CHANGES IN CARDIORESPIRATORY FITNESS, POWER, STRENGTH, AND FLEXIBILITY AFTER PARTICIPATION IN A SHORT 8-9 WEEK INTERVENTION BASED PROGRAM

By

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Abstract: While previous literature has shown improvements for aerobic capacity, and or strength/muscular endurance after performing structured exercise prescriptions, limited research has assessed a blended training program (both cardio and resistance training in the same workout/program) and how this form of training can affect aerobic and strength measurements.. Furthermore, a paucity of literature is available for such training interventions with employee and community wellness populations. Therefore, the purpose of the present study is to see if cardiorespiratory fitness, power (force/time), strength (force/mass), body composition and flexibility can be positively affected after participation in an 8-week intervention based program. Ten recreationally active adults (mean ± SD: age = 40.70 ± 8.45 years, stature = 167.10 ± 8.47 cm, mass = 72.24 ± 17.20 kg) participated in a structured exercise program which comprised of both cardiovascular (C) and resistance (R) training. Workouts were three times a week for 8 weeks, and lasted ~50 total minutes. Participants were assessed before the program began (week 1), and immediately after the program ended (week 10). All participants had their body weight, body composition (3-site skinfold), strength (YMCA bench press), aerobic capacity (Cooper 12-min walk/run test), flexibility (sit-n-reach box) and jumping performance (average power, average velocity, peak power, peak velocity, vertical jump height) assessed. A one-way repeated measures ANOVA (variable × time) was used to analyze each individual variable. The present findings revealed no significant changes for any variables ($P = 0.68$-0.962) after performing an 8-9 week HIIT training program.

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CHAPTER I

INTRODUCTION

Previous research suggests that regular exercise substantially improves physical and mental health (1). For example, participating in regular exercise has been found to be feasible for all demographics (age, sex, current activity level, etc.) and can be accomplished with various approaches; whether it be by utilizing bodyweight movements, resistance training, walking, or by other means (2,3,4,). Despite the depth of knowledge surrounding exercise, a well-defined understanding of the dynamics concerning combining several forms of exercise into one exercise regimen is ambiguous. For example, even with abundant research little is known about the dynamics of high intensity interval training (HIIT), as well as how implementing a multitude of exercises into one regimen can improve cardiorespiratory fitness (VO2max), power, strength, flexibility, and anthropometric measurements collectively. Additionally, limited research has been conducted on acute and long duration based HIIT intervention protocols.

While cardiovascular and resistance training movements are commonly performed with HIIT protocols (5,6,7,8,9,10), understanding these two important variables (cardiovascular and resistance training) can assist with exercise design and prescription. For example, cardiovascular training refers to the development of the cardiovascular system to elicit improvements in cardiovascular function and cardiorespiratory fitness (11). This system is responsible for transporting oxygen, nutrients, hormones, and cellular waste products to the body's tissues and cells. Generally, cardiovascular training includes physical activity (walking, swimming, biking etc.) that elevates the heart rate above the resting rate and popular methods of cardiovascular training include specific physical activity at a determined percentage of maximal heart rate (12).

Resistance training is comprised of exercises that improve muscular mass, strength, and endurance (11). Generally, resistance training refers to the movement of limbs against constant forces from gravity, bodyweight, machine, free-weights, etc. Current research reports that the adaptability and response (neuromuscular adaptations) of the neuromuscular system to resistance training may elicit improvements in force production (13,14,15,16,17) .

Within the last decade HIIT has become a prominent form of exercise and a preference for participants and fitness professionals (18). HIIT programs have gained popularity due to their short duration, modifiability, and the various exercises that can be incorporated. These programs are characterized by brief, but intense periods of work and short periods of rest before progressing to another exercise or set of exercises. Popular methods of high-intensity exercise incorporate anaerobic, power, strength, and flexibility components and place emphasis on the proper execution of exercises such as squats and deadlifts, which replicate daily tasks (19,20,21,22). Following a tradition of applied research investigating the benefits of participating in regular exercise, this paper seeks to further the understanding of the advantages associated with participation in an 8 week intervention based (HIIT) program.

1.1. Study Variables

The dependent variable for the study is the exercise protocol being implemented, high-intensity interval training. All participants completed intermittent and multi-modal cardiorespiratory and resistance training during each exercise session. The primary independent variables of the study were related to body composition (lean mass, fat mass, and body fat percentage) assessed by a 3-site skinfold and physiological profiles for aerobic(VO2max, strength, and power) strength, flexibility, and lower-body power measured with the Rockport 12 minute run/walk, YMCA bench press test, and a maximal vertical jump. The secondary dependent variable was flexibility measured through a sit and reach test.

1.2. Hypothesis

HA1: There will be a difference in cardiorespiratory fitness after performing HIIT training.

HA2: There will be a change in peak power after performing HIIT training.

HA3: There will be a change in strength after performing HIIT training.

HA4: There will be a change in the gains in lower body force production (as measured by vertical jump height, peak power, peak velocity, average power, and average velocity) after performing HIIT training.

HA5: There will be a change in flexibility (as estimated by the sit and reach test) after performing HIIT training.

1.3. Conceptual Model

High intensity interval training is a type of cardiovascular training that incorporates high-intensity periods of exercise followed by lower intensity periods of exercise, or rest, that is repeated for a specific number of repetitions depending on the fitness level of the individual (2). The rest periods allow for waste (from the breakdown of carbohydrates, fats, and proteins) to be removed from the blood ensuring recovery for the next high-intensity interval. Williams (2012) of the National Strength and Conditioning Association (NSCA) suggests that four variables should be considered when constructing a HIIT program: "intensity or speed of each interval, distance or time of each interval, active rest or rest of each interval, and the total number of intervals to be completed during the workout" (23).

Generally, three systems produce the energy needed to accomplish exercise; ATP-PC (adenosine triphosphate-phosphocreatine), anaerobic (without oxygen) system, and aerobic (with oxygen) system. The ATP-PC system provides energy to complete shorter intervals of high intensity exercise. The anaerobic system provides energy to complete intervals of moderate exercise intensity. The aerobic system provides energy for longer intervals with lower physical demands. Williams also suggests that, "All three energy systems will have different workloads and recovery times due to the intensity, and the time allowed for the buffering of lactic acid and replenishment of ATP so that the following interval may be completed at a high rate of work" (23).

Seeing how resistance training is primarily anaerobic and cardiorespiratory fitness can be either anaerobic or aerobic, it can be surmised that performing both resistance and cardiorespiratory fitness training in a HIIT protocol may produce positive outcomes when considering the shifts between energy systems required to complete the workout.

1.4. Operational Definitions

Cardiorespiratory fitness (CRF) is, "a health-related component of physical fitness defined as the ability of the circulatory, respiratory, and muscular systems to supply oxygen during sustained physical activity (24). CRF is usually expressed in metabolic equivalents (METs) or maximal oxygen uptake (VO2 max) measured by exercise tests such as treadmill or cycle ergometer. CRF is not only a sensitive and reliable measure of habitual physical activity, but also a relatively lowcost and useful health indicator for both symptomatic and asymptomatic patients in clinical practice (24).” Generally, the terms “VO2max”, “aerobic capacity”, and “cardiorespiratory fitness” can be used interchangeably.

Power is defined as, “the product of the force and velocity of muscle contraction” and is considered a primary determinant of (athletic) performance that requires explosive production of force such as throwing and jumping (15,16, 25). Typically expressed in watts (W), muscular power assessments can be implemented to determine the maximal amount of force/velocity produced in the least amount of time.

Strength is defined as, “the maximal amount of force that can be generated by a muscle or group of muscles, regardless of the amount of time it takes” (13). Often times, strength is assessed with maximal or sub-maximal exercises and may be expressed in pounds, kilograms, or total repetitions. 1-repetition maximum (utilizing maximal force), completing a maximal amount of repetitions (utilizing sub-maximal force), and near-maximal isometric movements all assess strength utilizing different techniques.

Flexibility is defined as, “the ability of a joint or series of joints to move through an unrestricted, pain free range of motion” (26). Flexibility can assess a variety of limb-joint interactions in most instances with a goniometer or ruler/measuring tape (27). Values rendered from flexibility assessments are typically expressed in centimeters, inches, or on a point system.

Anthropometric measurements (body composition) are defined as, “the study of the human body in terms of the dimensions of bone, muscle, and adipose (fat) tissues” (28). Body composition measurements often include height, weight, and fat vs. muscle percentages.

1.5. Assumptions

It was assumed that the participants gave their true maximum effort during the YMCA bench press test since this protocol was designed to assess maximal muscular endurance. Because the cardiovascular exercise bout was based on the VO2max estimated from the Cooper 12 minute run/walk test, it was assumed that the participants gave their true maximum effort during the 12 minute run/walk test. It was also assumed that the 12 minute walk/run test provided a valid estimate of VO2max. Because the loss of body fat or increase in muscle mass is also dependent on nutrition, it was assumed that the participants would follow a nutrition plan to decrease body fat mass or increase their muscle mass depending on their goals.

1.6. Limitations

A limitation of the present study was that there was only one group observed, the participation group. This group was composed of OSU-STW benefits-eligible employees and community members with a membership at Oklahoma State University's Department of Wellness. It may have been beneficial to include a control group in this study to compare the differences between a group who participated in the 8 week intervention based program and a group who continued their regular exercise regimen. Another limitation of this study was that in order to participate, it was required that participant's be exercising 3 times a week for the past 6 months. A number of potential participants were not included in this study because they did not quite meet weekly or monthly exercise requirements. It is well understood that increases in training adaptions are observed in trained individuals as opposed to untrained individuals (19). The use of a treadmill for this test was also a limitation because of not being as difficult as a 12 minute walk/run on a traditional track where the participant would have to propel their body weight through space. The study was also limited by the field-based tests that were implemented: specifically the test assessing power which required participants to perform 3 maximum countermovement vertical jumps. This type of assessment may not have been the most practical for participants with a past medical history of musculoskeletal or soft tissue injury, or who were not comfortable jumping. In future studies it may be beneficial to assess and account for each of these limitations.

1.7 Delimitations

While it is optimal to have a broad spectrum of participants without regard to age, gender, or health status, for convenience purposes there were delimitations placed on this study with regard to the subjects. The participation sample included 3 men and 7 women who exercised 3 times a week for the past 6 months and no diagnosed musculoskeletal injury within the past 6 months. Should this intervention based program prove to be effective, the study can then be repeated with a similar group of participants to see if the same is true across multiple populations for dissemination to the general public. The study participants may have some experience in training in a gym environment, but may or may not have performed all of these tests or exercises.

1.7. Significance

The purpose of this study was to investigate the benefits of participating in an 8 week intervention based program. It is hypothesized that participation in an 8 week intervention program will yield increases in cardiorespiratory fitness, power, strength, body composition and flexibility. Previous research demonstrates direct and positive relationships between regular exercise, body composition, and performance measures. However, few studies have investigated relationships between exercise and flexibility and/or exercise and the aforementioned variables collectively. The results of this study may contribute to the current body of knowledge by providing a novel approach to intervention based exercise programming for healthy adults and assessing the benefits of said program. Growing research suggests that high-intensity interval training (HIIT) is a time-efficient exercise strategy to improve cardiorespiratory and metabolic health. Recent studies, however, have revealed the potential for other models of HIIT, which may be more feasible but are still time-efficient, to stimulate adaptations similar to more demanding low-volume HIIT models and high-volume endurance-type training.

As little as 3 HIIT sessions per week including warm-up, recovery between intervals and cool down, has been shown to improve aerobic capacity, skeletal muscle oxidative capacity, exercise tolerance and markers of disease risk after only a few weeks in both healthy individuals and people with cardio-metabolic disorders (12). Inducing intervention based physiological adaptations requires a multifaceted approach to improve results in body composition, performance, and flexibility. Specifically, it should be a combined effort of the medical, nutritional, and exercise professionals helping those interested in exercising in making healthy lifestyle changes that include not only increasing physical activity but modifying eating habits as well. The primary role of exercise professionals in this lifestyle change is to prescribe safe and effective workout regimens specific for the participant and their goal(s). The pre/post-testing protocol, design of the exercise protocol, and each exercise regimen provided via this study may allow exercise professionals to better target their clients' training goals to improve health outcomes by focusing on implementing exercises that increase desired outcomes of body composition, power, and flexibility.

CHAPTER II

REVIEW OF LITERATURE

2.1. Exercise Recommendations

Scientific evidence supporting the benefits of physical activity is extensive and well understood. Previous and current research alike associate regular exercise with copious health benefits. For most adults, the benefits of regular physical activity far outweigh the risks. For example, it is suggested that bone mineral density, muscle mass, heart health, and stress (1,2,3,4,5) can all be positively affected from exercise. The American College of Sports Medicine (ACSM, 2017), Center for Disease Control (CDC, 2017), and American Heart Association (AHA, 2017) are three of the most prominent health organizations in the United States. In accordance with their recommendations on physical activity, cardiovascular and resistance training have been determined as important components that should be regularly included in one's life in order to improve and maintain physical fitness and health.

As each health organization provided distinct evidence based recommendations for regular physical activity; specific frequencies, intensities, duration, and types of physical activity that elicit the greatest health benefit were also identified. For instance, research conducted by Garatachea et al. (2015) and Agarwal et al. (2012) concluded that participation in regular physical activity is feasible and beneficial for diverse populations. Agarwal (2012) reviewed the beneficial effects of regular exercise on cardiovascular diseases. Previous literature examined in this review linked cardiovascular disease prevention to several modifiable risk factors including but not limited to; blood pressure, blood sugar, cholesterol levels, smoking, obesity, diet, and physical inactivity. Physical inactivity or a sedentary lifestyle is associated with increased cardiovascular events and premature death (Held et al., 2012). In conjunction with previous literature that provided evidence of regular physical activity improving cardiovascular health, the AHA recommends 30 minutes of physical activity 5 days a week to experience these benefits (AHA, 2017). Ultimately, the authors concluded that physical activity is an easy, inexpensive, and effective way to avoid CVD.

2.2. Exercise recommendations for healthy adults

The ACSM (2014) recently provided guidelines for cardiorespiratory, resistance, and flexibility exercises. For adults, at least 30 minutes per day of moderate-intensity cardiorespiratory exercise training for at least five days per week, totaling 150 minutes was recommended. According to the ACSM (2014), moderate-intensity cardiorespiratory exercise training includes exercises performed at 40%-60% of heart rate reserve (HRR) and can be measured in metabolic equivalents (METs). Smith (2006) defined METs as, "a measure of exercise intensity based on oxygen consumption". More specifically, defining a single MET as, "the amount of oxygen a person consumes (or the energy expended) per unit of body weight during 1 minute of rest. It is equal to about 3.5 milliliters (ml) of oxygen consumption per kilogram (kg) of body weight per minute, or 1 kilocalorie (kcal) per kg of body weight per hour." Generally, 3-6 METs are required to achieve moderate-intensity cardiorespiratory exercise (ACSM, 2104, p. 3).

Another form of exercise training is vigorous-intensity cardiorespiratory exercise training which are exercises performed at 60%-90% of HRR (ACSM, 2014). Because of the higher intensity, ACSM suggests that this form of training only be performed 20 minutes a day on at least 3 days a week for a total of at least 75 minutes per week. Generally, ≥6 METs are required to achieve vigorous-intensity cardiorespiratory exercise (ACSM, 2014, p. 3). If one were to combine both moderate- and vigorous-intensity exercise, the goal would be to achieve a total energy expenditure of at least 500-1000 MET/minute/week (ACSM, 2014). In addition to cardiovascular exercise, the ACSM also suggests that people should resistance train two/three days per week.

Generally, resistance training includes exercises for each of the major muscle groups, and motions that will involve balance, agility, and coordination. The ACSM recommends, each major muscle group should be trained 2-3 times per week and at various percentages of a person's one-repetition maximum (1RM) depending on their goals (ACSM, 2014, p. 185). The ACSM also placed importance on flexibility (the range of motion around a joint). It was recommended that each stretching day include a series of flexibility exercises for each of the major muscle-tendon groups (a total of 60s per exercise) on at least 2 days per week (ACSM, 2014, p. 188).

The Center for Disease Control (CDC) also provides exercise guidelines which are similar to the ACSM's (CDC, 2015). For substantial health benefits, the CDC suggested that adults should do at least 150 minutes (2 hours and 30 minutes) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) a week of vigorous-intensity aerobic activity, with aerobic activity performed in episodes of at least 10 minutes spread throughout the week. For additional and more extensive health benefits, it was recommended that adults increase their aerobic physical activity to 300 minutes (5 hours) a week of moderate-intensity, or 150 minutes a week of vigorous-intensity aerobic physical activity. For resistance training, the CDC recommends that adults also should do muscle-strengthening activities that are moderate to high-intensity and involve all major muscle groups on two or more days a week, as it has been proven that these activities provide additional health benefits (CDC, 2015).

Pollock et al. (2018), Knaeps et al. (2016), and Myers et al. (2015) conducted research to assess the importance of adhering to exercise recommendations. Pollock et al. (2018) assessed the relationships between sedentary time (ST), moderate to vigorous physical activity (MVPA), cardiorespiratory fitness (CRF) and cardiometabolic health in highly active older individuals. One hundred and twenty-five healthy amateur cyclists aged 55 to 79 years had their ST and MVPA levels assessed by actigraphy over a 7 day period and CRF was assessed using a maximal effort cycle ergometry test to determine VO2max. Markers of cardiometabolic risk were assessed and used to determine cumulative cardiometabolic risk. Findings revealed that CRF was associated with training volume, but not ST or MVPA. Thus, higher CRF was associated with significantly lower cumulative cardiometabolic risk, body fat percentage, triglyceride and HDL levels. MVPA was associated with improvements in body fat percentage and ST was not associated with any marker of cardiometabolic risk for regularly active individuals. Overall, this study provided evidence for regular physical activity (specifically CRF) significantly improving cardiometabolic risk to maintain current health levels even in a group of older individuals with high fitness levels. The findings from this study set a precedent for our research as we sought to elicit improvements in CRF to improve other measures.

Knaeps et al. (2016) aimed to investigate the independent associations of a 10-year change in sedentary behaviour (SB), moderate-to-vigorous physical activity (MVPA) and objectively measured cardiorespiratory fitness (CRF), with concurrent change in clustered cardiometabolic risks in a population-based sample of 425 middle-aged adults. It was determined that risk factors were influenced by changes in CRF (for SB and MVPA), waist circumference (for SB, MVPA and CRF) and dietary intake (for SB Participants). Greater increases in SB were associated with increases in cardiometabolic risks and greater decreases in MVPA were associated with greater increases in clustered cardiometabolic risks. Greater decreases in CRF were associated with more detrimental changes in clustered cardiometabolic risk and all individual components. It was concluded that a combination of decreasing SB and increasing MVPA, would result in improved CRF, and would likely be most beneficial towards reducing cardiometabolic risks.

Myers et al. (2015) reviewed the evidence supporting the premise that physical activity (PA) and CRF are independent risk factors for CVD. Further, Myers et al. also looked at the interplay between both PA and CRF and other CVD risk factors; more so, the impact CRF had on metabolic risk and obesity rates. Based on more than five decades of epidemiological studies, it was conclude that higher PA patterns and levels of CRF are associated with better health outcomes. The results from this study corresponded with exercise recommendations for adults and provide an opportunity for future research to investigate how various methodological approaches to implanting CRF in exercise protocols may affect performance measure and health outcomes.

2.3. Cardiovascular Training

Cardiovascular training has been proven to elicit benefits in cardiovascular function, muscle cell and fiber adaption, reduction of risk for cardiovascular disease, etc. While previous research on the specific details of how and why cardiovascular training affects the human body has been focused on single modality activities, contemporary research suggests that similar effects may be elicited by modifying variables like the frequency and intensity of cardiovascular training.

Agarwal (2012) reviewed the effects of various modes of cardiovascular training on cardiovascular diseases. Findings from this study suggested that various forms of cardiovascular training be feasible and effective for reducing CVD risk factors. Pugh et al. (2017), Chéilleachair et al. (2016), and Matsuo et al. (2014) examined the effects of various modes of resistance and cardiovascular training had on maximal aerobic capacity. Gormley et al. (2008) conducted research aimed at identifying whether various intensities of aerobic training differentially affected aerobic capacity as well as resting HR and resting blood pressure. Gillen et al. (2014) primarily studied the effects of HIIT as a mode of cardiovascular training to elicit cardiovascular improvements similar to that observed utilizing traditional methodological approaches.

Pugh et al. (2017) examined whether a single bout of concurrent resistance exercise (RE) and high-intensity interval training (HIIT) alters the satellite cell response following exercise compared to RE alone. Skovgaard (2018) defines type I or slow twitch muscle fibers as highly oxidative with the ability to facilitate aerobic (long duration) exercise, and type II or fast twitch muscle fibers as less oxidative with the ability to facilitate anaerobic (short duration) exercise. Pugh et al. (2017) found an increase in type-I-specific Pax7+ after both exercise trials. However, type-I-specific MyoD+ cell number increased after RE only. This provides evidence that utilizing a blended methodological approach to HIIT may potentially elicit improvements in type I and II muscle fiber capacity.

Chéilleachair et al. (2016) compared the effects of long slow distance training (LSD) to high-intensity interval training (HIIT) in nineteen well-trained rowers (endurance athletes). Participants were randomly assigned to a HIIT or LSD group. The LSD group completed 10 weekly aerobic sessions. The LSD sessions were comprised of The HIIT also comprised 10 weekly sessions: 8 aerobic and 2 HIIT. The HIIT sessions comprised 6-8 × 2.5 min intervals at 100% PPO with recovery time based on heart rate (HR) returning to 70% of participant's maximal heart rate. Results demonstrated that the HIIT produced greater improvement in 2000 m time trial performance than the LSD (effect size (ES) = 0.25) and greater improvements in VO2max (ES = 0.95, P = 0.035). While this study highlighted the benefits of HIIT on aerobic capacity, there is a need for research on the benefits of implementing cardiovascular training into a HIIT protocol for healthy adults looking to start or maintain physical activity.

Gormley et al. (2008) aimed to determine whether various intensities of aerobic training differentially affected aerobic capacity as well as resting HR and resting blood pressure (BP). The researchers found that when the volume of cardiovascular training is controlled, higher intensities of exercise are more effective for improving VO2max than lower intensities of exercise in healthy, young adults. Sixty-one healthy young adult subjects participated in this study and were randomly assigned to a moderate- (50% VO2 reserve (VO2R), vigorous (75% VO2R), near-maximal-intensity (95% VO2R), or a non-exercising control group. Intensity during exercise was controlled by having the subjects maintain target HR based on HR reserve and exercise volume was controlled across the three training groups by varying duration and frequency. Findings from this study discovered that VO2max significantly increased in all exercising groups by 7.2, 4.8, and 3.4 mL.min.kg in the near-maximal-, the vigorous-, and the moderate-intensity groups, respectively. This research was beneficial in identifying the relationship between three distinct types of cardiovascular training and cardiovascular health; which generates optimism for future research seeking to examine and produce similar findings. Although we did not control for HR like the previous author, due to similar study designs we anticipated similar improvements in VO2max.

Matsuo et al. (2014) compared the effects of time-efficient, low-volume interval exercises on cardiorespiratory capacity and left ventricular (LV) mass with traditional continuous exercise in sedentary adults. Forty-two young healthy but sedentary male subjects participated in an 8-week program that consisted of proctored workouts which were offered five times a week. Participants were randomly assigned to one of three exercise protocols: sprint interval training (SIT, 5 min, 100 kcal), high-intensity interval aerobic training (HIAT, 13 min, 180 kcal), and continuous aerobic training (CAT, 40 min, 360 kcal). Cardiorespiratory fitness (VO2max) and LV mass (3T-MRI) were measured pre-intervention and post-intervention. The researchers observed significant increases in V˙O2max in all three groups, with the HIAT group experiencing the greatest of the three. While traditional means for cardiovascular training elicited improvements in VO2max amongst other measures, findings from this study provided evidence that alternative forms of cardiovascular training may elicit significant outcomes for cardiorespiratory fitness. This is especially useful as we attempt to implement a novel methodological approach of plyometric and endurance training to elicit similar outcomes in our study.

Gillen et al. (2014) reviewed literature that suggested HIIT as a time-efficient exercise strategy to improve cardiorespiratory health. Alternate models of HIIT that produced similar adaptations to more demanding low-volume HIIT models and high-volume endurance-type training which were both ad hearable and time-efficient, were identified. Findings from this study revealed that "All out" HIIT models such as Wingate-type exercises were particularly effective in improving aerobic capacity, skeletal muscle oxidative capacity, exercise tolerance and markers of disease risk after only a few weeks in both healthy individuals and people with cardiometabolic disorders. However, maximal or supra-maximal intensity exercise may not be safe, tolerable or practical for many individuals. Being that our HIIT protocol incorporated an alternative methodological approach to high-volume endurance-type training, we expected to find similar improvements in aerobic capacity observed in other HIIT protocols.

2.4. Resistance Training

Resistance training has been proven to elicit improvements in cardiovascular function, muscle cell and fiber adaption, reduction of risk for cardiovascular disease, etc. While previous research on the specific details of how and why cardiovascular training affects the human body has been focused on single modality activities, contemporary research suggests the utilization of multi-modality activities may elicit similar affects.

Research on the effects of resistance training on the human body has primarily focused on the benefits for strength and power. Some of those studies (31,32) have observed the changes in body composition from resistance training programs, specifically increases in fat free mass. Although not a primary aim of our study, we anticipate improvements in body composition by implementing resistance training into our intervention. Sale (1988) postulated that strength performance depended not only on the quantity and quality of the involved muscles, but also upon the ability of the nervous system to appropriately activate the muscles. This literature reviewed studies that assessed muscle electromyography in cross-training and concluded that the specificity of (strength) resistance training causes neural adaptations associated with increased motor unit recruitment, firing patterns, and activation of prime mover muscles which yield increases in peak force and rate of force development. With this knowledge, we expect to observe improvements in strength as we implement a cross-training (multi-modal) approach to resistance training.

Kawamori & Haff (2004) also postulated that training loads utilized in resistance training protocols are some of the most important factors that determine the training stimuli and the consequent training adaptations. Their research showed that the use of different training loads elicited different training adaptations and further indicated the load- and velocity-specific adaptations in muscular-power development. Likewise, we utilized different training loads in our study in attempt to elicit positive training adaptations.

Gabriel et al. (2006) reviewed the neural adaptations in strength, with the goal of laying the foundations for practical applications in sports medicine and rehabilitation. Researchers in this study found that an increase in muscular strength without noticeable hypertrophy is the first line of evidence for neural involvement in acquisition of muscular strength. While this has obvious implications that training specific neural adaptations that elicit increases in muscular strength, motor unit synchronization, and firing patterns exist, it also raises a question about the alteration in body composition, specifically muscle mass, after participation in resistance training.

2.5. High Intensity Interval Training

High intensity interval training (HIIT) has been defined as a group of short intense exercises, separated by short rest periods or low-intensity exercises (Gillen & Gibala, 2014). HIIT protocols have been used by professional coaches and athletes for years as a part of overall training programs to improve athletic performance (Gibala et al., 2012). Hence, the primary application of HIIT protocols being associated with elite athletes for many years. Dr. Izumi Tabata initially studied the HIIT protocol to enhance physical fitness of Olympic sprint skaters, which was conducted on a cycle ergometer by completing 8 bouts of 20 seconds at 170% of VO2max, followed by 10 seconds rest periods (Tabata et al., 1996). Recently, HIIT has gained much attention in the scientific community, and has become one of the most popular types of exercise among fitness athletes. Accordingly, HIIT exercise has been reported as the top fitness trend worldwide for 2014, and also the second top fitness trend in 2015 (Williams & Kraemer, 2015). Recently, studies have shown that low-duration, high-intensity interval training involves significant physiological responses, including improved VO2max, strength, power, and body composition (Duffield et al., 2006).

The increasing interest in high intensity interval training has heightened the need for research examining the variations in training protocols and the potential benefits and risks of participating in such an exercise regimen. Tabata et el. (1996) compared the effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic and aerobic capacity. Anaerobic capacity is the maximal amount of adenosine triphosphate resynthesized via anaerobic metabolism (by the whole organism) during a specific mode of short-duration maximal exercise (Green, 1993). Aerobic capacity describes the functional capacity of the cardiorespiratory system, (the heart, lungs and blood vessels) in the presence of oxygen (Hebestreit, 2008). Tabata et al. (1996) recruited 14 male university students to participate in their study; assigning 7 of the participants to the endurance training group and the remaining 7 to the HIIT training group. The endurance training group completed 6 weeks of moderate-intensity endurance training utilizing a braked cycle ergometer for 60 minutes a day, 5 days a week, at 70% of their VO2max. The HIIT training group completed 6 weeks of exhaustive intermittent training consisting of seven to eight sets of 20 second exercise bouts, at an intensity of approximately 170% of their VO2max utilizing a braked cycle ergometer. After the training protocol, significant increases were reported for aerobic capacity in the endurance group, but anaerobic capacity did not increase significantly. However, significant increases in both anaerobic and aerobic capacity were reported for the HIIT group. The findings from Tabata et al. (1996) study indicated that HIIT interventions may elicit benefits in anaerobic and aerobic capacity, which measured pre and post-intervention.

In a similar study, Gibala et al. (2012) studied the benefits of low-volume HIIT in comparison to traditional endurance training. The Wingate test was the model of low-volume HIIT consisting of 30 seconds of cycling against a supra-maximal workload performed four- to-six times with ~ 4 minutes of rest between each bout. Results from this study demonstrated that as little as six sessions of this type of exercise resulted in superior physiological adaptations in healthy individuals and diseased populations despite a lower time commitment and reduced total exercise volume. However, while the HIIT protocol (Wingate test) utilized for this intervention was low-volume and time sensitive, workloads were completed at high intensities which may not be achievable by obese, physically inactive or other at-risk populations.

Prior related research documenting the benefits of high-intensity interval training has generated interest in the efficacy of specific forms of such training and heightened the need for further research. Williams et al. (2015) compared the effectiveness of kettlebell high-intensity interval training (KB-HIIT) and sprint interval cycling (SIC) for eight males between 20 and 23 years of age. In the KB-HIIT group, participants often performed exercises that required dynamic or complex movements, as many times as possible within an allotted amount of time. While this may have been a sufficient methodological approach for this demographic, transferability of this study design to at-risk populations may be considered a limitation. Participants completed a KB-HIIT session and a SIC session with 5-7 days of rest between each session. VO2max, respiratory exchange ratio (RER), tidal volume (TV), breathing frequency (f), minute ventilation (VE), caloric expenditure rate ($kcal \cdot min^{-1}$), heart rate (HR), and total caloric expenditure were compared between the KB-HIIT and SIC protocols A significant group effect, time effect, and group × time interaction were found for VO2max, RER, and TV, with VO2max being higher and TV and RER being lower in the KB-HIIT compared with the SIC. The results of this study suggested that KB-HIIT can be effective in stimulating cardiorespiratory and metabolic responses that could improve health and aerobic performance.

2.6. Body composition

The growth and development of interest in high-intensity interval training (HIIT) has heightened the need for scholarly research which examines its effect on body composition. The terms anthropometric measurements and body composition can be used interchangeably and are defined as, “the study of the human body in terms of the dimensions of bone, muscle, and adipose (fat) tissues” (19). Prior related research has documented significant improvements in body composition after participation in HIIT protocols (8).

2.6.1. The effects of HIIT on body composition

Bernard et al. (2002) and Giannaki et al. (2016) performed similar studies assessing the effects of HIIT on body composition and visceral adiposity. The Global Diabetes Community (57) suggests that visceral adiposity is, “body fat that is stored within the abdominal cavity and is therefore stored around a number of important internal organs such as the liver, pancreas and intestines. Visceral fat is sometimes referred to as 'active fat' because research has shown that this type of fat plays a distinctive and potentially dangerous role affecting how our hormones function. Storing higher amounts of visceral fat is associated with increased risks of a number of health problems including type 2 diabetes.”

Thirty nine healthy adults volunteered to participate in an eight-week intervention study conducted by Bernard et al. (2002). The control group was comprised of twenty three participants who performed regular gym training 4 days/week, and the remaining 16 participants engaged twice a week in HIIT and twice in regular gym training (HIIT-C group). Total body fat and visceral adiposity levels were calculated using bioelectrical impedance analysis. Both exercise programs were effective in reducing total body fat and visceral adiposity ($P<0.05$) and a between groups analysis revealed that HIIT-C resulted in a significantly greater reduction in both abdominal girth and visceral adiposity compared with conventional training ($P<0.05$). This study showed that both regular cardiovascular and resistance training are beneficial. However, participation in HIIT twice a week may elicit greater improvements in body composition.

Ouerghi et al. (2017) examined the effects of short high-intensity interval training (HIIT) on body composition in overweight/obese compared to normal-weight young men. Nine overweight/obese and nine normal-weight men (control group) aged 17 to 20 years underwent a HIIT program three times per week for eight weeks. The HIIT program resulted in small reductions in body mass (-1.62%, P=0.016, ES=0.11) and fat mass (-1.59%, P=0.021, ES=0.23) in obese, but not in normal-weight subjects. This study provided a methodological approach that was feasible for both healthy and obese participants, and concluded that HIIT may not be as effective in reducing body and fat mass in healthy subjects. However, it seems that future research could improve upon this study by designing a methodological approach which yields greater improvements in both measurements.

Similarly, Keating et al. (2014) assessed the effect of high intensity interval training (HIIT) versus continuous aerobic exercise training (CONT) or placebo (PLA) on body composition by randomized controlled design. Body composition was measured before and after 12 weeks of intervention in 38 previously inactive overweight adults. No differences were observed for trunk fat. There was however, a significant reduction in android fat percentage in CONT (2.7 ± 1.3%) and PLA (1.4 ± 0.8%) but not HIIT (increase of 0.8 ± 0.7%). Data from this study suggests that while HIIT may be a time-efficient strategy for eliciting comparable fitness benefits to traditional continuous exercise in inactive, overweight adults, it may not confer the same benefit to body fat levels as continuous exercise training.

2.7.1 The effects of HIIT on cardiorespiratory fitness

Hatle et al. (2014) compared the cardiovascular adaptations in groups completing 24 high-intensity aerobic interval training sessions for either three or eight weeks. Twenty-one healthy subjects completed 24 high-intensity training sessions for either eight weeks (moderate frequency, MF) or three weeks (high frequency, HF). In both groups, VO_{2max} was evaluated before training, at the 9th and 17th session and four days after the final (24th) training session. Four days after ending training the HF group showed no improvement (+3.0%, p=0.126), whereas the MF group reached their highest VO_{2max} with a 10.7% improvement. The HF group reached their highest VO_{2max} (6.1% increase) twelve days after ending training, compared to a concomitant reduction to 7.9% of VO_{2max} above baseline in the MF group. This study provides evidence that various durations of HIIT exercise can improve VO_{2max}. However, research aimed at investigating the effects of exercise duration, rather than intensity may be needed to further the understanding of HIIT.

Daussin et al. (2007) studied the effects of continuous endurance training (CT) versus interval training (IT) on exercise capacity. Ten recreationally healthy subjects participated in this study which consisted of two exercise sessions each week over an eight week period. Maximal oxygen uptake ($VO2_{max}$), cardiac output (Q_{max}) and maximal arteriovenous oxygen difference ($Da\text{-}vO2_{max}$) were obtained during before and after each training period. $VO2_{max}$ and Q_{max} increased only after IT (from 26.3 +/- 1.6 to 35.2 +/- 3.8 ml min$(^{-1})$ kg$(^{-1})$ and from 17.5 +/- 1.3 to 19.5 +/- 1.8 l min(-1)). $Da\text{-}vO2_{max}$ increased after both protocols (from 11.0 +/- 0.8 to 12.7 +/- 1.0 and from 11.0 +/- 0.8 to 12.1 +/- 1.0 ml 100 ml (-1), in CT and IT). These results suggest that adaptations in oxygen transport and utilization may be training-modality dependent. Furthermore, this study provided evidence that two IT exercise sessions each week for eight weeks is not only beneficial, but potentially elicits greater improvements in cardiorespiratory fitness when compared to CT.

Helgerud et al. 2007 compared the effects of aerobic endurance training at different intensities and with different methods matched on maximal oxygen uptake ($VO2_{max}$) and running economy (CR) were examined. Forty recreationally healthy male subjects were randomly assigned to one of four groups:1) long slow distance (70% maximal heart rate; HR_{max}); 2)lactate threshold (85% HR_{max}); 3) 15/15 interval running (15 s of running at 90-95% HR_{max} followed by 15 s of active resting at 70% HR_{max}); and 4) 4 x 4 min of interval running (4 min of running at 90-95% HR_{max} followed by 3 min of active resting at 70%HR_{max}). All four training protocols resulted in similar total oxygen consumption and were performed three days/week for eight weeks. High-intensity aerobic interval training resulted in significantly increased $VO2_{max}$ compared with long slow distance and lactate-threshold training intensities. The percentage increases for the 15/15 and 4 x 4 min groups were 5.5% and 7.2%, respectively, reflecting increases in $VO2_{max}$ from 60.5 to 64.4 mL ^{x} kg$^{(1)}$ ^{x} min$^{(1)}$ and 55.5 to 60.4 mL ^{x} kg$^{(1)}$ ^{x} min$^{(1)}$. It was concluded that, high-aerobic intensity endurance interval training is significantly more effective in improving $VO2_{max}$ than long slow distance training. Similar to the conclusion made by Daussin et al. (2007), this study provides further evidence for three HIIT exercise sessions each week for eight weeks eliciting (greater) improvements in $VO2_{max}$ when compared to traditional approaches to cardiovascular training. However, it may be useful for future research to examine the effects of combining plyometric exercises into cardiovascular training.

Ouerghi et al. (2017) examined the effects of short high-intensity interval training (HIIT) on physical performance in overweight/obese compared to normal-weight young men. Nine overweight/obese and nine normal-weight men (control group) aged 17 to 20 years underwent a HIIT program three times per week for eight weeks. Body composition, indices of aerobic [maximal aerobic velocity (MAV) and maximal oxygen uptake ($VO2_{max}$)] and anaerobic [squat jump (SJ), counter-movement jump (CMJ), five-jump test (FJT), 10-m and 30-m sprint] performances, as well as fasting plasma lipids, were assessed in the two groups at PRE and POST HIIT. MAV (+5.55%, P=0.005, ES=0.60 and +2.96%, P=0.009, ES=0.82), $VO2_{max}$ (+5.27%, P=0.006, ES=0.63 and +2.88%, P=0.009, ES=0.41), FJT (+3.63%, P=0.005, ES=0.28 and +2.94%, P=0.009, ES=0.52),

2.7.2. The effects of HIIT on power

Schoenmakers et al. (2016) evaluated the effects of HIIT and moderate-intensity continuous training (MICT) on the physiological capacity after 7 weeks of hand-cycling performance. Twenty four recreationally active men (22 +/- 2 years; 1.84 +/- 0.04 m; 79 +/- 10 kg) were matched on incremental hand-cycling pre-test performance (peakPO) and then randomly assigned to HIIT, MICT, or a non-training control group (CON, 3 x n = 8). Participants in HIIT completed 14 interval training sessions, performing 4 x 4 min intervals at 85% heart rate reserve (%HRR), and seven continuous training sessions at 55 %HRR (every 2nd training session of the week). Participants in MICT performed 21 training sessions of 30 min at 55 %HRR. After the intervention, changes in peak oxygen uptake (peakVO2) and peak power output (peakPO) were compared within and between HIIT, MICT and CON. Researchers in this study found that the average external training load per training session did not differ between MICT and HIIT (p = 0.713). Improvements after HIIT in peakVO2 (22.2 +/- 8.1%) and peakPO (47.1 +/- 20.7%) were significantly larger compared with MICT and CON. Improvements after MICT in peakVO2 (10.7 +/- 12.9%) and peakPO (32.2 +/- 8.1%) were higher compared to CON. Higher improvement after HIIT occurred despite training 22% less time than MICT and no significant changes were found in CON. This study provides further evidence that while both HIIT and MICT both elicit improvements in aerobic capacity and power, HIIT may cause greater improvements. This is especially important as performance measures in our study are aerobic capacity and power.

Ouerghi et al. (2017) examined the effects of short high-intensity interval training (HIIT) on physical performance in overweight/obese compared to normal-weight young men. Nine overweight/obese and nine normal-weight men (control group) aged 17 to 20 years underwent a HIIT program three times per week for eight weeks. Body composition, indices of aerobic (maximal aerobic velocity (MAV) and $VO2_{max}$) and anaerobic (squat jump (SJ), counter-movement jump (CMJ), five-jump test (FJT), 10-m and 30-m sprint) performances were assessed in the two groups at PRE and POST HIIT. SJ and CMJ significantly increased in overweight/obese and normal-weight groups, respectively and 30-m sprint time significantly decreased in both groups. Findings from this study provided proof that HIIT has the potential to improve measurements of power such as; the SJ and CMJ. For our study, these findings are significant as we attempt to elicit similar results with a similar (three times per week for eight weeks) methodological approach.

Herbert et al. (2017) investigated whether a six-week program of low-volume HIIT would improve peak power output (PPO) in seventeen male masters athletes (60 +/- 5 years). The intervention was comprised of nine HIIT sessions over six weeks. HIIT sessions involved six 30-s sprints at 40% PPO, interspersed with 3 min active recovery. Researchers found that absolute PPO and relative PPO increased from pre- to post-HIIT respectively. Altogether, this data indicates that HIIT protocols like this one have the potential to improve PPO.

2.7.3. The effects of HIIT on strength

Chéilleachair et al. (2016) compared the effects of long slow distance training (LSD) to high-intensity interval training (HIIT) in nineteen well-trained rowers. Results demonstrated that the HIIT produced greater improvement in 2000 m time trial performance than the LSD (effect size (ES) = 0.25). Moreover, the HIIT produced greater improvements in $VO2_{max}$ (ES = 0.95, P = 0.035) and power output at lactate threshold (WLT) (ES = 1.15, P = 0.008). Eight weeks of HIIT performed at 100% PPO is more effective than LSD in improving performance and aerobic characteristics in well-trained rowers. Three tests were performed before and after an 8-week training intervention: 2000 m time trial, seven-stage incremental step test to determine $VO2_{max}$, power output at $VO2_{max}$, peak power output (PPO), rowing economy and blood lactate indices and, seven-stroke power-output test to determine maximal power output (Wmax) and force (Fmax). The HIIT protocol consisted of 10 weekly sessions: 8 aerobic and 2 HIIT. The HIIT sessions consisted of 6-8 sets × 2.5 min intervals at 100% PPO with recovery time based on heart rate (HR) returning to 70% HR.

Androulakis-Korakakis et al. (2018) compared the effect of exercise modality, i.e., a traditional aerobic mode (AM) and strength mode (SM), during HIIT on aerobic fitness and strength. Sixteen well resistance-trained male participants, currently competing in powerlifting and strongman events, completed 8 weeks of approximately effort- and volume-matched HIIT in 2 groups: AM (cycling, n = 8) and SM (resistance training, n = 8). Aerobic fitness was measured as predicted VO2max using the YMCA 3 minute step test and strength as predicted 1 repetition maximum from a 4-6RM test using a leg extension. Both groups showed significant improvements in both strength and aerobic fitness. There was a significant between-group difference for aerobic fitness improvements favoring the AM group. There was no between-group difference for change in strength. In conclusion, while results from this study support improvements in strength and aerobic fitness irrespective of exercise modality (e.g., traditional aerobic and resistance training), future research should investigate the impact of exercise modality on upper body strength and power.

Ikezoe et al. (2017) compared the effects of low-load, higher-repetition training (LLHR) with those of high-load, lower-repetition training (HLLR) on muscle strength and mass in healthy young men. Fifteen healthy men (age, 23.1 +/- 2.6 years) were randomly assigned to one of the two groups: LLHR or HLLR group. Resistance training on knee extensor muscles was performed 3 days per week for 8 weeks. One-repetition maximum (1RM) strength, maximum isometric strength and thickness of the rectus femoris muscle were assessed every 2 weeks. The 8-week resistance training intervention significantly increased 1RM, maximum isometric muscle strength, and muscle thickness by 36.2%-40.9%, 24.0%-25.5%, and 11.3%-20.4%, at weeks 2, 4, and 8, respectively. Findings from this study suggest that alternate methods for resistance training can exert similar effects on muscle mass and characteristics as high-load training. Our research seeks to identify a relationship between, HIIT and utilizing loads for plyometric and endurance training to improve upper body strength.

2.7.4. The effects of HIIT on several performance measures

Giannaki et al. (2016) found that participation in eight weeks of combined group-based HIIT and conventional training can significantly improve several physical fitness parameters. Improvements were observed for body composition, strength, anaerobic capacity, power, and flexibility in this study. However, improvements in cardiorespiratory fitness levels were only observed for the group that completed a combination of HIIT and conventional training. In a similar study, Stöggl & Sperlich (2014) assigned participants to one of four groups: high-volume training (HVT), "threshold-training" (THR), high-intensity interval training (HIIT) and a combination of these aforementioned concepts known as polarized training (POL). The purpose of this study was to explore which of these four training concepts provides the greatest response on key components of endurance performance in well-trained endurance athletes. HIIT demonstrated improvements in VO2max with a 4.8 ± 5.6% increase,

Shepherd et al. (2015) investigated the improvements in VO2max, cardio-metabolic risk and psychological health in comparison to traditional moderate-intensity continuous training (MICT) after a 10 week intervention. Observed in this study, was a greater adherence to HITT, improved VO2max, insulin sensitivity, reduced abdominal fat mass, and induced favorable changes in blood lipids ($p<0.05$). HIT also induced beneficial effects on health perceptions, positive and negative affect, and subjective vitality ($p<0.05$). No differences in performance measures were observed between HITT and MICT groups in this study. This study supports the notion that HITT has the potential to improve several measures and is an exceptional alternative to traditional forms of exercise while dedicating less time to exercise.

2.8. Flexibility

Stretching, whether static or dynamic has been widely accepted as a means to improve flexibility. However, research conducted by Simão et al.(2011), Santos et al. (2010), and Leite et al. (2017) demonstrated that flexibility can be improved by adherence to a resistance training exercise regimen. In studies designed to examine the effects HIIT has on improving flexibility, Fatouros et al. (2006) and Giannaki et al. (2016) provided evidence that this novel approach to resistance and cardiovascular training shows promise for significantly improving measures of flexibility.

2.8.1. The effects of HIIT on flexibility

While limited research is available regarding the effect HIIT has on flexibility, Giannaki et al. (2016) found that participation in HIIT and conventional training significantly improved flexibility. Thirty nine healthy adults volunteered to participate in this eight-week intervention and were separated into two experimental groups. Twenty three participants performed regular gym training 4 days a week (C group), whereas the remaining 16 participants engaged twice a week in HIIT and twice in regular gym training (HIIT-C group) as the other group. It was concluded that both exercise protocols were effective in significantly improving flexibility, thus providing further evidence that participation in HITT has the potential to improve flexibility. However, it is unclear whether three sessions of HIIT a week would have the same effects on flexibility.

Leite et al. (2017) investigated the effects of six months of different resistance training volumes had on flexibility in young men. Forty-seven men were randomly divided into three training groups performing either one set (G1S), three sets (G3S), or five sets (G5S) of all exercises in a resistance training session or a control group (CG). The exercise order for all training groups was: bench press (BP), leg press (LEG), lat-pulldown (LAT), leg extension (LE), shoulder press (SP), leg curl (LC), biceps curl (BC), abdominal crunch lying on the floor (ABD), and triceps extension (TE). The control group (CG) did not participate in the training program. Training sessions were performed three days per week and flexibility in all groups was assessed pre- and post-training via Sit-and-Reach test and range of motion of 10 joints: shoulder flexion, extension, abduction and horizontal adduction, elbow flexion, hip flexion and extension, knee flexion, and trunk flexion and extension was assessed using goniometry. The results demonstrated significant differences pre- to post-training for the Sit-and-Reach test for all training groups; however, only the G5S group showed significant differences when compared to the CG (31.04 ± 5.94cm vs. 23.56 ± 6.76cm, respectively; $p < 0.05$). Of the ten joint movements measured, there were significant range of motion increases observed in shoulder flexion (G1S), shoulder extension (G3S), elbow flexion (G3S), and knee flexion (G3S) when compared to baseline measurements($p < 0.05$). Findings from this study implicate that resistance training at different volumes may improve flexibility by improving the range of motion in a joint.

Freitas & Mil-Homens (2015) conducted a high-intensity stretching intervention targeting the knee flexors with an 8-week intervention in order to observe the effects on biceps femoris long head (BF) architecture. Participants ($n = 5$) performed an average of 3 assisted-stretching sessions per week, whereas a control group ($n = 5$) did not perform stretching. The knee extension passive maximal range of motion (ROM), and BF fascicle length (FL), fascicle angle, and muscle thickness were assessed before and after the intervention. A significant increase was observed for FL (+12.3 mm, $p = 0.04$) and maximal ROM (+14.2°, $p = 0.04$) for the stretching group after the intervention, and no significant changes were observed for the control group in any parameter. It was concluded that an 8-week high-intensity stretching program efficiently increased the BF FL, as well as the knee extension maximal ROM. This study demonstrated that stretching intensity and duration may play an important role on MA adaptations. By utilizing dynamic and static stretches at various intensities and durations in conjunction with resistance training, we expect to observe improvements in flexibility.

CHAPTER III

METHODOLOGY

3.1. Participants

Ten recreationally active adults (mean ± SD: age = 40.70 ± 8.45 years, stature = 167.10 ± 8.47 cm, mass = 72.24 ± 17.20 kg) volunteered for the study. Participants were included in this study if they participated in regular exercise 3 times a week for 6 months. Participants were excluded if they had not consistently exercised three times a week for the past 6 months or had a musculoskeletal injury that had been diagnosed within that time. Participants were recruited with face to face personal intercept, and personal contacts with the permission of the director of employee wellness. Each participant was informed of the experimental risks involved with the research and all participants provided written informed consent to participate. The research design was approved by the institutional review board at Oklahoma State University.

3.2. Procedure

Participants visited the Seretean Wellness Center (SWC) on two separate occasions. The first day (Pre) included participants signing the informed consent. Next, participants had their height, and weight measured, as well as body fat percentages which were measured with skinfold calipers. Skinfolds (measure the thickness of skin, the thickness of skin can allow the researcher to calculate how much of the skin is composed of fat or muscle) measurements for men were assessed at their (chest, abdominals, and thigh) skinfold measurements for women were measured at the (tricep, above the hip bone, and thigh). After all aforementioned measurements were taken, participants were asked to put on a heart rate monitor (Polar FT4), and perform a 5 minute warm-up on a seated bike (recumbent bike). Resistance stayed at one, and participants were asked to keep revolutions per minute (RPM's) between 60- 80 RPM's. Following the warm-up, participants performed 3 maximum counter movement squat jumps (CMSJ) wearing a linear transducer. The transducer allowed for power and velocity to be recorded with each jump. After the vertical jump test, participants completed a Cooper 12 minute run/walk test on a treadmill. While the test was volitional based, it required participants to run/walk as far as possible in 12 minutes. After completing the Cooper 12 minute run/walk test, strength was assessed by utilizing the YMCA Bench Press Test. This test required participants to bench press a pre-determined weight (80lbs. for Men – 35lbs. for Women) at a pace of 60 beats per minute until they could no longer keep that pace. Lastly, flexibility was assessed by utilizing the Sit-and-Reach test. This test requires you to take your shoes off and sit on the floor with your legs extended and feet touching the front of the box. When ready, participants leaned forward as far as they could while pushing the ruler on the top of the box. This study was designed to last approximately 45 minutes. The time was divided as follows: Anthropometric measurements (ht, wt, BMI, 3-site skinfold), ~5 minutes warmup – 5 minutes, vertical jump – power assessment – ~2 minutes, cardiorespiratory fitness assessment with cooldown - ~17-20 minutes, strength assessment - ~3 minutes, flexibility assessment - ~3 minutes. Post-testing followed the same order as pre-testing.

3.3. Exercise protocols

The participants met with their personal trainer three times per week. Exercise regimens were the same for each participant, but were modifiable if need be. Each workout session followed a similar protocol which consisted of a 5-minute dynamic movement warm up consisting of stretches that activated large muscles groups (quadriceps, hamstrings, pectoralis, abdominus, etc.), increased their heart rate, and were similar to the exercises they would perform that day. After warming up, the exercise (HIIT) portion of the exercise regimen was ~45-50 minutes in duration and primarily consisted of plyometric and muscular endurance training. Following the completion of the exercise portion, participants performed static cool down stretches of large and small muscle groups in order to restore their range of motion.

3.4. Statistical Analyses

A one-way Repeated Measures ANOVA (time) was used for each dependent variable (Strength, distance, VO2max, body fat %, weight, CMSJ performance and flexibility). Independent samples t-tests with Bonferroni-corrections were used with either a significant interaction, or main effect was observed (collapsed across time). PASW software version 21.0 (SPSS Inc, Chicago, IL, USA) was used for all statistical analyses. An alpha level of $P \leq 0.05$ will be considered significant for all comparisons.

CHAPTER IV

RESULTS

4.1. Anthropometrics

Mean and *SD* for all anthropometric measurements are presented in Table 1. There were no significant or main effects observed for body weight ($p = 0.36$). Additionally, there were no significant differences or main effects observed for body fat percentage ($p = 1.68$).

4.2. Power

Mean and *SD* for all CMJ and power measurements are presented in Table 1. There were no significant differences or main effects observed for CMJ height ($p = 0.67$), average velocity ($p = 0.96$), and average power ($p = 0.62$). Additionally, there were no significant differences or main effects observed for CMJ peak velocity ($p = 0.68$) and peak power ($p = 0.96$).

4.3. Cardiorespiratory Fitness

Mean and *SD* for all cardiorespiratory fitness measurements are presented in Table 1. There were no significant differences or main effects observed for distance ($p = 0.18$) and $VO2_{max}$ ($p = 0.18$).

4.4. Strength

Mean and *SD* for all strength measurements are presented in Table 1. There were no significant differences or main effects observed for strength ($p = 0.07$).

4.5. Flexibility

Mean and *SD* for all flexibility measurements are presented in Table 1. There were no significant differences or main effects observed for flexibility ($p = 0.31$).

Figure 1. Body Weight

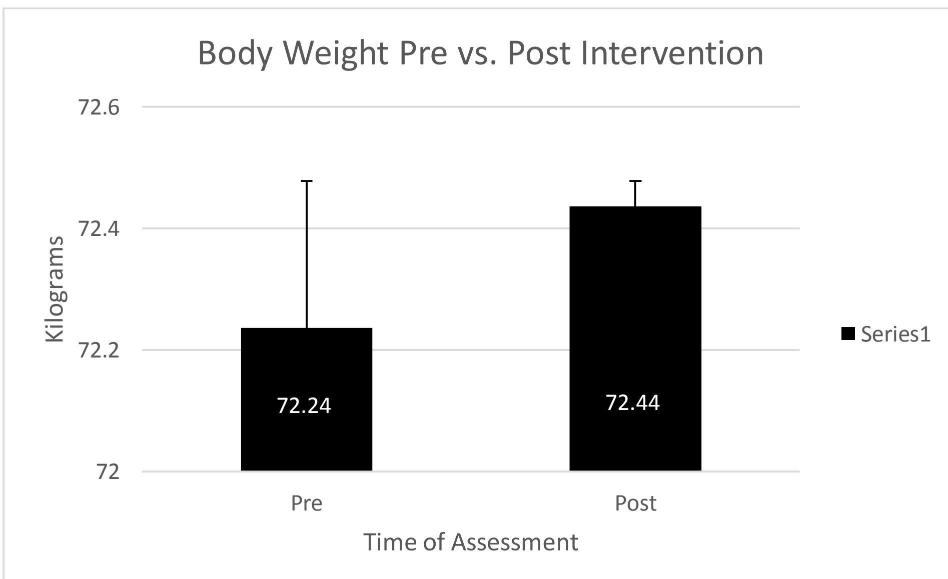

Figure 2. Body Composition

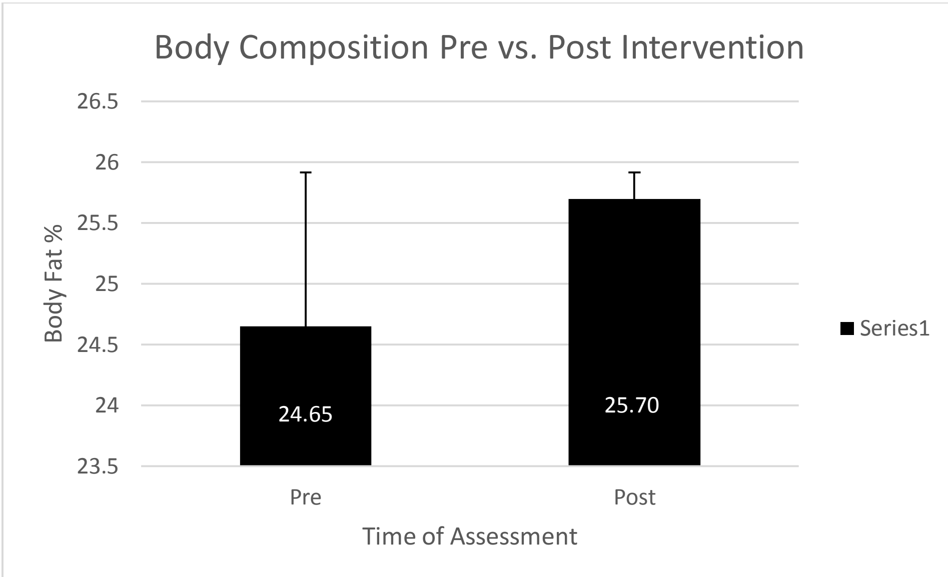

Figure 3. Distance

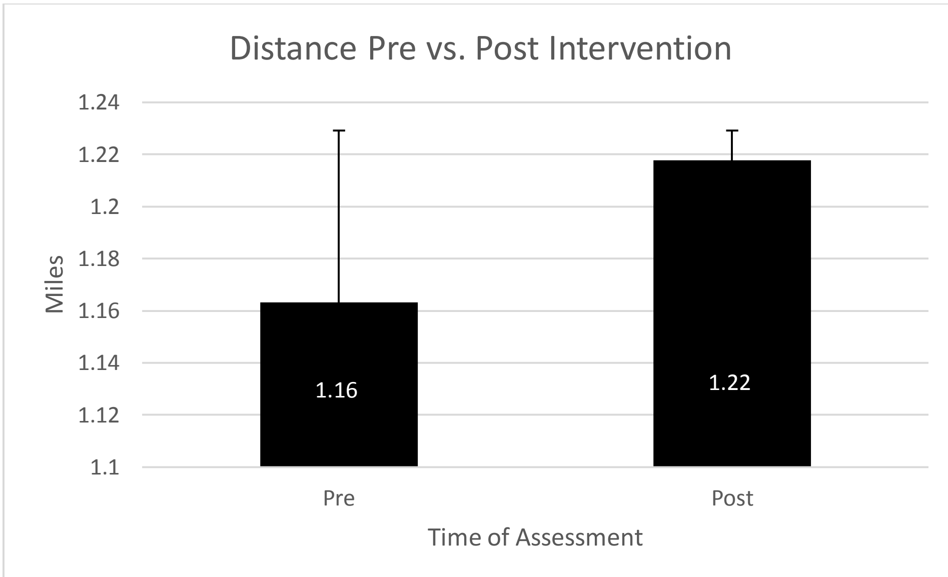

Figure 4. $VO2_{max}$

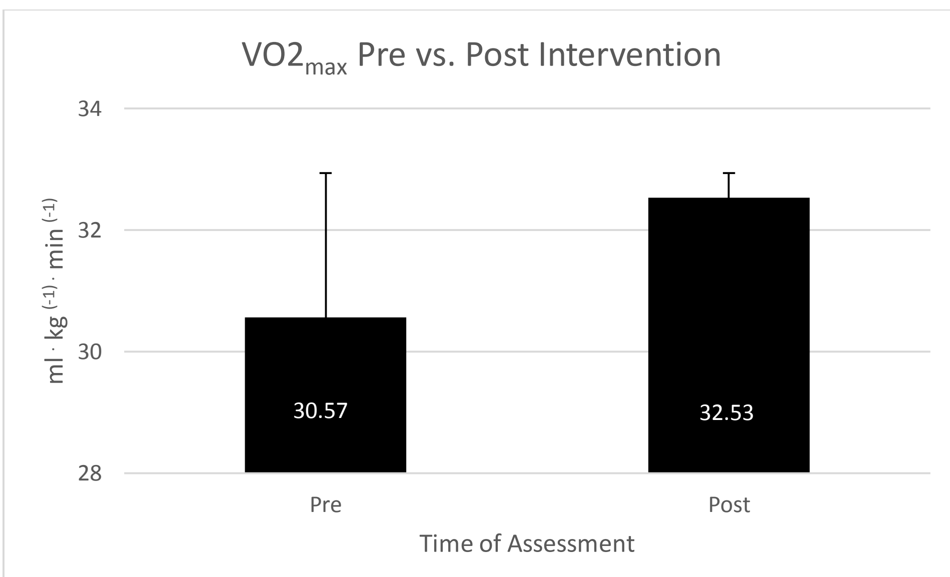

Figure 5. CMJ Height

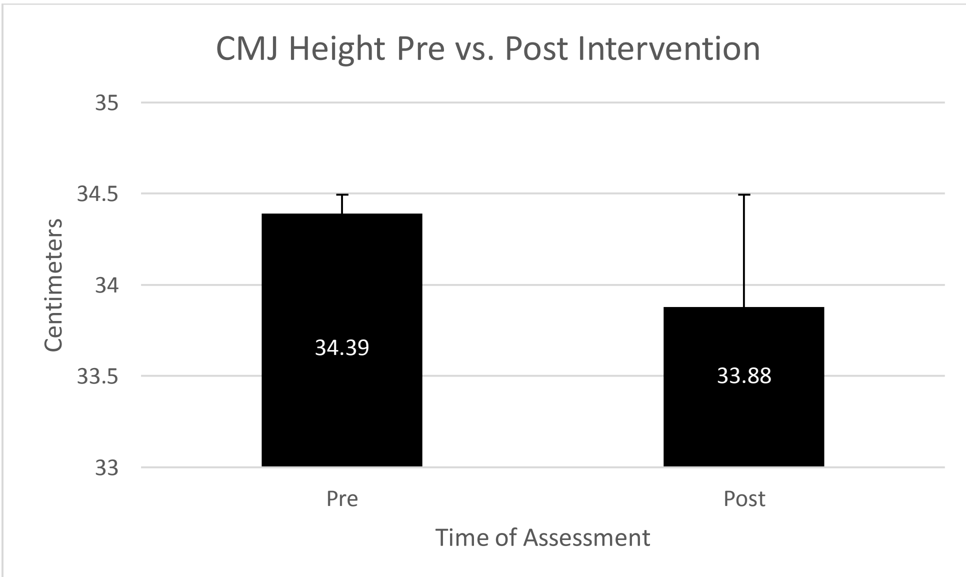

Figure 6. Peak Velocity

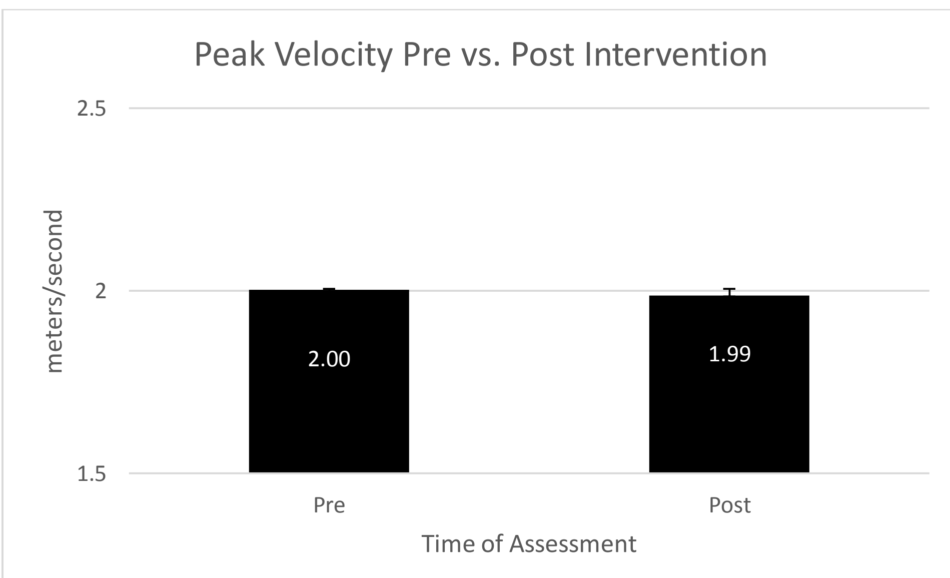

Figure 7. Peak Power

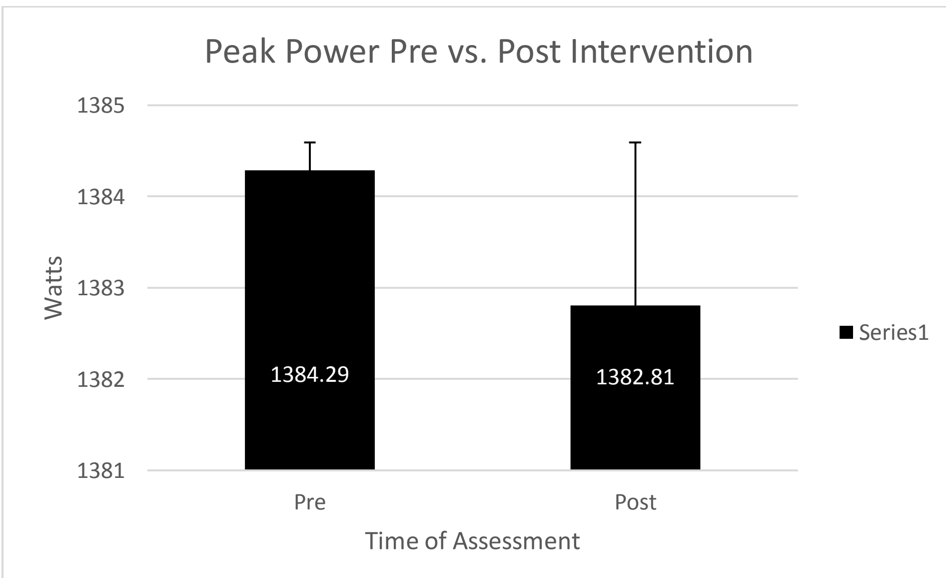

Figure 8. Average Velocity

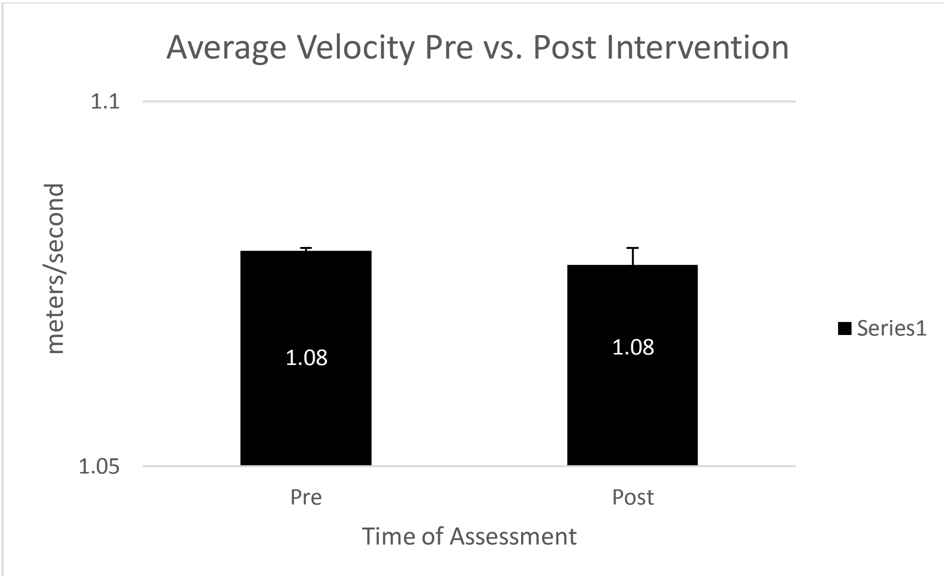

Figure 9. Average Power

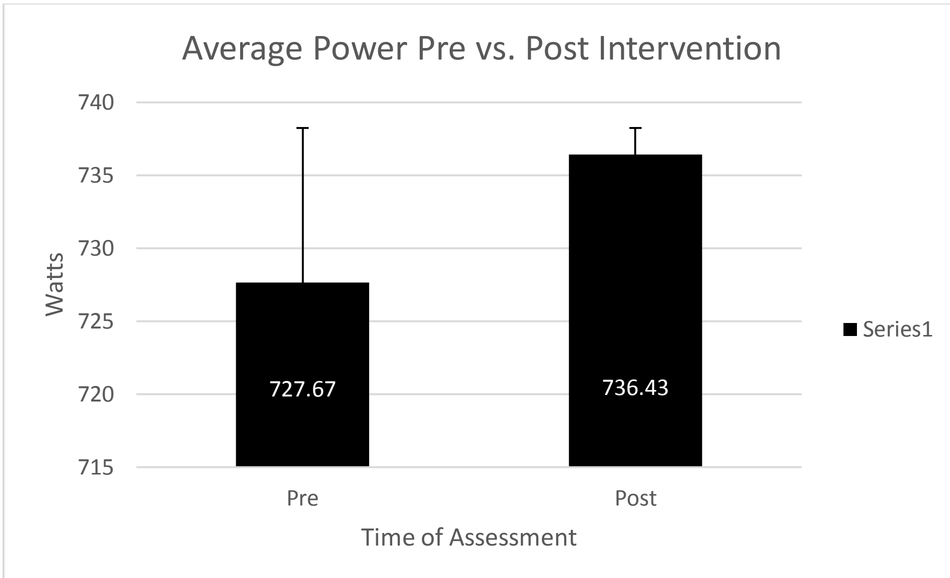

Figure 10. Strength

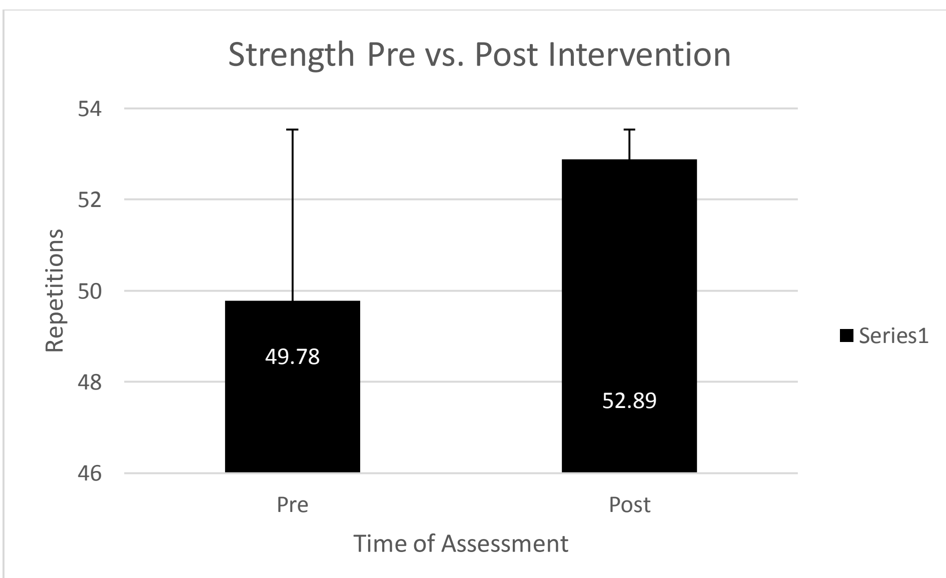

Figure 11. Flexibility

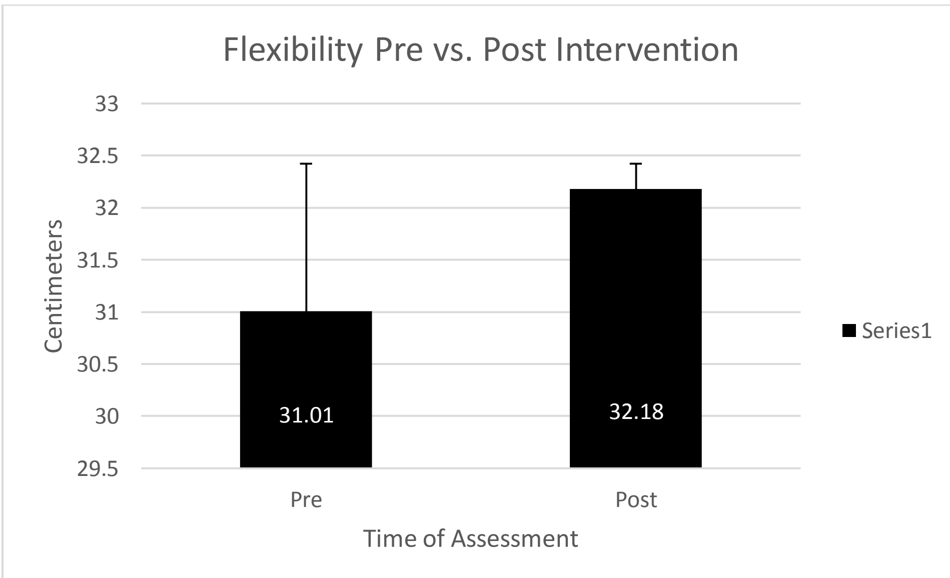

Table 1. Meand and *SD* for Intervention Measures

Table 1. Mean and *SD* for Intervention Measures

	Pre		Post	
	Mean	SD	Mean	SD
VO2max (ml/min/kg)	30.57	10.95	32.53	12.15
Distance (mi.)	1.16	0.30	1.22	0.34
AP (w)	727.67	215.07	736.43	257.00
AV (m/s)	1.08	0.19	1.08	0.21
PP (w)	1384.29	607.16	1382.81	571.74
PV (m/s)	2.00	0.60	1.97	0.52
CMJ height (cm)	34.39	4.14	33.88	3.06
BW (kg)	72.24	17.20	74.44	17.59
BF% (mm)	24.65	7.32	25.69	7.09
Flexibility (cm)	31.01	10.10	32.18	9.67
Strength (repetitions)	49.78	24.08	52.89	23.15

*V02MAX=Maximal aerobic capacity; AP=Average Power; AV=Average Velocity; PP=Peak Power; PV=Peak Velocity; BW=Body Weigh
BF%=Body Fat Percentage

CHAPTER V

DISCUSSION

The purpose of the present study was to see if cardiorespiratory fitness, power (force/time), strength (force/mass), body composition and flexibility could be positively affected after participation in an 8-week intervention based program. A secondary objective of this study was to see if the present program was effective in designing a HIIT exercise regimen, based on plyometric and endurance exercises that produced results similar to previous HIIT studies. Results from the present study indicated no significant differences for any variables after the 8-week training intervention.

While the present study did not see any differences in strength (YMCA Bench Press Test) after performing an 8 week intervention, the present findings are similar to results (Chéilleachair et al., 2016 and Androulakis-Korakakis et al., 2018). Chéilleachair et al., (2016) compared the effects of long slow distance training (LSD) to high-intensity interval training (HIIT) in nineteen well-trained rowers over eight weeks. The HIIT protocol consisted of 10 weekly sessions: eight aerobic and two HIIT. The HIIT sessions consisted of 6-8 × 2.5 min intervals at 100% PPO with recovery time based on heart rate (HR) returning to 70% HR. Strength (maximal force (Fmax)) was assessed with a seven-stroke power output test, improved slightly over the course of the study. Androulakis-Korakakis et al. (2018) compared the effect of exercise modality during HIIT on leg extension strength. Sixteen well resistance-trained male participants, currently competing in powerlifting and strongman events, completed eight weeks of approximately effort- and volume-matched HIIT. A 1RM for strength was predicted from a 4-6RM test using a leg extension test. In the future, research should be focused on further examining the relationship between HIIT and strength.

Additionally, the present study did not observe any positive increases in flexibility (Sit and Reach Test) post-program. The present study's findings are also similar to (Leite et al., 2017 and Fatouros et al. 2006) who also saw no differences in flexibility post-program. Over the course of six months, Leite et al. (2017) investigated the relationship between varied resistance training volumes and flexibility in forty-seven recreationally active men. Participants were randomly divided into three training groups performing either one set (G1S), three sets (G3S), or five sets (G5S) of all exercises in a resistance training session or a control group (CG). Similar to our study, hamstring flexibility was determined by the Sit-and-Reach test. When compared to the control group, only one group (G5S) demonstrated an increase in flexibility pre- to post-training for the Sit-and-Reach test. Fatouros et al. (2006) investigated the impact exercise intensity had on flexibility. Fifty-eight healthy but sedentary older men (65- 78 yrs) were randomly assigned to 1 of 4 groups: a control group (C, n = 10), a low-intensity resistance training group (LI, n = 14, 40% of 1 repetition maximum [1RM]), a moderate-intensity resistance training group (MI, n = 12, 60% of 1RM), or a high-intensity resistance training group (HI, n = 14, 80% of 1RM). Subjects in exercise groups followed a 3 day per week, whole-body (10 exercises, 3 sets per exercise) protocol for 24 weeks. Strength (bench and leg press 1RM) and range of motion in trunk, elbow, knee, shoulder, and hip joints were measured at baseline and during training and detraining. Flexibility demonstrated an intensity-dependent enhancement (3-12% in LI, 6-22% in

MI, and 8-28% in HI), and decreases were noticed in an intensity-dependent manner (90-110% in LI, 30-71% in MI, and 23-51% in HI). In the future, research should be aimed to further examine the relationship between HIIT and flexibility.

Similarly to (Hatle et al., 2014, Daussin et al., 2007, Helgerud et al., 2007) the present study did not see any differences in cardiovascular fitness (VO2max and Distance) after performing an 8 week intervention. While duration, program type, and participants were different by program, the aforementioned studies, as well as the present one, all saw similar results. Hatle et al. 2014 compared the VO2max of 21 recreationally active participants who were asked to complete 24 high-intensity aerobic interval training sessions for either three or eight weeks. In both groups (eight weeks/moderate frequency, MF) and (three weeks/high frequency, HF), VO_{2max} was evaluated before training, at the 9th and 17th session and four days after the final (24th) training session. Four days after the conclusion of the intervention, the HF group showed no improvement (+3.0%, p=0.126), whereas the MF group's VO_{2max} improved by 10.7%. Daussin et al. 2007 did not see any differences in $VO2_{max}$ after studying the effects of continuous endurance training (CT) versus interval training (IT) on exercise capacity in ten recreationally healthy participants. Participants completed two exercise sessions a week for eight weeks and after the intervention, $VO2_{max}$ only improved in the IT group (26.3 +/- 1.6 to 35.2 +/- 3.8 ml min(-1) kg(-1)). However, increases in $VO2_{max}$ were not significant for either the IT or CT groups. At different intensities and with different methods matched on $VO2_{max}$, Helgerud et al. 2007 compared the effects of aerobic endurance training in forty recreationally healthy male subjects over eight weeks. Participants were randomly assigned to one of four groups:1) long slow distance (70% maximal heart rate; HRmax); 2)lactate threshold (85% HRmax); 3) 15/15 interval running (15 s of running at 90-95% HRmax followed by 15 s of active resting at 70% HRmax); and 4) 4 x 4 min of interval running (4 min of running at 90-95% HRmax followed by 3 min of active resting at 70%HRmax). All four training protocols resulted in similar $VO2_{max}$ with no differences being observed between groups or from initial measurements. In the future, research should be focused on further examining the relationship between HIIT and cardiovascular fitness.

While the present study did not see any differences in body composition or body mass measurements after performing an 8 week intervention, similar results were also observed in previous studies (Ouerghi et al., 2017 and Keating et al., 2014). Ouerghi et al. 2017 examined the effects of short high-intensity interval training (HIIT) on body composition in overweight/obese compared to normal-weight young men. Nine overweight/obese and nine normal-weight men (control group) aged 17 to 20 years underwent a HIIT program three times a week for eight weeks. The HIIT program resulted in small reductions in body mass (-1.62%, P=0.016, ES=0.11) and fat mass (-1.59%, P=0.021, ES=0.23) in obese participants, and no change in normal-weight subjects. Likewise, Keating et al. (2014) assessed the effect of high intensity interval training (HIIT) versus continuous aerobic exercise training (CONT) or placebo (PLA) on body composition. Body composition was measured before and after 12 weeks of intervention in 38 previously inactive overweight adults. Slight reductions in trunk fat were observed in CONT by 3.1 ± 1.6% and in PLA by 1.1 ± 0.4%, but not in HIIT (increase of 0.7 ± 1.0%). Reductions in android fat percentage were also observed in CONT (2.7 ± 1.3%) and PLA (1.4 ± 0.8%) but not HIIT (increase of 0.8 ± 0.7%). Similarly, in the future, research should be focused on further examining the relationship between HIIT, body composition, and body mass.

Not unlike other studies, the present investigation has limitations. The sample size of participants and absence of a control group are limitations that cannot be overlooked. The present investigation hoped to have at least 10 more participants. A larger sample size could have allowed for a more robust total population and could have helped provide researchers more information on the participants and the effectiveness of the intervention. Additionally, a control group would have provided researchers information to compare differences between participants in our study and a sample who continued recreational exercise. Furthermore, another limitation of this study was the training status of participants. While the inclusion principle required participants to be exercising at least three times a week for six months, researchers did not control for exercise that participants partook in outside of our intervention. Several participants from our sample were endurance or strength athletes and participated in additional exercise in conjunction with our intervention. There is a chance that additional exercise may have delayed or inhibited adaptions to our intervention. While participants were recreationally active, our HIIT intervention was demanding in the aspect that it often required participants to perform as many repetitions of a movement as possible within an allotted amount of time. Due to these high demands, we believe that participant motivation may have been a limitation to our study. Low participant motivation may have also contributed to the findings observed in this study.

Due to the findings of this study, more research will need to be performed to find a relationship between plyometric and endurance based HIIT programs on anthropometric and performance based measurements (body composition, cardiorespiratory fitness, power, strength and flexibility). Future studies should involve a sample of participants who are not currently active, and provide an adjusted HIIT protocol. Additionally, future studies should investigate the use of a variety of performance measurements in conjunction with those outlined in this study to see if other differences are observed.

Our pilot study observed the effects of an eight-to-nine week plyometric and endurance based HIIT intervention on body composition, cardiorespiratory fitness, power, strength and flexibility, collectively. While there were no significant findings or any main affects ($p > 0.05$) were observed, this study provided the first few steps to exploring how HIIT impacts several performance measures collectively. By accounting for limitations previously mentioned in this study, it is possible that future research may produce significant findings.

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APPENDICES

Oklahoma State University Institutional Review Board

Date:	Monday, July 24, 2017	**Protocol Expires: 6/11/2018**
IRB Application No:	ED1756	
Proposal Title:	Changes in cardiorespiratory fitness, power, strength, and flexibility after participation in an 8 week intervention based program.	
Reviewed and Processed as:	Expedited **Modification**	

Status Recommended by Reviewer(s) **Approved**

Principal Investigator(s):

Quincy Johnson	Eric Conchola	Douglas Smith
	180 Colvin Center	180 CRC
Stillwater, OK 74078	Stillwater, OK 74078	Stillwater, OK 74078

The requested modification to this IRB protocol has been approved. Please note that the original expiration date of the protocol has not changed. The IRB office MUST be notified in writing when a project is complete. All approved projects are subject to monitoring by the IRB.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

The reviewer(s) had these comments:

Mod to use pre and post data from Summer 2017 S.W.E.A.T. participants. Consent will be obtained during the post-testing.

Signature :

Hugh Crethar, Chair, Institutional Review Board

Monday, July 24, 2017
Date

ADULT CONSENT FORM

OKLAHOMA STATE UNIVERSITY

PROJECT TITLE: Changes in cardiorespiratory fitness, power, strength, and flexibility after participation in a 10-16 week HIIT based program.

INVESTIGATORS: Quincy Johnson, B.S. – Oklahoma State University
Doug B. Smith, PhD, – Oklahoma State University
Eric Conchola, PhD, – Oklahoma State University

PURPOSE:
The purpose of this study is to see if cardiorespiratory fitness, power, strength, body composition and flexibility can be positively affected after participation in a 10-16 week high intensity interval training (HIIT) based program.

Participant Approval:
We are seeking your approval to use your pre and post testing information for Quincy Johnsons Master's Thesis. All study data entered into statistical analyses and publication reports will have no identification to participants. Only mean (average) values will be reported.

BENEFITS OF PARTICIPATION:
Findings from this study can allow researchers and clinicians a physiological profile how anthropometric, anaerobic and aerobic profiles may change after completing a structured 8-week strength and conditioning exercise protocol.

CONFIDENTIALITY:
Confidentiality will be maintained by coding all information with individual identification numbers. The master list will be kept in a locked file cabinet in the co-investigators (Eric Conchola) office. Only Eric Conchola and the Oklahoma State University Institutional Review Board (IRB) will have access to the database containing study information. No individual or group other than the research team will be given information, unless specifically requested by the IRB. All primary data sources will be kept in a file cabinet in the co-investigators office 005AE; the door to the co-investigators office will be locked at all times the co-investigator is not in their office.

CONTACTS :
This study has been reviewed and approved by the Oklahoma State University Review Board (IRB). If you have questions about the research project you may contact Quincy Johnson, B.S.,(405) 308-1055. quincy.johnson@okstate.edu, Eric Conchola Ph.D., at eric.conchola@okstate.edu and Doug Smith, Ph.D at doug.smith@okstate.edu
If you have questions about your rights as a research volunteer, you may contact Dr. Hugh Crethar IRB Chair 223 Scott Hall, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu

CONSENT DOCUMENTATION:
I have been fully informed about the procedures listed here. I am aware of what I will be asked to do and of the benefits of my participation. I also understand the following statements:
I affirm that I am 18 years of age or older.

Preface the signature lines with the following statement (expand if appropriate):
I have read and fully understand this consent form. I sign it freely and voluntarily. A copy of this form will be given to me. I hereby give permission for my participation in this study.

____ _________________________

Signature of Participant Date

I certify that I have personally explained this document before requesting that the participant sign it.

____ _________________________

Signature of Researcher Date

VITA

Quincy Rashad Johnson

Candidate for the Degree of

Master of Science

Thesis: CHANGES IN CARDIORESPIRATORY FITNESS, POWER, STRENGTH, AND FLEXIBILITY AFTER PARTICIPATION IN A SHORT 8-9 WEEK INTERVENTION BASED PROGRAM

Major Field: Health and Human Performance

Academic Qualifications

Master of Science in Health and Human Performance May 2018
Oklahoma State University - Stillwater, Oklahoma

Bachelor of Arts in Exercise Science May 2016
Midland University, Fremont, NE

Professional Appointments – Academia

TRIO-SSS - Graduate Teaching Assistant Fall 2017- Spring 2018
Oklahoma State University - Stillwater, Oklahoma

- Assist in developing curricula for study skills, time management, and financial literacy workshops
- Develop distance-based learning opportunities for students.

Professional Appointments – Field Experience

Dir. of Strength and Conditioning – OSU Police Department Winter 2016
Oklahoma State University - Stillwater, Oklahoma

- Develop and implement specific strength and conditioning programming beneficial for law enforcement professionals
- Coach and demonstrate proper and safe core and power lifts, as well as plyometric techniques.

Founder of Midland University Powerlifting Summer 2015
Midland University - Fremont, Nebraska

- Establish a platform for student-athletes to pursue an education while participating in university funded athletics.

Professional Memberships
National Strength and Conditioning Association