to the last training session. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated

measures found a condition*time interaction ($p = 0.05$); however, a follow-up analysis test found no significance for HIIT ($p > 0.05$) or MIIT+BFR ($p > 0.05$).

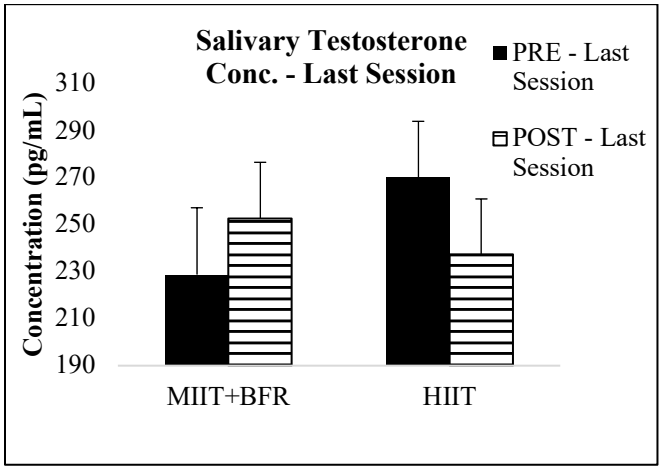


Figure 105. Salivary Testosterone Concentration (Conc.) – Last Session

Figure 106 displays the changes in salivary leptin concentration in response to the first training session. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found no significance for a condition or a time main effect ($p > 0.05$), nor was there a condition*time interaction ($p > 0.05$).

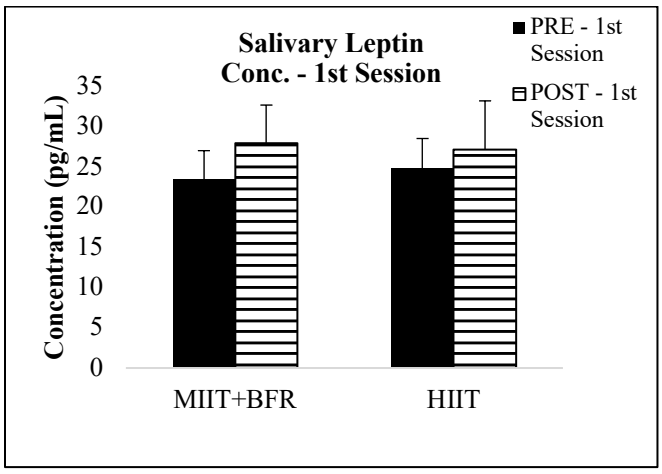
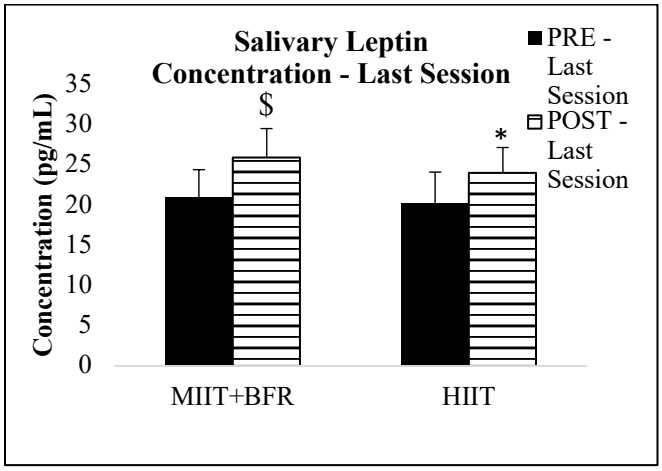


Figure 106. Salivary Leptin Concentration (Conc.) – 1st Session

Figure 107 displays the changes in salivary leptin concentration in response to the last training session. One-way ANOVA found no significant baseline differences. Levene's test detected no significance for homogeneity of variance ($p > 0.05$). Two-way ANOVA with repeated measures found a significance for time main effect ($p = 0.002$) from pre- to post-values. Follow-up analysis test determined that MIIT+BFR and HIIT significantly increased salivary leptin levels from pre to post of the last training session ($p = 0.009$, $p = 0.04$, respectively).



$Significantly different ($p < 0.01$) from baseline.
*Significantly different ($p < 0.05$) from baseline.
Values reported as mean ± SE.

Figure 107. Salivary Leptin Concentration (Conc.) – Last Session

CHAPTER V

DISCUSSION

This study compared the effects of two different anaerobic training protocols, which are high-intensity interval training (HIIT) and moderate-intensity interval training with BFR (MIIT+BFR), on the adaptations in body composition, salivary hormone concentration, peak oxygen uptake, average anaerobic power output, and arterial elasticity in young overweight and obese male adults. The study's primary objective was to determine which training protocol results in the best fat loss, salivary hormone concentrations, lean mass, average anaerobic power output, strength, peak oxygen uptake, and arterial elasticity. The secondary outcome of this study was to determine the acute and chronic hormone concentrations of testosterone, cortisol, and leptin in response to one exercise session and after 8 weeks of low-volume exercise training.

Body Composition

Evidence has shown mixed results in regarding the chronic effects of HIIT on body composition in overweight and obese individuals (Smith-Ryan et al., 2015; Tsirigkakis et al., 2021; Reljic et al., 2020; Zhang et al., 2017; Kong et al., 2016; Gerosa-Neto et al., 2019; Racil et al. 2016a; Racil et al., 2016b). Previous studies reported that the changes in body composition in response to HIIT were dependent on training frequency and the length of the training program (Smith-Ryan et al., 2015; Tsirigkakis et al., 2021; Reljic et al., 2020; Zhang et al., 2017; Kong et al., 2016; Gerosa-Neto et al., 2019; Racil et al. 2016a; Racil et al., 2016b). The present study demonstrated that eight weeks of HIIT and MIIT+BFR had a significant time effect on fat-free

mass, lean gynoid mass, lean leg mass, total bone mineral content (BMC), trunk BMC, gynoid BMC, leg BMC, and leg fat mass (FM) to total FM ratio in overweight and obese male participants. However, the follow-up analysis test demonstrated that HIIT induced a trending increase from pre- to post-training in fat-free mass, lean leg mass, lean gynoid mass, and gynoid BMC while significantly increasing total BMC, leg BMC, and Trunk BMC. MIIT+BFR only significantly increased leg FM to total FM ratio from pre- to post-training.

Former studies reported that HIIT resulted in weight loss in obese individuals (Racil et al., 2016a; Racil et al., 2016b; Zhang et al., 2017; Tsirigkakis et al., 2021). However, three-to-six weeks of HIIT has no effect in reducing body weight, fat mass, and visceral adipose tissue regardless of training frequency, intensity, and duration (Smith-Ryan et al., 2015; Kong et al., 2016; Gerosa-Neto et al., 2019). A study by Smith-Ryan et al. (2015) subjected overweight and obese male participants to three weeks of HIIT, with one group performing 10 × 1-minute of cycling at 90% W_{peak} (1MIN-HIIT), and the second group had to execute 5 × 2-minutes of cycling (2MIN-HIIT) at fluctuating intensities ranging from 80% to 100% VO_{2peak} per session. Nine sessions of 1MIN-HIIT or 2MIN-HIIT within three weeks had no significant effect on reducing fat mass or body fat percentage. Kong et al. (2016) also conducted five weeks of HIIT, four sessions per week, consisting of 60 × 8 seconds of cycling at 90% VO_{2peak} interspersed with 12 seconds of passive recovery. The overweight and obese young female participants experienced no changes in body weight or total fat mass (Kong et al., 2016). HIIT was also ineffective in changing body weight and visceral fat in obese participants after six weeks of HIIT, consisting of 10 × 1-minute bouts at 100% VO_{2max} interspersed by 1-minute of passive rest (Gerosa-Neto et al., 2019).

Several other previous studies also indicated that short-term HIIT has no significant effect on body weight, fat mass, and visceral adipose tissue in overweight and obese individuals (Smith-

Ryan et al., 2015; Kong et al., 2016; Gerosa-Neto et al., 2019), and eight weeks of HIIT consisting of 16 bouts of 30 seconds of cycling at 80-100% W_{avg} had no effect either, as shown in the present study. However, Tsirigkakis et al. (2021) demonstrated that obese male participants subjected to eight weeks of HIIT three sessions per week significantly decreased body mass, BMI, body fat percentage, total fat mass, and trunk fat mass. Tsirigkakis et al. (2021) subjected their obese male participants to two types of HIIT protocols cycling at 100% W_{peak} three sessions per week: 48 × 10 seconds of cycling with 15 seconds of active recovery and 8 × 60 seconds of cycling with 90 seconds of active recovery for 24 training sessions. The present study did not require their participants to make dietary intake changes, and the total exercise volume for ergometer cycling was the same as Tsirigkakis et al. (2021) study. Yet, the participants in the present study had no changes in body fat percentage, total and regional fat mass, or visceral fat. The plausible explanation for the lack of fat loss in the present study is that the current study's training volume was low (16 sessions vs. 24 sessions) compared to Tsirigkakis et al. (2021) study. Reljic et al. (2020) determined that severely obese participants with two additional cardiometabolic risk markers can significantly reduce body weight and body fat mass after 12 weeks of low-volume HIIT, two sessions per week, with nutritional counseling to promote weight loss. As previously mentioned, the participants in the present study were told not to make any changes in their daily dietary intake. However, caloric intake was not assessed, and no nutritional counseling was provided. Therefore, it can be speculated that increased daily caloric intake or lack of nutritional knowledge could be another possible explanation for the lack of weight and fat loss in overweight and obese participants (Reljic et al., 2020; Tsirigkakis et al., 2021).

Although the overweight and obese participants of the present study did not experience any weight loss, eight weeks of low-volume HIIT induced a trending increase in fat-free mass, lean

leg mass, and lean gynoid mass. In the Tsirigkakis et al. (2021) study, the obese male participants experienced a significant increase in lean body and leg mass. Even Smith-Ryan et al. (2015) study of three weeks of 1MIN-HIIT and 2MIN-HIIT, three sessions per week, had a trending increase of 2.1 kg and 1.7 kg in lean mass, respectively. Smith-Ryan et al. (2015) subjected their overweight and obese participants to a total exercise volume of 10 minutes of ergometer cycling per training session. A 12-week HIIT intervention consisting of alternative cycling at 8-seconds of sprint cycling at 80-90% of peak heart rate (HR_{peak}) and 12-seconds of active recovery at 40 revolutions per minute (rpm) until achieving 20-minute per training session, three per week, significantly increased total, leg, and trunk fat-free mass in overweight men (Heydari et al., 2012). The non-significant increase in fat-free mass, lean leg mass, and lean gynoid mass in response to HIIT are due to the high forces exerted by the legs while cycling against the high resistance set on the fly-wheel of the bike ergometer (Tsirigkakis et al., 2021). In addition, the relative exercise intensity contributes to an increase in fat-free mass (Heydari et al., 2012), and increases in lean mass may be due to muscle protein synthesis induced by manageable interval-duration bouts of one or two minutes (Smith-Ryan et al., 2015). Thus, it can be speculated that the overweight and obese male participants could reach significance in lean and fat-free mass if the training intensity is programmed with a manageable interval training bout, and vice versa.

In the present study, the MIIT+BFR group experienced no positive changes in body weight, whole body fat mass, regional fat mass, body fat percentage, fat-free mass, and whole body and regional lean mass. There was a significant time main effect in the leg FM to total FM ratio for the MIIT+BFR group. Even though both groups experienced a slight increase in the leg FM, the slight decrease and increase in total FM for the MIIT+BFR and HIIT groups (respectively) resulted in a significant leg FM to total FM ratio for the MIIT+BFR group ($p = 0.005$). A lack of significant

change in body composition is similar to that of de Oliveira et al. (2016) study, where healthy young adults had no changes in body mass or body fat percentage after four weeks of interval training with intermittent BFR. The BFR protocol consisted of two sets of 5-8 × 2-minute cycling with intermittent BFR (140-200 mmHg) at 30% W_{max} interspersed by 1-minute rest between bouts and 2-minute rest between sets, three sessions per week (de Oliveira et al., 2016). The total exercise volume per training session in the de Oliveira et al. (2016) study was 20-32 minutes of cycling with intermittent BFR, three sessions per week. The present study had a total exercise volume of 8-minute cycling with continuous BFR per training session, two sessions per week. The exercise intensity stayed at 30% W_{max} throughout de Oliveira et al. (2016) study, whereas the training intensity for the present study would gradually increase from 40% W_{avg} to 60% W_{avg}. Although the exercise intensity was higher and would gradually progress in the present study, it did not cause significant changes in body composition with a low exercise volume. It could be speculated that an eight-week interval training intervention with BFR with a greater exercise volume at 40-60% W_{avg} with a training frequency of three sessions per week and/or longer bouts would induce changes in body composition.

It was reported that a minimum of 4-6 months is required to observe any changes in bone mineral density (BMD) in response to long-term exercise training (Fujimura et al., 1997; Vincent & Braith, 2002). On the contrary, the present study demonstrated that HIIT significantly increased total BMC ($p=0.002$), leg BMC ($p=0.02$), and trunk BMC ($p=0.02$) from baseline while inducing a trending increase for gynoid BMC ($p=0.07$). In the Lu et al. (2022) study, sedentary young women experienced a significant increase in BMD by 8.5% after eight weeks of HIIT. The female participants were subjected to 6 × 3-minute bouts of running at 80-90% VO_{2max}, three sessions per week. Ravnholt et al. (2018) study also reported significant increases in BMD after seven weeks

of high-intensity intermittent running in untrained adults. Osteogenic formation results from high-intensity and short-duration exercise (Lu et al., 2022). Since HIIT is characterized as repeated short, vigorous bouts interspersed by short periods of passive or active recovery, the exerted forces induced by the contractile activity of skeletal muscles on bones increase BMD and BMC (Lu et al., 2022). It could also be speculated that the sedentary overweight and obese male participants in the present study were more sensitive to mechanical loading; the high-intensity exercise-induced joint reaction forces have a greater stimulus on bone, thus increasing BMC (Lu et al., 2022; Ravnholt et al., 2018).

Cardiovascular Responses

Eight weeks of HIIT or MIIT+BFR had no effect on PWV. The percent changes in HIIT and MIIT+BFR from pre- to post-training are -0.40% and 0.35%, respectively. Similar findings were also found by Kim et al. (2017), where sedentary adults' arterial stiffness was unaffected by eight weeks of HIIT, four sessions per week, consisting of 4 × 4-minute bouts of all-extremity non-weight-bearing air braked cycling at 90% HR_{peak} interspersed by 3-minutes of active recovery at 70% HR_{peak}. A HIIT study by Ramírez-Vélez et al. (2019) consisted of 4 × 4-minute fast walking and running intervals at 85-95% of heart rate reserve (HRR) interspersed by 4-minute active recovery at 75-85% HHR three days a week for 12 weeks. The sedentary adults significantly decreased PWV by -0.4 m/s, which is attributed to the duration of the work-to-rest intervals allowing recovery from repeated HIIT bouts (Ramírez-Vélez et al., 2019). Taha et al. (2023) subjected middle-aged obese hypertensive women to 12 weeks of HIIT consisting of 4 × 4-minute cycling at 85-90% HR_{peak} interspersed by 3-minute active recovery at 60-70% HR_{peak}, three days a week, thus, causing a significant decrease in PWV by 1.14 m/s. The present study's volume and/or duration could be factors responsible for non-significant changes in PWV. In long-duration

HIIT, non-rapid exercise-induced shear stress results in a magnitude of wall distension that leads to the reduction of the resistance to blood flow in peripheral arteries by stimulating a mechano-biochemical signal that promotes vasodilation (Ramírez-Vélez et al., 2019; Taha et al., 2023). Therefore, it can be speculated that interval training at a moderate-to-high exercise intensity with longer duration bouts interspersed by long active recovery and lengthier training program may be necessary to improve arterial elasticity in overweight, obese males (Ciolac et al., 2010; Guimaraes et al., 2010).

Although there were no changes in PWV, the augmentation index at 75 beats per minute (AIx@75) decreased significantly by -5.6% in response to HIIT. AIx@75 evaluates arterial stiffness by normalizing the augmentation index for a heart rate of 75 beats per minute (bpm) (Durmus et al., 2014). The central augmentation index (AIx) is the percentage of the augmentation pressure (AP) divided by the central pulse pressure (Wilkinson et al., 2000; Durmus et al., 2014). AP is the difference between two systolic peaks ($P_2 - P_1$) of the central arterial waveform, and the central pulse pressure (cPP) is the difference between the aortic systolic blood pressure (cSBP) and aortic diastolic blood pressure (cDBP) (Wilkinson et al., 2000; Santos et al., 2021). In addition, the augmentation index is influenced by heart rate and depends on the arterial tree's elastic and muscular properties (Durmus et al., 2014). An increase in AIx@75 represents an increased wave reflection or a fast return of a reflected wave caused by a greater PWV value associated with increased arterial stiffness (Yoon et al., 2010; Durmus et al., 2014). In fact, Taha et al. (2023) demonstrated a significant decrease in AIx@75 by -8.45% in response to 12 weeks of HIIT in hypertensive obese women. The authors indicated that a reduction in AIx@75 in response to HIIT is caused by an increase in endothelial nitric oxide (NO) synthase activity, which improves endothelial function and reduces blood flow resistance. Thus, it could be logical to assume that the

non-significant decrease in total vascular impedance (TVI), larger arterial elasticity index (LAEI), small arterial elasticity index (SAEI), and PWV were caused by the endothelial NO synthase activity that was developing at the end of the eight-week HIIT protocol.

The cardiac index (CI), a measure of heart function and health, significantly decreased after eight weeks of HIIT. The cardiac index normalizes the cardiac output (CO) relative to a person's body surface area. The CI formula follows cardiac index = CO/body surface area (Patel et al., 2022). HIIT significantly reduced CI by -0.2 L/min/m^2 (-4.1%), yet CO and total body mass did not significantly change as HIIT reduced mean CO by -0.2 L/min and increased mean total mass by 1.0 kg. Despite no significant change in CO and total body mass, a small decrease in CO along with a slight increase in body surface area may signify a reduction in heart function for a person's bigger body size (Patel et al., 2022).

There was no significant change in the large arterial elasticity index (LAEI) and small arterial elasticity index (SAEI) after eight weeks of HIIT or MIIT+BFR. The percent changes for LAEI in HIIT and MIIT+BFR from pre- to post-training are 15.9% and 9.4%, respectively, and the percent changes in SAEI are 8.8% and 10.5%, respectively. The possible mechanisms responsible for reducing arterial stiffness while increasing arterial elasticity and vascular smooth muscle relaxation in aerobic training are an increase in NO bioavailability and a decrease in vasoconstrictor activity and sympathetic nervous system activity in the arterial smooth muscle cells (Ciolac et al., 2010; Guimaraes et al., 2010; Trammel and Sapra, 2022). On the contrary, the present study did not see any significant changes in resting HR, SVR, and TVI, demonstrating that HIIT and MIIT+BFR did not decrease vasoconstrictor and sympathetic nerve activity, regardless of not being directly measured. The HIIT protocol in the present study consisted of high-intensity repeated bouts of cycling interspersed by passive recovery periods, thereby increasing sympathetic

nerve activity, heart rate, and blood pressure at repeated intervals, thus counteracting any potential improvement for arterial elasticity (Kim et al., 2017; Guimaraes et al., 2010). On the contrary, Ramírez-Vélez et al. (2019) 12-week study of 4 × 4-minute fast walking/running intervals at 85-95% HRR interspersed by 4-minute active recovery for 36 sessions significantly improved flow-mediated dilation (FMD) in inactive adults. FMD is a measure of vascular function influenced by changes in shear stress caused by exercise, contributing to enhanced endothelial function and arterial elasticity (Ramírez-Vélez et al., 2019). The sedentary adults significantly decreased PWV by -0.4 m/s, which is attributed to the duration of the work-to-rest intervals allowing recovery from repeated HIIT bouts (Ramírez-Vélez et al., 2019). As for MIIT+BFR, the hypoxic environment that BFR induces in the working skeletal muscles could have led to endothelial activation, increasing NO bioavailability (de Oliveira et al., 2016). Hence, it could be speculated that a lengthier MIIT+BFR program, and/or longer bouts of exercise, and/or higher volume of weekly exercise by increasing the frequency of exercise sessions may be necessary to induce changes in arterial elasticity, resting HR, systemic vascular resistance (SVR), and TVI.

Since there were no significant changes in resting HR, SVR, and TVI, both aortic and brachial blood pressures did not significantly change after eight weeks of low-volume HIIT and MIIT+BFR. Improvements in brachial blood pressure in response to HIIT have been reported in obese men after 18 training sessions of 10 × 1-minute cycling at 100% VO_{2max}, resulting in a drop of -6.62 mmHg and -3.99 mmHg in SBP and DBP, respectively (Gerosa-Neto et al., 2019). In Kim et al. (2017) study, eight weeks of HIIT had no effect on HR, aortic and brachial blood pressures. Whereas Ciolac et al. (2010) study demonstrated significant decreases in resting DBP, exercising DBP, and resting SBP and DBP after 16 weeks of interval training. These findings have been attributed to decreases in vasoconstrictors norepinephrine and endothelin-1 (ET-1) during resting

and exercising and increases in vasodilator NO during resting, exercising, and recovery (Ciolac et al., 2010). Henceforth, improvements in brachial blood pressure may be attributed to either high-intensity, short-interval training, three sessions per week for six weeks total (Gerosa-Neto et al., 2019), or 16 weeks of interval training at moderate-to-high intensity with more prolonged duration bouts interspersed by active recovery (Ciolac et al., 2010; Guimaraes et al., 2010). Interval training at a moderate intensity (MOIT) is perceived as less strenuous for the obese population (Racil et al., 2016a). In fact, a study by Racil et al. (2016a) demonstrated that after 12 weeks of MOIT, there were significant decreases in brachial SBP and DBP by about -3.5% and -5.8%, respectively, in obese female adolescents. The MOIT protocol consisted of three bouts of running alternatively for 15 seconds at 80% maximal aerobic speed (MAS) and 15 seconds at 50% MAS until completing 4-8 minutes of exercise per bout for 36 training sessions (Racil et al., 2016a). In the present study, the MIIT+BFR protocol consisted of 8 × 1-minute cycling at 40-60% W_{avg} with continuous BFR interspersed by 1-minute rest. The application of BFR in the present study was used in response to previous research studies finding multiple beneficial adaptations caused by BFR training that is similar to high-intensity exercise (Amani-Shalamzari et al., 2020; de Oliveira et al., 2016; Amani-Shalamzari et al., 2019; Corvino et al., 2019). However, MIIT+BFR did not induce significant changes in cardiovascular parameters. Racil et al. (2016a) speculated that the significant improvement in brachial SBP and DBP, and resting HR in response to MOIT could be attributed to the significant decreases in body mass and body fat percentage. Henceforth, it can be suggested that future studies should look into the effects of MIIT+BFR with alternating bouts of cycling at moderate intensity with low-to-moderate active recovery, and/or more frequent training sessions, and/or longer duration of training period on hemodynamic responses and body composition.

Anaerobic Measurements

After eight weeks of low-volume HIIT, there was a trend for a time main effect for work rate and average power output. The percent change in average power output ($W_{avg.}$) in response to HIIT was a 5.0% increase. This outcome contradicts Kong et al. (2016) study, where 10 overweight and obese females experienced a 13.8% increase in peak power output (W_{peak}) after five weeks of high-volume HIIT. The findings from Kong et al. (2016) study are similar to de Oliveira et al. (2016) study, where young adults increased their W_{max} by 15.0% in response to four weeks of HIIT, three sessions per week. Furthermore, the severely obese individuals with two additional cardiometabolic risk factors from Reljic et al. (2020) study significantly improved maximal power output (W_{max}) and relative W_{max} by 24 W and 0.3W/kg, respectively, after 12 weeks of low-volume HIIT. It is worth mentioning that Tsirigkakis et al. (2021) study induced a significant 18.3% increase in W_{peak} in response to eight weeks of HIIT, three sessions per week, in their obese male participants. Although the present study had a trending increase in average power output, eight weeks of HIIT, two sessions per week, 16 × 30 sec of cycling at 80-100% $W_{avg.}$ was not sufficient to induce significant results. Previous research demonstrated that 4-8 weeks of HIIT, 3-4 sessions per week at high-intensity training is necessary to increase average power output (Kong et al., 2016; de Oliveira et al., 2016; Tsirigkakis et al., 2021). It could be claimed that if the present study extended the training program from 8-to-12 weeks, the overweight and obese participants would have significantly increased $W_{avg.}$ in response to low-volume HIIT, as seen in Reljic et al. (2020) study.

MIIT+BFR did not significantly change W_{avg}. MIIT+BFR non-significantly increased W_{avg} by 2.7%. Former previous studies increased anaerobic power output in short of three-to-four weeks of interval training with BFR (Oliveira et al., 2016; Amani-Shalamzari et al., 2019; Amani-

Shalamzari et al., 2020). In the de Oliveira et al. (2016) study, young adults significantly increased W_{max} by 11.7% after four weeks, three sessions per week, of low-intensity interval training with BFR (LIIT+BFR). Amani-Shalamzari et al. (2019) demonstrated significant improvements in W_{avg} above 10% with various combinations of occlusion pressure and exercise intensity in physically active collegiate women after four weeks of interval training, three sessions per week. Even as low as 10 sessions within three weeks of interval training with BFR significantly improved W_{avg} in futsal athletes (Amani-Shalamzari et al., 2020). The present study had an exercise intervention twice as long than the three mentioned studies. Yet, it did not induce any significant changes in W_{avg} with just 8 × 1-minute cycling at 40-60% W_{avg} with continuous BFR, two sessions per week. Thus, the plausible reason why the overweight and obese participants did not significantly improve their average anaerobic power output could be because of a small exercise volume and training frequency. For example, in the de Oliveira et al. (2016) study, the participants were subjected to two sets of 5-8 × 2-minutes of cycling at 30% W_{max} with an intermittent BFR pressure of 140-200 mmHg. In Amani-Shalamzari et al. (2020) study, the training protocol was 4-8 × 3-minutes of high-intensity physical activity with an intermittent BFR pressure of 110% of each leg individual's systolic blood pressure. As for Amani-Shalamzari et al. (2019) study, the participants were subjected to 10 × 2-minutes of running or 10-5 × 2-minutes of running with intermittent BFR. The BFR pressure would either progress from 160 to 240 mmHg or remain constant at 160 mmHg or 240 mmHg with a progressing exercise intensity from 60% to 85% vVO_{2max} or a constant exercise intensity of 60% vVO_{2max}. As mentioned, the three former studies had a training frequency of three days per week (Oliveira et al., 2016; Amani-Shalamzari et al., 2019; Amani-Shalamzari et al., 2020). Therefore, in total speculation, if the present study had increased the training frequency to three sessions per week and increased the exercise volume by 8 × 2-3-minute cycling at 40-60%

W_{avg} with continuous BFR, the overweight and obese participants would have significantly increased their average anaerobic power output.

Strength Measurements

Isokinetic strength increased significantly from pre- to post-training. Isokinetic testing consisted of two isokinetic right knee contraction tests at different angular velocities: 60°/s and 180°/s. The isokinetic tests consisted of leg extensions (away) and leg curls (toward), with each leg extension rep immediately followed by a repetition of leg curl until 10 repetitions were completed per exercise. HIIT significantly increased peak torque by 6.1% in the away portion and had a trending increase of 7.8% in the toward portion of the isokinetic 180°/s test, and MIIT+BFR significantly increased peak torque by 14.5% in the toward portion. The HIIT group demonstrated a significant increase in peak torque in the mean average of the first repetitions and the middle reps of the Thorstensson Test of Fatigability, thus, demonstrating an improved fatigue resistance from the beginning to the middle portion of the test. Whereas MIIT+BFR induced a superior significant increase in peak torque for the middle portion of the Thorstensson Test. High-intensity contractions induce greater recruitment of motor units compared to low-intensities (Martinez-Valdes et al., 2017; Martinez-Valdes et al., 2018). The increase in lean leg mass could explain why isokinetic strength increased over time for the HIIT group. In response to HIIT, increased lean mass can be associated with increased neural muscular factors, such as an improved discharge rate and recruitment of high-threshold motor units during exercise (Martinez-Valdes et al., 2017; Martinez-Valdes et al., 2018). As for the increases in isokinetic peak torque caused by MIIT+BFR, BFR training reduces oxygen availability and blood flow to the working muscles and venous return during exercise, increasing metabolic acidosis and inhibiting the force development of type I muscle fibers. This leads to the progressive recruitment of additional motor units of anaerobic type

II muscle fibers, maintaining or generating a greater muscular force (Amani-Shalamzari et al., 2019; de Oliveira et al., 2016).

The differences in peak torque for both groups in the ISO 180°/s test can be due to the differences in training intensity. The training intensity is essential for the development of force production (Haff & Triplett, 2016). Moreover, the quadriceps muscles are the prime movers during the downward motion of cycling, thereby contracting and creating force to push the pedals down (Haff & Triplett, 2016). Since the resistance used during cycling was greater during HIIT, the quadriceps muscles had to recruit more motor units and/or have a greater firing frequency to create a high force to push down against the high-load resistance during cycling (Haff & Triplett, 2016). Therefore, it is logical to assume that there was a greater neuromuscular adaptation in the quadriceps muscles following HIIT training, which was verified by the significant increases in peak torque in the away portion of the ISO 180°/s test. On the other hand, since the resistance used during cycling for the MIIT+BFR group was moderate, the quadriceps muscles would not experience similar mechanical stress compared to the HIIT group during the downward cycling motion, resulting in no significant increase in peak torque in the away portion of the isokinetic 180°/s test. However, the hypoxic environment created by the BFR cuffs must have affected the quadriceps and hamstring muscles during interval training with BFR. Even though bike training mainly targets the quadriceps muscles, the hypoxic environment must have challenged the hamstring muscle activity during cycling and resulted in neuromuscular adaptation, which was confirmed by the increased force production in the toward portion of the 180°/s test (Oliveira et al., 2016; Amani-Shalamzari et al., 2019). In addition, the hypoxic environment created by the BFR cuffs might be a factor contributing to the increased fatigue resistance, which was observed in the middle portion of the Thorstesson Test. Although MIIT+BFR did not increase peak torque

at the beginning of the Thorstensson Test, hypoxic training increased force production in reps 24, 25, and 26. Thus, the overweight and obese male participants got stronger in the hamstring muscles and built fatigue resistance in the quadriceps muscles.

The percent changes in maximal voluntary contraction (MVC) during isometric contraction are 4.1% and 3.0% for HIIT and MIIT+BFR. Further, there was no significant increase in MVC for both groups. Significant improvements in MVC were seen in Amani-Shalamzari et al. (2019) study by more than 18% and in the de Oliveira et al. (2016) study by 11.4%. These two studies had training interventions that were four weeks long, three sessions per week, at various lengthy durations, exercise modes, and training intensities. Although there were significant increases in isokinetic strength, the present study's findings suggest that the lack of a significant increase in MVC during isometric contraction is a consequence of low-volume interval training with or without BFR. Furthermore, it seems plausible that changes in muscular strength are not only specific to the training protocol, but the motor unit recruitment threshold depends on the type of exercise being executed (Martinez-Valdes et al., 2017; Martinez-Valdes et al., 2018).

Cardiorespiratory Fitness

Eight weeks of low-volume MIIT+BFR significantly increased VO_{2peak} by 9.8% from pre- to post-training, similar to previous findings of studies using different interval training protocols with BFR. In just four weeks of LIIT+BFR, three sessions per week, two sets of 5-8 × 2-minutes of cycling at 30% W_{max} with intermittent BFR, significantly increased VO_{2max} by 5.6% in young, healthy adults (de Oliveira et al., 2016). Even as low as 10 sessions within three weeks of 4-8 × 3-minutes of high-intensity physical activity with intermittent BFR significantly increased VO_{2max} by 11.1% in futsal athletes (Amani-Shalamzari et al., 2020). Different protocols of interval training with BFR lead to increases in oxygen uptake. However, those differences in exercise

intensity, duration, frequency, and BFR pressure result in various magnitudes of cardiorespiratory fitness levels (Amani-Shalamzari et al., 2020; de Oliveira et al., 2016; Amani-Shalamzari et al., 2019; Kong et al., 2016). Improvements in peak oxygen in response to BFR training may also be attributed to faster pulmonary oxygen uptake (VO_{2p}) kinetics (Corvino et al., 2019). The increased metabolic stress induced by BFR results in higher lactate levels, providing more energy substrate to be utilized by the anaerobic system, increasing lactate clearance, and improving the onset of blood lactate accumulation and lactate tolerance over time (Amani-Shalamzari et al., 2020). Fast VO_{2p} kinetics is associated with fatigue resistance and high exercise tolerance (Corvino et al., 2019). In the Corvino et al. (2019) study, VO_{2p} kinetics improved by 24% after four weeks of interval training with BFR, two sets of 5-8 × 2-minute cycling at 30% W_{avg} with intermittent BFR, three sessions per week. In response to MIIT+BFR, the time to reach peak oxygen uptake increased by 8.8% for the overweight and obese male participants. Therefore, it is logical to assume that the improvements in VO_{2peak} and time to reach VO_{2peak} from baseline in response to MIIT+BFR may also be attributed to an increase in VO_{2p} kinetics.

In the present study, the HIIT group non-significantly increased VO_{2peak} by 1.6%. Previous research studies with varying protocols of HIIT have resulted in significant increases in cardiorespiratory fitness. In the de Oliveira et al. (2016) study, four weeks of HIIT, three sessions per week, two sets of 5-8 × 2-minute cycling at 110% W_{max} with a 5% decrease in intensity every 30 seconds, significantly increased VO_{2max} by 9.2% in young, healthy adults. In the three-week HIIT study by Amani-Shalamzari et al. (2020), 4-8 × 3-minute high-intensity physical activity significantly increased VO_{2max} by 6.8% in futsal athletes. In just six weeks of HIIT, three sessions per week, 10 × 60 sec of cycling at 85% W_{max}, VO_{2peak} increased by 18% in overweight women (Tan et al., 2018). Even the obese male participants from Tsirigkakis et al. (2021) study

significantly increased VO_{2peak} by 20% and 18% in response to two short HIIT protocols consisting of 48 × 10-second cycling with 15-second active rest and 8 × 60-second cycling with 90-second active recovery for three training sessions per week for eight weeks. Tsirigkakis et al. (2021) also reported a significant increase in peak fat oxidation with an overall decrease in blood lactate concentration with no differences between groups. In addition, Tan et al. (2018) also demonstrated a significant increase in markers of capillarization and mitochondrial content in type I and type II muscle fibers. An enhanced microvascular and mitochondrial density is essential for delivering and utilizing oxygen to support the skeletal muscle's oxidative capacity (Tan et al., 2018). According to de Salles Painelli et al. (2018), an increase in muscle buffering and H^+ removal capacity is an adaptive response to tolerate high-intensity effort in response to HIIT. Since the previous HIIT studies with significant changes in aerobic capacity, (Amani-Shalamzari et al., 2020; Oliveira et al., 2016; Tan et al., 2018; Tsirigkakis et al., 2021) had three sessions per week, it can be speculated that the frequency of HIIT may be an important factor and the insignificant changes seen in peak oxygen uptake and time to reach VO_{2peak} for HIIT can be attributed to a lower frequency of training.

Hormone Response

Although there were no significant changes for salivary testosterone and cortisol from pre- to post-values in the first training session for both groups, it is plausible that a duration of 8 × 1-minute cycling with continuous BFR at the exercise intensity of 40% W_{avg} or 16 × 30-second cycling at 80% W_{avg} for MIIT+BFR and HIIT, respectively, was not physically exerting. Thus, both groups' cycling duration per bout and exercise intensity were ineffective in inducing a significant anabolic and catabolic response. Amani-Shalamzari et al. (2020) demonstrated that one session of 4 × 3-minutes of high-intensity physical activity with or without intermittent BFR

significantly increased testosterone and cortisol serum levels from pre- to immediate post-exercise. In addition, the high-intensity physical activity bouts with intermittent BFR induced a superior increase in testosterone than the non-BFR group (Amani-Shalamzari et al., 2020). The physical activity bouts in Amani-Shalamzari et al. (2020) study was three minutes long, whereas the present study's bout duration was 1-minute or 30 seconds. Thereby, a longer period of high-intensity of exercise could build up a greater accumulation of lactate levels and metabolites, which would activate the Leydig cells of the testes by the hypothalamic-pituitary-gonadal axis and testicular cAMP production, directly increasing testosterone production from the testis (Amani-Shalamzari et al., 2020; Dote-Montero et al., 2021a; Hwang & Willoughby, 2019). As for a significant change in cortisol levels, the accumulation of metabolites and metabolic acidosis induced by BFR upregulate the production of cortisol by stimulating the hypothalamic-pituitary axis via group II and group IV afferent fibers (Amani-Shalamzari et al., 2020). In terms of increased cortisol production in response to HIIT, high-intensity exercise induces a stress stimulus that activates the hypothalamic-pituitary-adrenal axis, synthesizing cortisol (Dote-Montero et al., 2021). Hence, it could be speculated that the HIIT and MIIT+BFR protocols did not induce a stress stimulus nor significant levels of blood lactate and metabolites, resulting in no significant changes in salivary testosterone or cortisol during the first training session.

The present study showed no significant changes in salivary testosterone and cortisol from pre- to post-values in the last training session for MIIT+BFR. MIIT+BFR non-significantly increased salivary testosterone from 228.8 pg/mL to 252.7 pg/mL and salivary cortisol from 0.40 µg/mL to 0.52 µg/mL. In fact, after three weeks of 4-8 × 3-minutes of high-intensity physical activity strictly with and without intermittent BFR, testosterone levels continued to significantly increase immediately after the last training session for both groups compared to baseline (Amani-

Shalamzari et al., 2020). The BFR group from Amani-Shalamzari et al. (2020) study also significantly increased cortisol immediately after the last training session. According to Amani-Shalamzari et al. (2020), an elevation in testosterone levels immediately post-exercise is also related to a decrease in blood lactate levels because testosterone upregulates the monocarboxylate transporter-1 (MCT1) and MCT4 proteins that facilitate blood lactate clearance. It is plausible that an exercise volume of 4-8 × 3-minute interval training with BFR is optimal to constantly elevate testosterone and cortisol concentrations and cause other muscular adaptations. Whereas the exercise volume in the present study was 8 × 60 seconds cycling at 60% W_{avg} with continuous BFR, which did not induce significant changes in salivary testosterone and cortisol during the last training session in overweight and obese individuals. It is worth mentioning, however, that Amani-Shalamzari et al. (2020) combined BFR with a high-intensity physical activity such as futsal, a physically demanding sport, for three-minute bouts interspersed by 2-minute rest. Thus, the high intensity of the sport must have also been a contributing factor in continuously inducing significant changes in testosterone and cortisol in just three weeks. Therefore, it can be speculated that significant changes in testosterone and cortisol in response to interval training with BFR are caused by exercise volumes greater than eight minutes with exercise intervals longer than a minute at a high-intensity exercise.

The present study also showed no significant changes in salivary testosterone and cortisol from pre- to post-values in the last training session for HIIT. HIIT non-significantly decreased salivary testosterone from 270.3 pg/mL to 237.5 pg/mL, and salivary cortisol non-significantly increased from 0.33 µg/mL to 0.44 µg/mL. As mentioned, Amani-Shalamzari et al. (2020) non-BFR group continued to significantly increase testosterone immediately after the last training session compared to baseline. However, the non-BFR group did not significantly increase cortisol.

Kong et al. (2016) five-week study of HIIT did not result in any significant changes in the resting serum levels of testosterone and cortisol in overweight and obese young females. The HIIT protocol from Kong et al. (2016) study consisted of 60 × 8-second cycling at 90% VO_{2peak} interspersed by 12 seconds of passive recovery for four training sessions per week. Moreover, the initial resistance set on the bike was 1.0 kg, and the resistance would increase by 0.5 kg per completing two sessions until reaching 5% of body weight (Kong et al. 2016). Both Hayes et al. (2017) and Herbert et al. (2017) used the same HIIT protocol for sedentary older males and male master athletes, respectively, to determine the resting serum levels of testosterone and cortisol. The HIIT protocol consisted of nine sessions of 6 × 30-second sprint cycling at 40% of peak anaerobic power output (W_{peak}) interspersed by a 3-minute active recovery, separated by five days of rest. Hayes et al. (2017) study resulted in a significant increase in free testosterone compared to baseline, but cortisol levels were unchanged. Whereas Herbert et al. (2017) reported a significant increase in free testosterone and cortisol in male master athletes. According to Hayes et al. (2017) and Herbert et al. (2017), significant increases in free testosterone are associated with training intensity, and a decrease in testosterone and an increase in cortisol are associated with greater stress and overtraining (Herbert et al., 2017). However, the target population of the present study was overweight and obese young male adults who did not result in a significant change in testosterone and cortisol; thus, it is unlikely that they were subjected to overtraining or great stress, and they did not require five days of rest between sessions. The lack of significance in testosterone and cortisol levels in overweight and obese young females from the Kong et al. (2016) study could be due to insufficient training intensity and exercise volume. As mentioned, Amani-Shalamzari et al. (2020) non-BFR group did not significantly increase cortisol, possibly demonstrating a muscular adaption to the stress of the training protocol. It could be speculated that a HIIT protocol

with longer bout duration, high-intensity exercise, and greater training frequency is necessary to cause a significant change in salivary cortisol and testosterone.

In non-obese individuals, leptin regulates body weight, energy homeostasis, and neuroendocrine function and reduces insulinemia and appetite; however, high levels of adipose tissue with high levels of leptin indicate endogenous leptin resistance, which contributes to chronic low-grade inflammation and insulin resistance and suppressing fat oxidation and mitochondrial function (Falcão-Pires et al., 2012; Leal & Mafra, 2013). Thus, elevated leptin concentrations produced from high adipose tissue concentrations result in leptin resistance in overweight and obese individuals (Leal & Mafra, 2013; Pereira et al., 2021). This leads to a loss of function in leptin, contributing to more obesity (Obradovic et al., 2021; Alizadeh Pahlavani, 2022). A decrease in resting leptin levels is related to high energy expenditure during training sessions (Gerosa-Neto et al., 2019). After exercise, leptin stimulates energy expenditure by increasing fatty acid oxidation through the adenosine monophosphate-activated protein kinase (AMPK) pathway, which is activated by the sympathetic nervous system (Racil et al., 2016a). However, changes in leptin concentration depend on optimal training intensity (Racil et al., 2016a)

The present study measured leptin levels through saliva. It is highlighting that resting plasma leptin levels have been reported to be higher than salivary leptin levels in healthy individuals and patients with metabolic syndrome (Thanakun et al., 2014). Aydin et al. (2005) also reported a slightly lower salivary leptin concentration than blood leptin levels in healthy young adults. Moreover, Thanakun et al. (2014) reported a discrepancy in plasma leptin levels being significantly elevated in patients with metabolic syndrome compared to healthy individuals. However, there were no significant differences in salivary leptin levels between groups (Thanakun et al., 2014). Therefore, salivary leptin levels do not entirely reflect the circulating leptin

concentration (Aydin et al., 2005; Thanakun et al., 2014). It could be speculated that leptin transport mechanisms exist in the salivary glands, which saturate the salivary leptin (Schwartz et al., 1996; Aydin et al., 2005).

The present study found no significant change in salivary leptin from pre-values to post-values in the first training session for HIIT (24.9 vs. 27.1 pg/mL, $p>0.05$) and MIIT+BFR (23.4 vs. 28.0 pg/mL, $p>0.05$). In the de Souza et al. (2018) study, sedentary obese men were subjected to one session of high-intensity interval exercise consisting of ten 1-minute bouts of running at 90% of maximal treadmill velocity (MTV) interspersed by a 1-minute active recovery at 30% MTV, resulting in a significant reduction in blood leptin immediately after exercise compared to pre-exercise values. This outcome is quite similar to the Larsen et al. (2019) study, where overweight, inactive men experienced a -35% decrease in capillary blood leptin levels 30-minutes after a single session of HIIT, consisting of 6 × 60-second sprint cycling at 100% VO_{2peak} interspersed by 4-minute active recovery at 50% VO_{2peak}. In another study, young overweight and obese women significantly decreased plasma leptin levels by -21.3% after five minutes of completing one HIIT session, consisting of 4 × 30-seconds of supramaximal cycling at 6.5% of their body weight (BW) interspersed by 4-5-minutes of recovery (Vardar et al., 2018). According to Bouassida et al. (2006), exercise will not decrease leptin levels if the generated energy expenditure is less than 800 kcals. Different types of exercises that resulted in a high energy expenditure greater than 800 kcals induced a significant decline in blood leptin concentration post-exercise (Bouassida et al., 2006). Although Vardar et al. (2018), Larsen et al. (2019), and de Souza et al. (2018) did not record energy expenditure in their respective studies, it is safe to assume that their HIIT protocols must have generated a caloric expenditure greater than 800 kcals. It is important to note that the studies mentioned in the previous sentence subjected their participants

to near-maximal or maximal intensity and had high exercise volumes that include the exercise intervals and recovery periods (Vardar et al., 2018; Larsen et al., 2019; de Souza et al., 2018). In the present study, the exercise volume for the HIIT protocol was 24 minutes in total and 18 minutes in total for MIIT+BFR. It can be speculated that the intensities and total volume of exercise for MIIT+BFR (40% W_{avg}) and HIIT (80% W_{avg}) in the present study were not optimal to induce a caloric expenditure greater than 800 kcals, thus not significantly changing salivary leptin after completing the first training session.

Interestingly, in the last training session, HIIT significantly increased salivary leptin concentrations from 20.2 pg/mL to 24.0 pg/mL from pre to immediate-post ($p=0.04$), but MIIT+BFR induced a superior increase from 20.9 pg/mL to 26.0 pg/mL ($p=0.01$). However, in the Vardar et al. (2018) study, the overweight and obese females continued to decrease plasma leptin levels after three weeks of HIIT, consisting of 4-6 × 30-seconds of supramaximal sprint cycling against 6.5% of BW interspersed by 4-5-minute recovery. Blood leptin levels significantly dropped by -16.6% after five minutes of the last training session (Vardar et al., 2018). The present study significantly increased salivary leptin immediately post-exercise for HIIT and MIIT+BFR. It is worth noting that previous studies with similar study design (Vardar et al., 2018; Larsen et al., 2019; de Souza et al., 2018) analyzed the changes in leptin in blood not in saliva. In addition, no previous studies tested the reliability of the changes in leptin in saliva vs. blood before and after exercise. Therefore, it is logical to speculate that there may be differences in the duration for a hormone to reach the peak level in blood vs. saliva before and after exercise. In summary, the discrepancies regarding changes in salivary leptin may be attributed to the total calories (duration of exercise session and intensity of exercises performed) and method of hormone analysis (saliva vs. blood).

Conclusion

This study compared the effects of two different anaerobic training protocols, which are high-intensity interval training (HIIT) and moderate-intensity interval training with BFR (MIIT+BFR), on the adaptations in body composition, salivary hormone concentration, peak oxygen uptake, average anaerobic power output, and arterial stiffness in young overweight and obese male adults. The study's primary objective is to determine which training protocol results in the best results for fat loss, salivary hormone concentration, lean mass, average anaerobic power output, strength, peak oxygen uptake, and arterial elasticity. The secondary outcome of this study is to determine the hormone concentration levels of testosterone, cortisol, and leptin in response to one exercise session and after 8 weeks of low-volume exercise training.

The following research questions are addressed:

1. Which training protocol, HIIT or MIIT+BFR, will improve body composition in overweight and obese young male adults?
2. Will low-volume HIIT and MIIT+BFR significantly improve isometric and isokinetic strength in the legs?
3. Will low-volume HIIT and MIIT+BFR significantly improve average anaerobic power output and peak oxygen uptake in overweight and obese males?
4. Which training protocol, HIIT or MIIT+BFR, will induce significant changes in arterial elasticity, pulse wave velocity, and pulse wave analysis in overweight and obese males?
5. Which training protocol, HIIT or MIIT+BFR, will significantly improve salivary hormone concentrations?

Research Hypothesis 1. MIIT+BFR will result in similar benefits on body weight, fat, lean, and fat-free mass as HIIT.

The results of the present study do not support this hypothesis. After eight weeks of low-volume training, a trending increase in fat-free mass, lean leg mass, and lean gynoid mass were seen in the HIIT group. Interestingly, a HIIT protocol consisting of 16 × 30-second cycling at 80-100% W_{avg} was sufficient to stimulate an osteogenic formation which is proven with a significant increase in total BMC, leg BMC, and trunk BMC and a trending increase in gynoid BMC. Future studies should look into HIIT and MIIT+BFR with a greater training frequency and exercise volume to determine the effects on body composition on overweight and obese young male adults.

Research Hypothesis 2. MIIT+BFR will result in similar strength adaptations as HIIT.

The results of the present study do partially support this hypothesis. MIIT+BFR only significantly increased peak torque in the toward portion of the isokinetic 180°/s test and induced a superior increase in the middle portion of the Thorstensson Test of Fatigability. In contrast, HIIT significantly increased peak torque in the away portion of the isokinetic 180°/s test and the mean average of the first repetitions and middle reps of the Thorstensson Test of Fatigability. Moreover, HIIT had a trending increase in peak torque for the toward portion of the isokinetic 180°/s test. Although MIIT+BFR shows promise in improving muscular strength, HIIT results in more benefits. However, HIIT and MIIT+BFR did not improve MVC or peak torque in the isokinetic 60°/s test.

Research Hypothesis 3. MIIT+BFR will result in similar improvements in average anaerobic power output and peak oxygen uptake like HIIT.

HIIT had a trending increase for average anaerobic power output (W_{avg}), but there were no significant improvements in W_{avg}. MIIT+BFR did not show any trend or significant changes in average W_{avg}; thus, the results do not support the hypothesis of MIIT+BFR inducing similar improvements as HIIT.

The results of the present study support that MIIT+BFR significantly improved peak oxygen uptake (VO_{2peak}), but HIIT did not significantly change VO_{2peak}. 8 × 1-minute cycling at 40-60% W_{avg} with continuous BFR, two sessions per week, eight weeks total, significantly improved peak oxygen uptake from baseline by 2.8 ml/kg/min in overweight and obese young male adults. Whereas HIIT only improved VO_{2peak} by 0.5 ml/kg/min.

Research Hypothesis 4. MIIT+BFR will result in a similar improvement in hemodynamic and cardiovascular parameters as HIIT.

The results of the present study do not support this hypothesis. MIIT+BFR and HIIT did not affect PWV, LAEI, SAEI, aortic and brachial SBP, DBP, MAP, PP, and HR. Both groups did not affect other hemodynamic and cardiovascular parameters such as SV, CO, CEJ, SVR, TVI, ESP, AP, and AIx. HIIT induced a significant improvement in AIx@75 and a significant but negative decrease in CI. Moreover, both groups did not experience a negative effect on arterial elasticity. The lack of significance in hemodynamics and cardiovascular parameters may be associated with a short exercise volume and a training frequency of two sessions per week.

Research Hypothesis 5. MIIT+BFR will result in similar improvements in salivary hormones like HIIT.

The results of the present study do partially support this hypothesis. In the last training session, MIIT+BFR induced a superior increase in salivary leptin from pre- to post-values. HIIT also significantly increased salivary leptin from pre- to post-values in the last training session. However, both HIIT and MIIT+BFR did not induce significant changes in salivary testosterone and cortisol from pre- to post-values in the first and last training sessions. Thus, HIIT MIIT+BFR only significantly increased the salivary leptin levels immediately after the last training session.

In conclusion, this is the first study to format a HIIT protocol based on the muscular performance derived from a 30-second cycling Wingate test, not a grade exercise cycling test, in overweight and obese young male adults. In just eight weeks of training, low-volume HIIT can significantly increase total BMC, leg BMC, and trunk BMC. Significant increases were also seen in isokinetic 180^{o} peak torque in the quadricep muscles in response to HIIT. However, eight weeks of low-volume MIIT+BFR can significantly improve cardiorespiratory fitness levels with a significant increase in isokinetic 180^{o} peak torque in the hamstring muscles. HIIT and MIIT+BFR did not significantly improve any changes in PWV, LAEI, SAEI, SV, CO, SVR, TVI, aortic and brachial SBP, DBP, MAP, and PP. Future research should focus on improving hemodynamic and cardiovascular parameters while improving body composition in overweight and obese young male adults with low-volume moderate-intensity interval training with blood flow restriction and high-intensity interval training.

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APPENDIX A

APPENDIX A

RECRUITMENT FLYER

Get Paid to Lose Weight And Get Fit!

Free Exercise Sessions!

We Need Male Participants to Join Our Research Study

Men Join Our Research Study and Engage In 21 Sessions of Bike Training and Get Rewarded with A $50 Gift Card

High-Intensity Interval Training

Moderate-Intensity Interval Training + BFR

Two Sessions Per Week at Your Own Convenience at The Neuromuscular Performance Laboratory Located at the UTRGV, Brownsville Campus

You Can Find Us at Room #216 In The M-1 Building, Beside Cortez Hall

***Participants Must Have a Body Mass Index Greater Than 24.9**
***Participants' Age Must Be Between the Ages of 18 to 40**

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APPENDIX B

APPENDIX B

INFORMED CONSENT

The University of Texas Rio Grande Valley

INFORMED CONSENT FORM

Study Title: The Effects of Low Volume HIIT vs. MIIT + BFR on Body Composition, Hormone Concentration, and Arterial Elasticity in Overweight or Obese Male Adults.

Consent Name: RESEARCH STUDY PARTICIPATION CONSENT FORM

Principal Investigator:	Dr. Murat Karabulut	**Telephone:** (956) 882-7236
Co-Investigators:	Alexis Lopez	**Telephone:** (956) 562-0015
Other Study Personnel:	Jorge Bejar, Antonio Vargas, and Megan Zamora	
Department:	Health and Human Performance	
Emergency Contact:	Dr. Murat Karabulut	Telephone: (956) 882-7236

Key points you should know

- We are inviting you to be in a research study we are conducting. Your participation is voluntary. This means it is up to you and only you to decide if you want to participate in the study. Even if you choose to join the study, you are free to leave at any time if you change your mind.
- Take your time and ask to explain any words or information you do not understand.
- We are doing this study because we want to learn.
    - This study will be conducted to compare the effects of two different anaerobic training protocols: [1) high-intensity interval training (HIIT) and 2) Moderate-intensity interval training (MIIT) with blood flow restriction (BFR) (which is a technique that restricts venous blood return during exercise by placing specifically designed cuffs over target limbs and inflating them to a pressure that has been set beforehand.)] on the adaptations in body composition, hormone and cytokine concentration, and arterial stiffness in young overweight or obese male adults.

- Why are you being asked to be in this study?
    - You are being asked to participate in this study because you meet the following qualification criteria: between 18-40 years of age, body mass index (BMI) > 24.9, sedentary or physically active, and healthy (not known to have any diseases).
    - However, you will be excluded if you are diagnosed with diseases (e.g., diabetes, heart disease, etc.), musculoskeletal injuries impairing physical performance, history of blood clots, varicose veins, deep vein thrombosis (DVT), or other conditions that would impede venous return.
- What will you do if you agree to be in the study?
    - Participate in a 10-week study compromised of an 8-week training program and laboratory visits.
    - A total of 21 sessions is required.
    - Depending on the group assigned, the total time commitment is about 18 to 20 hours.
    - All study procedures will be conducted in the Exercise Science Laboratory (M-1 building, room 216), and a body composition scan will be performed in Cortez Hall, room 214.
    - You and the researcher will agree on time schedules when most convenient for you.
    - You will fill out several health-related questionnaires, be familiarized with the study procedures, and will carefully read and sign an informed consent before any testing takes place.
    - If you do not fulfill the required criteria set in the study, you will be excluded from this study.
    - The procedure will maintain a schedule as follows:
        - Session 1: Paperwork, questionnaires, and informed consent.
        - Session 2: If you qualify, your height, weight, waist circumference, body composition, heart and blood vessel parameters, and average anaerobic power output will be assessed under 8-hour fasted and hydrated conditions.
        - Session 3: Under 8 hours fasted and hydrated conditions, your level of cardiorespiratory fitness and muscular endurance will be measured.
        - Session 4-19:
            - High-Intensity Interval Training Group – Anaerobic cycling followed by resistance band exercises per session
            - Moderate-Intensity Interval Training + BFR Group – Anaerobic cycling with BFR followed by non-BFR resistance band exercises per session
        - Session 20-21: Under 8-hour fasted and hydrated conditions, you will visit the laboratory and be reassessed for weight, height, waist circumference, body composition, heart and blood vessel parameters, average anaerobic power output, cardiorespiratory fitness, and muscular endurance.
    - Pre- and Post-tests that will be performed for sessions 2, 3, 20, and 21 are as follows:
        - Before collecting your heart and blood vessel parameters, you will rest lying facing upwards for a minimum of 5 minutes and two noninvasive equipment (SphygmoCor and HDI/PulseWave) will be used to measure the heart and blood vessels related variables.

- Your average anaerobic power output will be determined by performing a 30-second cycling test.
- Body composition will be measured using the *dual*-energy *x-ray absorptiometry* (DXA, one of the most accurate methods for measuring body composition).
- Your cardiorespiratory fitness will be measured using a graded treadmill exercise test, and your muscular endurance test will be measured using a 50-repetition leg extension test.
- On the first and last training day, these sessions will be performed in the morning under 8- hour fasted and hydrated conditions because saliva samples will be collected using a saliva sample collection kit via the passive drool method at pre-and post-exercise.
- The saliva sample collection aims to determine the salivary concentration of hormones and cytokines.
    - The passive drool method requires the participants to rinse their mouth thoroughly with water and discard without swallowing. Next, the participants must allow the saliva to pool inside their mouths. Then with their head tilted forward, they will gently force the saliva to fall outside their mouth through a collection aid into a cryovial. A total of 2 ml of saliva will be collected before and after the first and last training session and stored at -20°C until it is ready to be analyzed.

- Session 4-19
    - You will be randomly assigned to one of the two groups performing one of the designed anaerobic and resistance band exercise training protocols.
    - High-Intensity Interval Training Group: will include leg cycling bouts followed by 3 circuits of upper-body resistance band exercises per session. You will come to the training room and perform the specified routine 2 times a week with at least 48 hours of rest between sessions.
    - Moderate-Intensity Interval Training + BFR Group: will include leg cycling bouts with BFR followed by 3 circuits of upper-body resistance band exercises per session. You will come to the training room and perform the specified routine 2 times a week with at least 48 hours of rest between sessions.
    - You will perform these sessions under the supervision of the investigators.
    - The training sessions will look as follows:
        - The MIIT+BFR will begin with the participant warming up with 5-minutes of unloaded cycling on a bike ergometer. Then, they will perform the training routine, which consists of 8 bouts of 60 seconds of leg cycling at an intensity of 40-60% P_{avg} with continuous BFR at 150-220 mm Hg on the proximal regions of both legs during exercise. After completing the leg cycling bouts, the participants will cool down for 3-minutes while cycling on the bike ergometer with no resistance and then rest for 2-minutes. Next, they will perform 3 circuits consisting of 4 upper body resistance band exercises at a light-to-moderate resistance for 10-20 repetitions per exercise. Each circuit is interspersed by 60

seconds of passive rest. The resistance band exercises will be performed without BFR. Afterward, the participants will cool down with 4 upper body stretching exercises without BFR.

- HIIT will begin with the participant warming up with 5-minutes of unloaded cycling on a bike ergometer. They will then perform the training routine, consisting of 16 bouts of 30 seconds of leg cycling at an intensity of 80-100% P_{avg} interspersed by 45 seconds of passive rest. After completing the leg cycling bouts, the participants will cool down for 3-minutes while cycling on the bike ergometer with no resistance and then rest for 2-minutes. Next, they will perform 3 circuits consisting of 4 upper body resistance band exercises at a light-to-moderate resistance for 10-20 repetitions per exercise. Each circuit is interspersed by 60 seconds of passive rest. Afterward, the participants will cool down with 4 upper body stretching exercises.

- Blood flow restriction will be implemented by putting on specialized cuffs filled with air (like blood pressure measuring cuffs) in the uppermost portion of the thighs before performing the leg cycling exercises. A specialized air pressure controlling machine will maintain the pressure on the cuffs. They will not be deflated until the completion of the leg cycling bouts. It will take about 17-20 minutes.

- Throughout The Length of The Study
  - Participants must not engage in vigorous activity within 24-48 hours before testing sessions.
  - Participants must only drink water during all sessions.
  - Participants must wear proper attire (i.e., exercise shorts, short sleeve t-shirt, close-toed shoes).
  - Participants must not consume caffeine at least 3-4 hours before training sessions.
  - Participants must not take any fat loss supplement throughout the length of the study.
  - Participants must maintain their daily eating habits.
  - Participants must not participate in any other resistance exercise throughout the length of the study.
  - Participants must not participate in any other structured exercise training protocol.

- Can you be harmed by being in this study?
  - You must understand there are always minimal risks to healthy individuals when performing any of the requirements for this project.
  - Even though these standard protocols have been approved at numerous other institutions and will be performed by qualified and trained personnel, it should be noted that this study has the following risks:
  - **Risks associated with Physical and major changes in exercise:** Exercise stress from any form of physical activity is considered a minimal risk which can result in muscle soreness and muscle injury. However, the risk of muscle soreness and injury will be minimized by doing a 5-minute warm-up and cool-down.

- **Risks associated with the use of BFR cuffs:** Minimal physical discomfort can result from BFR cuffs.
- **Risks associated with the use of approved devices:** The devices used in this study are non-invasive, scientifically approved, and used in many previous research studies. The physical risk of these devices is minimal.
- **Risk of radiation:** There is always a risk from radiation exposure. However, the amount of radiation used in DXA scans is minimal. The amount of radiation exposure in Annual Natural Background Exposure is 2400 uSv and in a Chest X-Ray is 50 uSv. However, a DXA test exposure is only 0.6 uSv, less than one-tenth the dose of a standard chest x-ray. DXA scan will be conducted by trained personnel certified and approved by the Radiation Safety Department. For other queries about radiation risk, please consult with your personal physician.
- **Risks to your personal privacy and confidentiality:** The physiological measurements collected are for research purposes, not for diagnosing health problems. Your participation in this research will be held strictly confidential, and only a code will be used to identify your stored data. However, confidentiality cannot be guaranteed because there will be a link between the code and your identity.
- There may be other risks that are not known at this time. Tell the study investigator or study staff right away if you have any problems.

- Will you get anything for being in this study?
  - There are no costs for participation in this study. Participation is voluntary, and you will receive a $50 gift card after completing all sessions of this study. If you decline to participate, you will not be penalized or lose benefits or services unrelated to the study. If you decide to participate, you may refuse to answer any question and may choose to withdraw at any time. However, you will not be rewarded with the $50 gift card for withdrawing from the study.
  - The benefits to participation are: You may notice improvements in your body fat percentage, body weight, resting blood pressure, resting heart rate, muscle mass, bone mineral density, and arterial health. Lastly, you will receive free personal anaerobic and aerobic training, which will help you maintain healthy bones, muscles, and joints and hopefully improve your quality of life.
- Could you be taken out of the study?
  - Suppose you miss 3 consecutive sessions, which equals one week of training. In that case, you will automatically be disqualified and removed from the study as the changes in the exercise training will be lost.

Can the information we collect be used for other studies?

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

What else should you know?

- We are asking 40 people to be in this study.
- Research tests using your sample and physiological data may result in inventions or procedures that have commercial value and are eligible for protection by a patent. By agreeing to use your sample in research, you are giving your sample without expectation of acknowledgment, interest in any commercial value or patent, or interest of any other type. However, you retain your legal rights during your participation in this research.
- The physiological measurements collected are for research purposes, not for diagnosing any health problems.
- The amount of radiation used in DXA scans is minimal. The amount of radiation exposure in Annual Natural Background Exposure is 2400 uSv and in a Chest X-Ray is 50 uSv. However, a DXA test exposure is only 0.6 uSv, less than one-tenth the dose of a standard chest x-ray.
- We will be sharing your pre- and post-training result with you upon request.

How will your information be used and shared?

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

What happens if I say no or change my mind?

- You can say you do not want to be in the study now, or if you change your mind later, you can stop participating.
- We will not collect, use, or share your information for this study.

- No one will treat you differently. You will not be penalized.
- You will not be rewarded with a $50 gift card for withdrawing from the study.

How will my privacy be protected?

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

Who is paying for this study?

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

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

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

Who to Contact Regarding Your Rights as a Participant?

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

Signatures

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

_____ ____/____/_____

Participant's Signature Date

APPENDIX C

APPENDIX C

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

2021 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

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

GENERAL HEALTH QUESTIONS

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

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

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

PARTICIPANT DECLARATION

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

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

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

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

Delay becoming more active if:

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

 1 / 4
01-11-2020

APPENDIX D

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HEALTH STATUS QUESTIONNAIRE

University of Texas at Rio Grande Valley

Health Status Questionnaire

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

Part 1. Information About The Individual

1. Date_____
2. Legal Name_____Nickname_____
3. Mailing Address_____
   _____
4. Home Phone _____Business Phone_____
5. Personal Physician Phone _____
6. Person to Contact in case of Emergency: Name _____ Phone _____
7. Preferred Hospital in Case of Emergency _____
8. Gender (Circle One): Female Male
9. Date Of Birth: ____/_____/_____ Month/Day/Year
10. Number of hours worked (occupational) per week:
    Less than 20 20-40 41-60 Over 60
11. More than 25% of time on job is spent (Circle all that apply):

    Sitting at desk Lifting or carrying loads Standing Walking Driving

Part 2. Medical Information

12. Circle any of the following if died of heart attack before age of 50:
    Father Mother Brother Sister Grandparent
13. Date of last medical physical exam: _____(Year)
14. Last physical fitness test: _____(Year)
15. Circle any surgeries you might have had:
    Back Heart Kidney Eyes Joint Neck
    Ears Hernia Lung Other_____

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

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

Other_____

17. Circle all medicine taken in last 6 months:

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

Other_____

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

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

a. Cough up blood	d. Leg pain	g. Swollen joints
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
b. Abdominal pain	e. Arm or shoulder pain	h. Feel dizzy
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
c. Low back pain	f. Chest pain	i. Dizziness
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

j. Breathless with slight exertion

1 2 3 4 5

Part 3. Health-Related Behavior

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

20. If you are a smoker, please circle the number of cigarette that you smoke per day:

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

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

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

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

0 1 2 3 4 5 6 7 days per week

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

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

25. Weight now_____ lb. One year ago_____ lb. Age 21_____ lb.

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

_____
_____
_____

APPENDIX E

APPENDIX E

VENOUS RETURN QUESTIONNAIRE

Questionnaire to Identify Individuals with Diseases Affecting Venous Return

Name: **Date:**

DOB:

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

APPENDIX F

APPENDIX F

DATA SHEETS

Name:	Age:	Date:
Phone #	Email:	
Preferred Method of Contact:		

Anthropometric Measurements	
Weight:	
Height:	
BMI:	

Training and Testing Availability (Circle)				
Monday	Tuesday	Wednesday	Thursday	Friday
09:00 AM	09:00 AM	09:00 AM	09:00 AM	09:00 AM
10:00 AM	10:00 AM	10:00 AM	10:00 AM	10:00 AM
11:00 AM	11:00 AM	11:00 AM	11:00 AM	11:00 AM
12:00 PM	12:00 PM	12:00 PM	12:00 PM	12:00 PM
01:00 PM	01:00 PM	01:00 PM	01:00 PM	01:00 PM
02:00 PM	02:00 PM	02:00 PM	02:00 PM	02:00 PM
03:00 PM	03:00 PM	03:00 PM	03:00 PM	03:00 PM
04:00 PM	04:00 PM	04:00 PM	04:00 PM	04:00 PM
05:00 PM	05:00 PM	05:00 PM	05:00 PM	05:00 PM
06:00 PM	06:00 PM	06:00 PM	06:00 PM	06:00 PM
07:00 PM	07:00 PM	07:00 PM	07:00 PM	07:00 PM

Any Other Time Available	
Day	Time

SESSION # **PRE-TEST / POST-TEST**
NAME: **AGE:** **DATE:**
HIDRATION LEVEL:

SPHYGMOCOR					**HDI/PULSEWAVE**			
Site Displacement	**Value (mm)**					**Trial 1**	**Trial 2**	**Trial 3**
Femoral Artery to Cuff					SYS			
Carotid Artery to Sternal Notch					DIA			
Sternal Notch to Cuff					MEAN			
Pulse Wave Analysis	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	PR			
Aortic Systolic Pressure								
Aortic Diastolic Pressure						**Trial 1**	**Trial 2**	**Trial 3**
Pulse Pressure					LAEI			
Mean Arterial Pressure					SAEI			
Heart Rate						**Trial 4**	**Trial 5**	**Trial 6**
AP					LAEI			
Alx					SAEI			
Alx75						**Trial 7**	**Trial 8**	**Trial 9**
HR Period					LAEI			
Ejection Period					SAEI			
Aortic T2								
P1 Height								
Buckerberg SEVR								
End Systolic Pressure								
Forward Pulse Height								
Reflected Pulse Height								
Reflection Magnitude								
Brachial Systolic Pressure								
Brachial Diastolic Pressure								
Head Position								
	Trial 1	**Trial 2**	**Trial 3**	**Trial 4**				
Pulse Wave Velocity								

30-SECOND WINGATE CYCLING PROTOCOL	
Cycle Ergometer Height	
5-Min Warm-Up @ 2.0% TBW	
5-Sec. Sprint Resistance @ 3.7% TBW at 2:00, 3:00, and 4:00 of Warm-Up	
Resistance (7.5% TBW)	
Revolutions Per Minute	
Average Power Output	
Relative Average Power Output	

SESSION # **PRE-TEST / POST-TEST**
NAME: **AGE:** **DATE:**
HIDRATION LEVEL:

BIODEX MEASUREMENTS		
Chair Front/Back		
Chair Height		
Dynamometer Left/Right		
Attachment Length		
Back Seat Forward/Backward		
Finger Width		
5-Minute Cycling Warm-Up @ 360 Kg · m · min^{-1} = 1.0 Kg × 6 m × 60 RPM		
MVC	**Trial #1**	**Trial #2**
Peak Torque (N·m)		
ISO 60	**Trial #1**	
Peak Torque (N·m)		
ISO 180	**Trial #1**	
Peak Torque (N·m)		
Thorstensson Test of Fatigability	**Peak Torque (N·m)**	
Rep #		
Rep #		
Rep #		
Rep # 24		
Rep # 25		
Rep # 26		
Rep # 48		
Rep # 49		
Rep # 50		

PEAK VO_2 TESTING					
Bruce Protocol	**Speed**	**Incline**	**Time**	**Heart Rate**	**RPE**
Stage 1	1.7 mph	10%	0-3 min		
Stage 2	2.5 mph	12%	3-6 min		
Stage 3	3.4 mph	14%	6-9 min		
Stage 4	4.2 mph	16%	9-12 min		
Stage 5	5.0 mph	18%	12-15 min		
Total Duration		**PEAK HR:**			

SESSION #

TRAINING SESSION #

NAME:

DATE:

HIGH-INTENISTY INTERVAL TRAINING:
16 BOUTS OF 30 SEC:45 SEC + 3 CIRCUITS OF RESITANCE-BAND EXERCISES

INTENSITY:

CYCLING RESISTANCE:

RPM: 60-70

Peak HR:

SEAT HEIGHT:

16 BOUTS OF 30 SEC:45 SEC							
	RPE	Pre-Ex HR	Post-Ex HR		RPE	Pre-Ex HR	Post-Ex HR
BOUT #1				BOUT #9			
BOUT #2				BOUT #10			
BOUT #3				BOUT #11			
BOUT #4				BOUT #12			
BOUT #5				BOUT #13			
BOUT #6				BOUT #14			
BOUT #7				BOUT #15			
BOUT #8				BOUT #16			

LIGHT-MODERATE RESISTANCE-BAND EXERCISES INTERSPERSED BY 60 SEC OF REST
COLOR OF RESISTANCE-BAND:

	BICEP CURLS	OHP	CHEST PRESS	PULL-APART			
	REPETITIONS	REPETITIONS	REPETITIONS	REPETITIONS	TOTAL REPS	RPE	HR
CIRCUIT #1							
CIRCUIT #2							
CIRCUIT #3							

COMMENTS:

SESSION #

TRAINING SESSION #

NAME:

DATE:

MODERATE-INTENISTY INTERVAL TRAINING + BLOOD FLOW RESTRICTION:
8 BOUTS OF 60 SEC:60 SEC + 3 CIRCUITS OF RESITANCE-BAND EXERCISES

INTENSITY:

CYCLING RESISTANCE:

RPM: 60-70

BFR:

Peak HR:

SEAT HEIGHT:

8 BOUTS OF 60 SEC:60 SEC							
	RPE	Pre-Ex HR	Post-Ex HR		RPE	Pre-Ex HR	Post-Ex HR
BOUT #1				BOUT #5			
BOUT #2				BOUT #6			
BOUT #3				BOUT #7			
BOUT #4				BOUT #8			

LIGHT-MODERATE RESISTANCE-BAND EXERCISES INTERSPERSED BY 60 SEC OF REST
COLOR OF RESISTANCE-BAND:

	BICEP CURLS	OHP	CHEST PRESS	PULL-APART			
	REPETITIONS	REPETITIONS	REPETITIONS	REPETITIONS	TOTAL REPS	RPE	HR
CIRCUIT #1							
CIRCUIT #2							
CIRCUIT #3							

COMMENTS:

BIOGRAPHICAL SKETCH

Alexis Lopez received his BS in Exercise Science in May 2020. He received his MS in Exercise Science in August 2023. Both degrees acquired from The University of Texas Rio Grande Valley in Edinburg and Brownsville, TX. alexis.lopez03@utrgv.edu