The Effects of High-Load Versus Low-Load Resistance Training on Isokinetic Knee Extensor and Flexor Peak Power, Vastus Intermedius, and Vastus Lateralis Muscle Thickness in Untrained Overweight and Obese Adults

by

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ABSTRACT

Sedentary behavior and excessive weight gain have been proven to deteriorate many characteristics of muscle. Low muscular power and mass with excess fat mass are risk factors for a multitude of chronic conditions and functional disabilities. Resistance training (RT) has long been accepted as a rehabilitative method of maintaining or enhancing muscular performance and composition. There are various methods of determining lower extremity muscular power; however, isokinetic dynamometry has emerged as one of the most accurate and reliable methods in clinical and research settings. Likewise, various methods exist for determining muscle thickness; however, many of those methods are expensive and can expose individuals to radiation. Ultrasonography has emerged as an accurate and reliable alternative to measuring lower extremity muscle thickness. The objective of this study was to assess the effects of high-load/low-volume (HLLV) and low-load/high-volume (LLHV) RT on isokinetic knee extensor and flexor peak power in sedentary, RT naïve, overweight or obese men and women (Body Mass Index ≥ 25 kg/m2). Twenty-one subjects (n = 21) completed this study and were randomized into one of the following groups: control, a HLLV group that performed three sets of 5 repetitions for all exercises until volitional fatigue and LLHV which performed three sets of 15 repetitions for all exercises until volitional fatigue. Subjects randomized to the RT groups performed full-body exercises routines on three non-consecutive days per week. Changes in isokinetic knee extensor and flexor peak power, quadriceps ultrasound muscle thickness, and right leg segment of dual energy X-ray absorptiometry (DEXA) scans were measured before and after the 12-week RT intervention. There were no significant differences found in group, time or, group by time interactions for knee extensor and flexor peak power using isokinetic dynamometry. Other than a group interaction for vastus intermedius muscle thickness (P=0.008), no significant interactions or differences were observed for any of the other variables tested. Based on the results of this study, neither high- nor low-load RT resulted in significant differences between intervention groups in peak power of the knee extensors and flexor, muscle thickness changes of the vastus intermedius and vastus lateralis and, in the right lower extremity segmented body composition measures using DEXA.

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TABLE OF CONTENTS

Page

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Overview

Physical inactivity and sedentary behavior represent a significant health problem in the United States. Approximately 86% of the United States population achieves less than the U.S. Government and World Health Organization (WHO) guidelines on daily physical activity for health (F. W. Booth, Roberts, Thyfault, Ruegsegger, & Toedebusch, 2017). Overwhelming evidence indicates that physical inactivity and lack of exercise can accelerate the development of chronic diseases. In contrast, there is an abundance of evidence that proves physical activity and exercise acts as rehabilitative/preventative treatment from inactivity-caused dysfunctions by increasing muscular power, strength, mass and functions (F. W. Booth, Roberts, & Laye, 2012).

In 2013 the American Medical Association (AMA) recognized obesity as a chronic disease. Between 2017-2018, the age-adjusted prevalence of obesity was 42.4%, or 140 million of the 331 million people living within the United States (Hales, Carroll, Fryar and Ogden, 2020). Obesity is dangerous chronic condition because of its direct association with other chronic diseases and impaired functional capabilities (F. W. Booth et al., 2012; Capodaglio et al., 2010). Overweight and obese adults who are physically inactive can display low muscular strength relative to lean mass and pose a higher risk for injury, hospitalization, morbidity, and mortality (F. W. Booth et al., 2012; Capodaglio et al., 2010).

Excess weight imposes abnormal mechanics on body movements, which could account for the high incidence of musculoskeletal disorders within obese populations

(Capodaglio et al., 2010). Additionally, excess fat mass in combination with physical inactivity can accelerate the loss of muscular strength, power, mass and function (Anton, Karabetian, Naugle, & Buford, 2013; F. W. Booth et al., 2012). Skeletal muscle is vital for survival and acts as a fundamental component of independent locomotion as well as, whole-body metabolic health (Mrowka & Westphal, 2018). Without adequate muscle mass, strength and function, the prevalence of chronic disease increases in addition to the risk of injury (Mrowka et al. 2018).

By the age of 50, healthy, non-disabled humans lose about 10% of their muscle mass and this process continues as individuals lose an additional 1% of muscle mass every year thereafter (Marcell, 2003). Although the loss of muscle qualities is inevitable with aging, research has demonstrated that maintenance strategies such as aerobic, resistance, flexibility and, neuromuscular training may counteract the detrimental effects of physical inactivity (Garber et al., 2011).

A critical component of independent healthy living is the ability to move without assistance or risking injury. Overweight or obese and physically inactive adults can experience a reduction in muscle strength per unit of muscle mass, dysfunction in individual muscle fiber contractile properties and, alterations in neuromuscular function (Anton et al., 2013; F. W. Booth et al., 2012; Tomlinson, Erskine, Morse, Winwood, & Onambélé-Pearson, 2016). Physically inactive adults increase the rate at which muscular power and mass are lost compared to muscular strength (Reid & Fielding, 2012). A review article by Reid and Fielding (2012) stated that “muscle power is a more discriminant predictor of functional performance in older adults than muscle strength.” Therefore, it is important to develop and implement strategies that can maintain or improve skeletal muscle power in overweight and obese adults. Thus, reducing the risk of injuries, hospitalizations, morbidity, mortality and ultimately enhancing the functional performance of ageing adults. Current literature on skeletal muscle power in physically inactive overweight or obese adults is very limited. Further research is required to understand the effects of different exercise treatment methods on skeletal muscle power in overweight/obese physically inactive adults.

The American College of Sports Medicine (ACSM) recommends adults participate in resistance training (RT) at least 2-3 days per week with 6-8 exercises to maintain or improve major muscle groups (American College of Sports, Riebe, Ehrman, Liguori, & Magal, 2018). Each exercise should consist of 2-4 sets of 8-12 repetitions at an intensity between 60-80% of an individual's 1-repetition maximum (1RM) (American College of Sports et al., 2018). Numerous studies have examined high intensity RT (>85% 1RM) and its effects on muscular power and strength; however, the majority of these studies focus on athletes and experienced exercises (Dinyer et al., 2019; Lasevicius et al., 2019; B. J. Schoenfeld, Grgic, Ogborn, & Krieger, 2017). Currently, the literature on high-load RT and its effects on RT naïve individuals is insufficient. Therefore, further research is required on the effects of high-load/low-volume (HLLV) RT on muscular power, strength, and mass in physically inactive, RT naïve, overweight or obese adults.

Overwhelming research indicates that a large portion of the U.S. is currently considered physically inactive and overweight or obese (F. W. Booth et al., 2017). Based on the information provided it is evident that physical inactivity and excessive fat-mass can hinder muscular power, strength, mass and function which play pivotal roles in functional movement, metabolic processes, prevention of injury, and chronic diseases (F.

W. Booth et al., 2012; Carlson, Adams, Yang, & Fulton, 2018). Impaired muscular performance and body composition increases the prevalence of many chronic diseases (Anton et al., 2013; F. W. Booth et al., 2012; Choi, 2016; Johnson Stoklossa et al., 2017). Thus, additional research is required regarding RT interventions and their effects on muscular power, body composition, and functional well-being, in individuals who are considered RT naïve, sedentary, overweight, and/or obese. For all the reasons stated in the previous sections, it is believed that research involving proper high-load/low-volume (HLLV) (<5RM) and low-load/high-volume (LLHV) (<15RM) RT interventions on untrained overweight and obese individuals will display significant results regarding muscular power and hypertrophy. To my knowledge, there is no research focused on comparing the differences in isokinetic knee extensor and flexor peak power, right quadriceps muscular thickness, and how these outcomes correlate with the right leg segment of DEXA scans after completing two different RT interventions using different RT intensities.

Purpose

The purpose of this study is to determine whether there is a difference between high-load/low-volume and low-load/high-volume resistance training on peak power outputs of the knee extensors and flexors of RT naïve overweight and obese individuals. Furthermore, this study will also compare differences in the right thigh region using ultrasonography imaging measures of muscle thickness (MT) following either a HLLV or LLHV RT intervention. Finally, this study will distinguish a correlation between quadriceps muscle thickness and the right leg segment of DEXA scans.

Aims & Hypothesis

Primary Aim: The primary aim of this study is to asses and compare dynamometer isokinetic peak power output in the knee extensors and flexors of RT naïve overweight individuals before and, following a 12-week high-load/low volume (HLLV) or low-load/high volume (LLHV) resistance training (RT) intervention as compared to a control group.

Primary Hypothesis: Our primary hypothesis is that the HLLV group will have greater isokinetic knee extensor and flexor peak power (PP) outputs compared to the LLHV group, which will be greater than control.

Secondary Aim: The secondary aim of this study is to analyze quantitative muscular thickness changes in the vastus intermedius (VI) combined with vastus lateralis (VL) by using musculoskeletal ultrasound imaging (MSK) and comparing groups before, and after undergoing either 12-week RT intervention as compared to a control group.

Secondary Hypothesis: We hypothesize that the analysis of VIVL muscle thickness using MSK ultrasound imaging will show greater quantitative changes in the LLHV group which will be greater than the HLLV group, which will be greater than control.

Tertiary Aim: Our final aim is to correlate the quantitative changes in ultrasound muscle thickness measures to the right lower extremity segment of dual-energy x-ray absorptiometry (DEXA) scans.

Tertiary Hypothesis: Our final hypothesis is that the quantitative changes in VIVL ultrasound muscle thickness measures will be positively correlated to the right lower extremity segment of DEXA scans. If we find no effect, we shall reject the hypothesis and claim null, such that, there is no significant difference between HLLV and LLHV resistance training in physically inactive, RT naïve, overweight or obese adults.

CHAPTER 2

REVIEW OF LITERATURE

Resistance Training and Chronic Disease

A review article by F. W. Booth et al. (2012) explored the association between lack of exercise/physical activity with various chronic conditions. F. W. Booth et al. (2012) stated that physical inactivity and sedentary behavior can lead to accelerated biological ageing, premature death, low cardiorespiratory fitness, hypertension, metabolic syndrome, obesity, sarcopenia, type 2 diabetes and various other chronic and fatal conditions. Exercise strategies, specifically, resistance training (RT) is supported by literature and is considered a powerful method to delay, or even counteract the effects of physical inactivity, excessive weight gain and ageing (Garber et al., 2011; McLeod, Stokes, & Phillips, 2019; Peterson, Sen, & Gordon, 2011).

Resistance training (RT) has long been accepted as a means for developing and maintaining muscular strength, endurance, power, and muscle mass. The beneficial relationship between RT, health factors, and chronic disease is relatively new. Before 1990, RT was not a part of the recommended guidelines for exercise training and rehabilitation for either the American Heart Association (AHA) or the American College of Sports Medicine (ACSM) (Pollock & Froelicher, 1990). In 1990, the ACSM acknowledged that RT is beneficial and a significant component of a comprehensive fitness program for healthy adults of all ages (Pollock & Froelicher, 1990).

Current Resistance Training Guidelines – The current resistance training guidelines set forth by the ACSM specify that improvements and maintenance of muscular fitness can be attained by consistently practicing a well-rounded RT regimen (American College of Sports et al., 2018). The ACSM recommends that individuals who focus on "general" or "overall" muscular fitness for the associated health benefits should train each major muscle group 2-3 days per week. Additionally, each RT session should consist of 6-8 exercises utilizing 2-4 sets of 8-12 repetitions between 60-70% 1RM for novice to intermediate exercisers. The ACSM's RT recommendations have shown to increase levels of muscular strength, endurance, power, and functionality (Cholewa et al., 2018; Dinyer et al., 2019; Fry, 2004; Goto et al., 2004). In addition, individuals who regularly participate in RT have shown to have a significantly lower risk of developing functional limitations, nonfatal diseases and, ultimately, display a lower risk of all-cause mortality (F. W. Booth et al., 2012; Peterson et al., 2011). The RT recommendations for optimal muscular health and strength provided by the ACSM are appropriate for men and women of virtually all ages (Garber et al., 2011).

Evidence indicates that high-load/low-volume (HLLV) RT (>80% 1RM) performed to volitional fatigue maximizes the development of muscular strength and power (Kawamori & Haff, 2004). Whereas, low-load/high-volume (LLHV) RT (<80% 1RM), performed until volitional fatigue, maximizes muscular hypertrophy (Garber et al., 2011; Brad J. Schoenfeld, 2010). However, the recommendations to maximize muscular power are still unclear, especially in RT naïve, physically inactive, overweight or obese adults. Studies in the past have indicated that the risk of accidental falls, bone fractures, and increased hospitalizations, are more closely related to a decline in muscular power rather than strength (Reid and Fielding, 2012). It is suggested that RT for inexperienced and frail individuals should emphasize the development of power to reduce the risk of injury and hospitalization.

Obesity - Adipose tissue represents the largest energy depot within the human body (Choe, Huh, Hwang, Kim, & Kim, 2016). Increasing amounts of people exhibit excessive fat deposition in adipose tissue leading to health complications and ultimately, obesity. Obesity is a multifactorial chronic disease with both adverse health effects and economic implications. According to the Heymsfield and Wadden (2017) obesity is defined as "weight that is higher than what is considered as a healthy weight for a given height."

Obesity is clinically classified using body mass index (BMI) as a tool. BMI is used by taking an individual's weight in kilograms and dividing it by height in meters squared (BMI = weight (kg)/height (m_2)). Using this calculation, specific ranges have been established and these ranges assist in the determination of an individual's health or risk of morbidity. If an individual's BMI is less than 18.5, it falls within the underweight range. A BMI between 18.5 to 24.9, it falls within the normal range. An individual's BMI between 25.0 to 29.9, it falls within the overweight range. Finally, if and individual has a BMI of 30.0 or higher, it falls within the obese range. Additionally, obesity is frequently subdivided into categories or "classes." Class I falls between a BMI range of 30 to 34.9. Class II is between a BMI range of 35 to 39.9. Finally, a BMI of 40 or higher is categorized as Class III. In addition, Class III obesity is sometimes categorized as "extreme" or "severe" obesity (Johnson Stoklossa et al., 2017).

Between 2017 and 2018, the age-adjusted prevalence of obesity in adults living in the U.S. was 42.4% (Hales et al., 2020). In addition, there were no significant differences between men and women among all adults or by age group (Hales et al., 2020). Regarding severe obesity, age-adjusted prevalence of severe obesity in adults within the U.S. was 9.2% and was higher in women than in men (Hales et al., 2020). The prevalence of severe obesity was highest among adults aged between 40 and 59, compared with other age groups. The medical cost for people who are considered obese (>30 BMI) was estimated to be $1429 higher per year than those of normal healthy weight (Finkelstein, Trogdon, Cohen, & Dietz, 2009).

Obesity's pathogenesis is multi-factorial and complex. The onset of obesity involves environmental factors as well as, socio-cultural, physiological, medical, behavioral, genetic, epigenetic and numerous others (Heymsfield & Wadden, 2017). Each of these factors contribute to the causation as well as, persistence of obesity (Heymsfield & Wadden, 2017). The main mechanisms involved in energy balance are energy intake and energy expenditure. Therefore, two parallel discussions revolve around the pathophysiology of obesity. The first discussion involves obesity from an energetic standpoint, and the second involves obesity from a nutritional standpoint. Within this literature review, the focus will mainly involve energetics because there is considerable consensus regarding the mechanisms of energy balance regulation, whereas there is confusion and controversy regarding optimal nutrient composition (Carneiro et al., 2016).

Energy expenditure is a significant determining factor of energy balance and body composition. Abundant and compelling literature supports the existence of a homeostatic system which dynamically adjusts energy intake and energy expenditure to promote stability of fat mass (Schwartz et al., 2017). This regulation or “defense” of adiposity is dependent on observations where individual adult body weight is notably stable to short-term experimental perturbations under constant environmental conditions. Research suggests that elevated fat mass/adiposity in obese subjects is defended similarly to healthy weighted subjects (Hall & Guo, 2017). This supports the notion that obesity is in fact a disease, therefore blame should be shifted from person to physiology.

A review article by Lam and Ravussin (2016) indicated that approximately 90% of energy ingested is metabolizable energy, with the rest being lost during excretion, and perspiration. There are three components that comprise total daily energy expenditure (TDEE). These three components are resting (or basal) metabolic rate (RMR), the thermic effect of food or “diet-induced thermogenesis” (TEF), and physical activity energy expenditure. RMR is referred to as the energy required to sustain important biochemical systems of the body at rest (Lam & Ravussin, 2016). In addition, RMR accounts for approximately 70% of TDEE in sedentary individuals. Clinicians, researchers and dieticians use RMR to represent energy expenditure independent of physical activity and TEF. Fat-free mass (FFM) or “lean mass” (LM) is by far the strongest determinant of RMR. FFM accounts for approximately 70% of RMR’s variance, with fat mass, sex, age, and familial traits being some of the remaining significant contributors. Physical activity’s energy cost is the most variable component of TDEE. It accounts for energy consumed with muscular work during spontaneous and voluntary exercise. It has been estimated that activity energy expenditure ranges between

~15% in physically inactive individuals and up to ~50% in highly active individuals (Lam & Ravussin, 2016).

A randomized-control trial by Kirk et al. (2009) sought to investigate and evaluate the impact of a 6 month RT program in sedentary young adults on 24 hour energy expenditure (EE), resting metabolic rate (RMR), and substrate oxidation assessed by whole room indirect calorimetry 72 hours after the last RT session in the intervention. Kirk et al. (2009) hypothesized that a group participating in a RT protocol would result in an increase in 24-hour EE, RMR, and fat oxidation compared to a non-exercising control group. Thirty-nine overweight (BMI >25 kg/m$_2$), young adult men and women (21.0±0.5 years) were randomized into RT (n=37) and control groups (n = 23). The 6-month RT protocol was minimalistic and consisted of 3 non-consecutive training days and 9 exercises that focused on the major muscle groups. Participants completed 1 set of 3-6 repetitions using loads between 85-90% 1RM.

Results of this study indicated that there was a significant (p <0.05) increase in 24-hour EE in the RT (527 +/- 220 kJ x d) and control groups (270 +/- 168 kJ x d); however there were no significant differences between groups (p = 0.30). In addition, 24-hour fat oxidation (g/day) was not altered after RT; however, reductions in RT assessed during both rest (P < 0.05) and sleep (P < 0.05) suggested increased fat oxidation in the RT group compared to control during the same time periods. RMR (7.4 +/- 8.7%) increased significantly in RT (P < 0.001) but not in the control group, resulting in a trend for significance (P = 0.07) between-group differences.

Increased EE, RMR, and fat oxidation are robust and beneficial outcomes of RT; however, characteristics of muscle such as power, strength, and mass provide greater insight into overweight individuals' health. A review article by Tomlinson et al. (2016) aimed to examine the known link between adiposity and skeletal muscle force and power generation through adolescence, to young adults, and finally old age. This review emphasized the association of functional limitations in muscular performance with obesity. For example, obesity increases the likelihood of developing functional disabilities within mobility, power, strength, posture, and dynamic balance (Tomlinson et al., 2016). There is an ongoing debate on whether obese individuals, regardless of age, have greater absolute maximum muscle strength than non-obese individuals. This comes from the notion that increased adiposity (fat-mass) acts as a chronic overload stimulus on antigravity muscles (i.e., quadriceps), ultimately increasing muscle size and strength (Hulens et al., 2001). However, a cross-sectional study by Hulens et al. (2001) normalized maximum muscular strength outcomes to FFM and found that obese individuals were significantly weaker compared to their non-obese counterparts. The relative weakness in relation to FFM demonstrated in the Hulens et al. (2001) cross-sectional study can be caused by reduced neural adaptations, changes in muscle morphology and functional mobility, which are associated with physical inactivity and obesity. Therefore, overweight or obese individuals require RT interventions to maintain or enhance important muscle qualities to prevent the dangerous chronic conditions associated with physical inactivity and poor muscle characteristics.

Sarcopenia - The term "sarcopenia" was first introduced in 1989 by Irwin H. Rosenberg (2011) to describe a generalized progressive loss of skeletal muscle mass with advancing age. Sarcopenia's loss of muscle mass is accompanied by a decline in muscle strength and performance with increased age (Aagaard, Suetta, Caserotti, Magnusson, & Kjær, 2010). Sarcopenia can be accelerated by factors such as hormonal milieu, physical inactivity, poor nutrition, chronic illness, and loss of integrity in the peripheral and central nervous systems (Aagaard et al., 2010). In addition, sarcopenia has a distinct relationship with loss of muscle strength and the loss of independence to perform regular daily activities. Consequently, producing many adverse outcomes such as increased rates of disability, frailty, falls, fractures, comorbidities, hospitalization, and nursing home admissions (Zhao, Zhang, Hao, Ge, & Dong, 2019).

According to Goates et al. (2019), the total estimated cost of hospitalizations in 2014 for individuals with sarcopenia was USD $40.4 billion within the United States. Sarcopenia has a higher prevalence in geriatric populations; however, it can be present in younger adults (Cherin, Voronska, Fraoucene, & de Jaeger, 2014). Individuals with sarcopenia had an annual marginal increase in the cost of $2315.7 USD per person compared to individuals without sarcopenia (Goates et al., 2019).

The primary mechanism involved with sarcopenia is age-related sex hormone loss, apoptosis, and mitochondrial dysfunction (Cruz-Jentoft et al., 2010). Secondary mechanisms involve endocrine dysfunction (e.g., insulin resistance), skeletal muscle disuse (e.g., physical inactivity) and, inadequate nutrition. These mechanisms involve, among others, protein synthesis, proteolysis, neuromuscular integrity, and muscle fat content, each of which are essential components to the total quality of muscle (Marcell, 2003). Although the onset and progression of sarcopenia involves several mechanisms, relative contributions may vary over time. Therefore, recognizing these mechanisms and their underlying causes is expected to facilitate the design and implementation of interventions that target one or more underlying mechanisms.

The measurable variables of sarcopenia are muscular mass, strength, and physical performance utilizing techniques such as dual-energy X-ray absorptiometry (DEXA) scans, handgrip strength and, isokinetic dynamometry. Changes are recognized by repeating the same measures over time in the same individuals. The following sections briefly review the stated measurement techniques which are used to determine sarcopenia in clinical practices.

Body Imaging Techniques - Currently, three different imaging techniques are used in clinical applications to estimate muscle mass or lean body mass. The first being computed tomography (CT scan), the second being magnetic resonance imaging (MRI), and finally, DEXA. CT and MRI scans are considered to be the gold standard for estimating muscle mass in research because of the precise imaging systems that can differentiate muscles, fat, and bone (Andreoli, Garaci, Cafarelli, & Guglielmi, 2016). However, due to high cost, limited access, and concerns about radiation exposure, the use of these whole-body imaging methods such as MRI and CT scans for routine clinical practice is limited (Andreoli et al., 2016). As a result, DEXA has emerged as an alternative method both for research and for clinical use to distinguish fat, bone mineral, and lean tissues. DEXA whole-body scans expose patients to minimal radiation;

however, the principal drawback is that the equipment cannot differentiate muscles and is not portable. Due to the inability to transport this equipment, DEXA has a limited capacity in its use in large-scale epidemiological studies (Andreoli et al., 2016).

Ultrasound Imaging – In recent years, diagnostic imaging using ultrasonography has been accepted into clinical settings because of improvements in accuracy and repeatability. Ultrasonography has the advantage of being less invasive, mobile and, has a greater capacity to be used in large-scale epidemiological studies. A study by Hida et al. (2018) analyzed a total of 201 participants and compared thigh muscle thickness measurements obtained via ultrasound and bioelectrical impedance analysis (BIA) to determine and diagnose whether or not participants had sarcopenia. During this time period, muscle mass measurement methods using ultrasonography, specifically for sarcopenia, had not yet been established. For this reason, Hida et al. (2018) also investigated the validity and cutoff values of ultrasound muscle thickness measurements. Within this study, thigh muscle thickness (TMT) was defined as the distance between the anterior fascia of the rectus femoris muscle and the posterior fascia of the vastus intermedius muscle at the axial aspect of the image. The results of this study indicated that TMT measurements for males were 34.0 mm ±4.9 mm in participants with sarcopenia and 38.9 mm ±7.1 mm in participants without sarcopenia. For female participants, TMT measurements were 30.3 mm ±4.8 mm in participants with sarcopenia and 36.5mm ±7.2 mm in those without sarcopenia. TMT was significantly lower in participants with sarcopenia in both genders ($p = 0.024$ in male and $p < 0.001$ in female). The ultrasonography cutoff values in the diagnosis of muscle loss for males and females were 36 mm and 34 mm, respectively.

Handgrip strength – According to Lauretani et al. (2003), lower extremity muscle power, knee-extension torque, and calf cross-sectional area, are strongly related to handgrip strength. In addition, Laurentani and colleagues (2003) determined that low handgrip strength is a better predictor of clinical outcomes than low muscle mass. Furthermore, there is also an association between grip strength measures and cardiovascular, respiratory, cancer outcomes, and all-cause mortality (Celis-Morales et al., 2018). For this reason, handgrip strength measured in standard conditions with a pertinent model of a handheld dynamometer with reference populations can be a reliable replacement for more complicated measures of muscle strength in the lower arms or legs.

Isokinetic Knee Flexion & Extension - Muscular strength refers to the maximal force that a muscle or muscle group can generate (Powers & Howley, 2018). Muscular power refers to how much work is accomplished per unit of time (e.g. the product of moment and actual angular velocity; Powers & Howley et al., 2018). In healthy geriatric populations, power is lost at a faster rate than strength (Reid & Fielding, 2012). Strength and power are important characteristics, however power is a better predictor of certain functional activities (Reid & Fielding, 2012). Muscle's ability to generate force can be measured in a multitude of ways. For instance, strength can be measured isometrically or iso-kinetically; however, isokinetic strength is a closer reflection of muscle function in everyday human activity (Leblanc et al., 2015). In research, isometric force is usually measured as a force applied to the ankle, with the subject seated in an adjustable straight-back chair, the lower leg unsupported, and the knee flexed between 60-90° (de Araujo Ribeiro Alvares et al., 2015). Isometric and isokinetic measurement techniques are suitable for research studies, but their use in clinical practice is limited by the need for special equipment and training.

A review article by Bortz (2002), reviewed the framework of frailty by determining the minimal amount of muscle mass and strength required to maintain independent living with advancing age. Bortz et al. (2002) determined that a loss of 30% of reserve capacity limits normal function, whereas a decrease of 70% results in system failure. For example, comparing the muscle mass of Los Angeles Rams defensive lineman Aaron Donald (127 kg. [~280 lbs.]) to that of the 2016 Olympic gold medalist in the marathon, Eliud Kipchoge (52 kg. [~115 lbs.]), which one would be considered sarcopenic? A 70% reduction in mass is suggested to lead to disability, yet Aaron Donald could afford to lose 70% of his lean body mass and still have greater muscle mass than that of Eliud Kipchoge. Thus, assuming muscle loss rates are similar, then the higher the (starting) reserve capacity, the longer it will be before sarcopenia, or physical frailty will compromise the function of the skeletal muscle system. For this reason, it is imperative to promote and facilitate RT interventions to delay, or even prevent the onset of sarcopenia in sedentary adults.

One of the most impactful treatments for the prevention of sarcopenia is considered to be resistance training (RT) because it exerts positive effects on both the nervous system and muscular systems and, ultimately, results in profound enhancements in muscle power, strength, mass and function (Kalyani, Corriere, & Ferrucci, 2014; William J. Kraemer & Looney, 2012; Brad J. Schoenfeld, 2010). For this reason, RT should be considered a first-line treatment strategy for managing and preventing outcomes such as sarcopenia. However, there are many components that must be understood to optimize resistance exercise prescriptions. Components such as exercise intensity, exercise volume and progression, are all critical factors that should be strongly considered and administered with an understanding of safety and current RT guidelines.

A study by Morton et al. (2016) aimed to determine the effects of a 12 week LLHV versus a HLLV RT intervention on the development of muscular strength and hypertrophy in forty-nine experienced resistance trained healthy young men (23 ± 1yr, 86d, 181 ± 1 cm, 86 ± 2 kg; means ± SE). Subjects were randomly allocated into either a LLHV or a HLLV group. The LLHV group performed 20-25 repetitions for 3 sets using loads approximately 30-50% of a participant’s 1RM. The HLLV group performed 8-12 repetitions for 3 sets and used loads that approximated between 75-90% of a participants 1RM. Both groups completed each working set to volitional fatigue. This study examined quantitative measures of skeletal muscle biopsies (cross-sectional area [CSA]), strength (1RM), and DEXA body composition pretraining and post-training.

The Morton et al. (2016) study resulted in strength increases (1RM) for all exercises in both groups ($P<0.01$) however; the bench press was the only exercise that was significantly different between both groups (LLHV, 9 +/- 1 kg, vs. HLLV, 14 +/- 1 kg, $P = 0.012$). Also, fat and lean body mass, as well as type I and type II muscle fiber CSA, increased following both RT interventions ($P<0.01$), but there were no differences between groups. This study's results indicate that RT loads (30-50% 1RM vs. 75-90% 1RM) performed to volitional fatigue do not dictate different strength or hypertrophy gains in resistance-trained men. Thus, this data indicates that RT with HLLV and LLHV to volitional fatigue provides a comparable and sufficient stimulus for hypertrophy and strength development. However, this investigation consisted of a key limitation.

The most glaring limitation begins with the RT loads chosen for both groups. According to American College of Sports et al. (2018) *"Guidelines for Exercise Testing and Prescription"* performing RT for 3 sets of 8-12 repetitions approximates to 70-80% 1RM is considered a moderate load and high-volume yet, Morton et al. (2016) categorized this RT protocol as "low-repetition/high-load." Similarly, the "high-repetition/low-load" group performed 20-25 repetitions for 3 sets with each set approximating between 50-60% 1RM. Utilizing these RT loads was key limitation because literature has shown that proper high-load RT maximizes strength and neural development in trained and untrained populations (B. J. Schoenfeld et al., 2017; B. J. Schoenfeld, Peterson, Ogborn, Contreras, & Sonmez, 2015). Whereas, proper low-load RT maximizes hypertrophy in trained and untrained populations (Lasevicius et al., 2019). Thus, further research is required utilizing proper high-load and low-load RT loading parameters in trained and untrained populations.

Muscular Power

Perhaps one of the most critical characteristics of skeletal muscle is power. Muscular power declines earlier and more precipitously with advancing age compared to muscle strength (Reid and Fielding, 2012). Muscle strength is defined as "the ability to generate maximal muscle force," and a lack of strength is an immediate vulnerability to the functional capabilities in older adults. Skeletal muscle power is defined as "the product of the force and velocity of muscle contraction." Muscular power has been shown to decline earlier and more rapidly than muscle strength with advancing age (Aargaard et al., 2010). The underlying physiological mechanisms that contribute to this reduction in muscle power output among older adults include a quantitative decline in muscle mass, changes in muscle composition, muscle quality or reduced muscle strength per unit muscle mass, individual muscle fiber contractile property changes and alterations in neuromuscular function (Aargaard et al., 2010; Lexell et al., 1995).

Mechanical power is defined as the rate of work or the force multiplied by the velocity of movement (i.e., $power = \frac{work}{time},\ power = force\ x \frac{distance}{time}, power = force\ x\ velocity$). Since power is the product of force and velocity, both components must be added into RT regimens to develop proper muscular power. Velocity and force work synergistically during muscular actions; however, during concentric muscle actions, the velocity of a muscular action increases yet the force that muscle can produce decreases. Thus, maximum power is accomplished at compromised levels of maximal force and velocity (Kawamori & Haff, 2004). According to several studies, maximal mechanical power is considered to occur at a RT load of 30– 45% of 1 repetition maximum (1RM; (Harris, Stone, O'Bryant, Proulx, & Johnson, 2000; Moss, Refsnes, Abildgaard, Nicolaysen, & Jensen, 1997; Newton et al., 1997). In contrast, numerous investigators have challenged this notion and supported using RT loads between 10–80% 1RM to maximize mechanical power output (Kawamori and Haff, 2014). Choosing the proper RT load depends on multiple factors such as the nature of the exercise (e.g. upper vs. lower body, single vs. multi-joint, traditional vs. explosive), training experience, and the phase of training within a periodized macrocycle (American College of Sports et al., 2018).

Research has indicated that high-power muscular production consists of a wide variety of neuromuscular factors (Moritani, 1993; M. H. Stone et al., 2003). Some of these neural factors include motor-unit recruitment, rate coding, and synchronization. Specifically, type II muscle fibers must be recruited for high-power outputs. Type II muscle fibers are the larger, more powerful motor units which are mainly recruited during maximal voluntary effort. Consequently, some untrained athletes may not be able to recruit such high-threshold motor units (M. Stone, Plisk, & Collins, 2002)Therefore, developing the ability to recruit high-threshold motor units by prescribing the proper RT load will theoretically improve one's high-power–production capabilities.

Several studies have resulted in improved power performance following traditional RT (Adams, O'Shea, O'Shea, & Climstein, 1992; W. J. Kraemer et al., 2004), indicating the dependency of muscular force and the development of power. Whereas other RT programs consisting of exercises with high power outputs using LLRT have shown to be superior for improving vertical jump and sprinting abilities compared to traditional RT (Häkkinen, Alén, & Komi, 1985; Häkkinen, Komi, & Alén, 1985). HLRT (slow velocity RT) improves maximal force production whereas power training (utilizing LLRT at high velocities) increases force output at higher velocities. However, these studies involved athletes and not RT naïve, sedentary, overweight or obese adults. Supervised HLRT may be beneficial to RT naïve, sedentary overweight or obese adults because HLRT may induce recruitment of high-threshold fast-twitch motor units on the basis of the size principle (Mendell, 2005). Load-specific RT programs can delay the loss of muscular power, strength, mass, function and neuromuscular capabilities to prolong the abilities necessary to perform activities of daily living without complications (Reid and Fielding et al., 2012).

A review by Reid and Fielding (2012) focused on examining lower extremity muscle power as a more critical variable for understanding the relationship between impairments, functional limitations, and resultant disability. Reid and Fielding (2012) determined that as muscle power is the product of force and contraction velocity, factors that lead to a reduction in either of these parameters or both, will contribute to reduced muscle power output. Decrements in muscle power production with advancing age can be attributed to well-described changes in muscle quantity and quality. Such factors include a quantitative loss of muscle mass and alterations in the properties of individual muscle fibers, in particular, the selective reduction in the number and size of type II muscle fibers with advancing age which can generate four times the power output of type I fibers (Lexell, 1995). Additionally, muscle power loss in physically inactive overweight individuals is influenced by increases in muscle fat infiltration, changes in neuromuscular function, muscle architecture, alterations in hormonal status, protein synthesis and inflammatory mediators (Aagaard et al., 2010; Lexell, 1995; Reid & Fielding, 2012). Lower extremity muscular power and size are a critical component of functional capabilities and if maintained or enhanced, can ease the demands of daily activities on muscles and joints, ultimately, improving one's quality of life.

Muscular Mass and Body Composition

Experimentation and analysis of body composition and muscle is expanding because of the essential role these measurements play in disease detection and prevention. For instance, excessive fat mass has been associated with deleterious outcomes such as orthopedic injury, cardiovascular disease, and other indications of metabolic disease (A. Booth, Magnuson, & Foster, 2014; Dhana et al., 2016; Jensen, 2008). Conversely, adequate FFM (e.g., lean mass), has been associated with decreased musculoskeletal injury risk in aging and clinical populations (Roelofs et al., 2015). There are standard body composition assessment techniques (e.g., skinfold analysis and bioelectrical impedance), which are based on two-compartment (2C) models. Two-compartment models divide the body into fat mass (FM) and FFM. Additionally, 2C models have advantages such low cost, accessibility and reliability (Smith-Ryan et al., 2017).

Quadriceps Ultrasound Muscle Thickness – Readily accessible, inexpensive and reliable methods of measuring muscle health are essential to progress research. Quadriceps muscle thickness, determined by ultrasonography, is defined as the distance between fascia (e.g., vastus intermedius and vastus lateralis) (Mechelli, Arendt-Nielsen, Stokes, & Agyapong-Badu, 2020). Ultrasound imaging for muscle thickness has proven to be significantly correlated to the cross-sectional area (CSA) of a muscle (Strasser, Draskovits, Praschak, Quittan, & Graf, 2013). There are multiple clinical applications for muscle ultrasonography, for example, muscle loss of intensive care unit patients could be monitored by thickness measurements of the vastus intermedius and vastus lateralis (Gruther et al., 2008). Ultrasound muscle thickness (UMT) is a bedside imaging method used to assess mass, as well as the architecture and composition of skeletal muscle. The disadvantage of ultrasound muscle thickness is the limited image size, which can prevent the direct measurement of CSA of larger muscles. Currently, magnetic resonance imaging (MRI) or computer tomography scans (CT scans) are considered the gold standards to measure CSA and muscle composition. These techniques are precise; however, MRI and CT scans are expensive, cause higher levels of radiation exposure, and have limited availability.

Dual Energy X-ray Absorptiometry (DEXA) - DEXA is considered a three-compartment (3C) or four-compartment (4C) model which factors in body mass (BM), fat mass (FM), and bone mineral content (BMC) and water content (WC) (Smith-Ryan et al., 2017). Three- and four-compartment models are considered by many as the gold standard in body composition testing (Smith-Ryan et al., 2017). The 3C and 4C models of measurement, and associated body compartments, are accomplished using a variety of equipment, but also requires considerable time and cost.

A study by Hobson-Webb et al. (2018) investigated the feasibility of using quadriceps ultrasound MT and DEXA. Hobson-Webb et al. (2018) aimed to determine the inter-rater reliability and reproducibility of quadriceps as well as the correlation between quadriceps ultrasound MT and DEXA measured right thigh muscle mass. Nineteen men and eight women (72.6 ± 5 yr; 172.2 ± 11 cm; 83.3 ± 19 kg; 28.1 kg/m2) volunteered for this study. Participants had three images measured of rectus femoris (RF), vastus intermedius (VI), and subcutaneous fat (SF) thickness and whole-body DEXA obtained by two independent examiners.

Results of the Hobson-Webb et al. (2018) investigation resulted in excellent intra-rater reliability for SF (r = 0.98, p <0.0001 [examiner 1], and r = 0.99, p <0.0001 [examiner 2]). RF was high for both examiners (r = 0.98, p < 0.0001) and VI had good agreement ($r = 0.98$, $p < 0.0001$ for [examiner 1], and $r = 0.99$, $p < 0.0001$ for examiner

2). Regarding inter-rater reliability for both examiners, SF was excellent ($r = 0.99$, $p < 0.0001$), RF and VI muscle thickness had similar results ($r = 0.98$, $p < 0.0001$ and $r = 0.97$, $p < 0.0001$, respectively). In addition, RF and VI muscle thickness correlated with DEXA measured right thigh muscle mass ($r = 0.53$, $p = 0.0045$ and, $r = 0.54$, $p = 0.004$, respectively). For, right thigh fat mass and SF thickness, there was a strong correlation ($r = 0.81$, $p < 0.0001$). These results indicate that quadriceps ultrasound MT measures are accurate and repeatable between examinations, considering imaging is conducted according to a standardized protocol. Moreover, these findings indicated that measures of quadriceps ultrasound SF thickness were accurate, given there was a strong correlation with right thigh fat mass ($r = 0.81$). Thus, due to the ease and accessibility of using ultrasound, quadriceps MT and SF thickness may provide reliable and accurate clinical and research measures for monitoring muscle mass and body fat composition.

Based on the information presented in this literature review, RT has beneficial effects on muscular strength, power, composition and metabolic function (Jenkins et al., 2016; McLeod et al., 2019; B. J. Schoenfeld et al., 2017; Van Roie, Delecluse, Coudyzer, Boonen, & Bautmans, 2013; Willis et al., 2012). Young adults (<55 years) who are physically inactive and overweight display losses or impairments in muscular power (William J. Kraemer & Looney, 2012; Reid & Fielding, 2012) mass and metabolic function, (F. W. Booth et al., 2017; Brook et al., 2016) which can result in an increased prevalence of developing detrimental conditions such as sarcopenia (Aagaard et al., 2010), obesity (Booth et al., 2012) or a combination of both (Johnson Stoklossa et al., 2017). Developing these conditions can result in impairments, functional limitations, disabilities, and increased morbidity and all-cause mortality (F. W. Booth et al., 2017;

Jenkins et al., 2016; Reid & Fielding, 2012). Current ACSM RT recommendations state that novice to intermediate exercisers should RT for 2-4 sets of 8-12 repetitions between 60-80% 1RM to enhance muscular strength and composition (American College of Sports et al., 2018). However, numerous studies (Kawamori & Haff, 2004) have challenged these recommendations and claimed that RT with higher loads is safe and maximizes muscular power and strength, meanwhile, RT with lower loads and higher volumes maximize the hypertrophic response of muscle (Lasevicius et al., 2018). Although these claims have been confirmed in athletic and healthy populations, further research is required on the effects of different RT loads on physically inactive, overweight and obese populations. Therefore, this study aimed to assess the effects of high-load/low-volume and low-load/high-volume RT protocols on isokinetic knee extensor peak power, vastus intermedius and vastus lateralis muscle thickness in physically inactive, RT naïve, overweight and obese young adults. In addition, due to the limited accessibility of advanced body composition assessment tools such as DEXA, this study will examine the correlation between the more accessible and mobile assessment methods of ultrasound muscle thickness.

CHAPTER 3

METHODS

Overview

Chapter three describes and justifies the necessary methods, procedures, and timeline required to conduct and complete this study. Additionally, this chapter discusses the characteristics of participants, recruitment process, rationale and predicted power of the study. Finally, this chapter provides details for the RT interventions, instrumentation used for data collection and, statistical analysis used to determine the results of the study.

Subjects

Inclusion criteria - This study included male and female participants between 18-55 years old who were clinically categorized as either overweight or obese (BMI ≥ 25 kg/m2). Additionally, participants were included who had no recent history of starting a structured exercise or diet program in the last 3 months. Furthermore, participants included within this study were considered sedentary (verified with pedometer) and RT naïve or inexperienced exercisers verified via Physical Activity Readiness Questionnaire (PAR-Q).

Exclusion criteria - This study excluded any participants if they were current smokers and/or recreational drugs users. Moreover, participants were excluded if they answered “yes” to one or more questions on the PAR-Q. Participants were also excluded if diagnosed with diabetes, heart disease or if they were taking medications for treatment of diabetes, heart disease, and hypertension. In addition, participants were excluded if they had history of anabolic steroid use in the past six months or if they had any orthopedic or musculoskeletal contraindications to resistance training. Female participants were required to take a pregnancy test due to the radiation produced by some of the testing equipment. If female participants returned with a positive test they were excluded. Participants unwilling to follow any aspect of the study protocol, weight training intervention and, unwilling to commute to Healthy Lifestyles Research Center and/or the ASU Sun Devil Fitness Center in Downtown Phoenix, were also excluded. Finally, participants which were willing and did not meet any of the exclusion criteria, received a Fitbit pedometer device that determined their levels of activity. Participants who exceeded >10,000 steps within a day were considered highly active and were excluded from this study.

Effect Size

The primary outcome variable of this study was isokinetic knee extensor and flexor peak power (*watts*) [PP]. The projected sample size was calculated for the primary aim to detect changes using PP (*watts*) over two periods of time between intervention and control groups. Utilizing a similar study (Van Roie, Bautmans, et al., 2013), which looked at similar outcomes in thirty-six young volunteers (*age* 21.82 +/- 2.06 years) an estimated mean difference in PP (watts) at the end of the 12-week resistance training intervention would be 18 watts in both RT groups. In addition, this effect size was applied to the comparison of RT groups, as well as control, which will depict no change or slight decrement over time. With these estimates, the power analysis of a three-group comparisons showed that a sample of 33 (n=33) subjects would be sufficient to have 80% statistical power at an α of 0.05.

Recruited

Recruitment of the following study began promptly after IRB approval. Subjects were recruited from the downtown campus of Arizona State University and the Greater Phoenix area. To gain the number of participants required flyers were posted around the downtown campus and sent through e-mail distribution lists provided by Arizona State University's College of Health Solutions. Additionally, participants were also recruited by word of mouth on the ASU Downtown Phoenix campus. Those who expressed interest within the study received an online screening questionnaire.

Study Design

The present study took approximately 12-13 weeks for each participant to complete. This study included three visits to the Healthy Lifestyles Research Center at the ASU Downtown campus in the Arizona Biomedical Collaborative 1 building. The first visit (visit 1) subjects experienced was the screening visit which took approximately one hour to complete. After participants met all inclusion criteria for the study following their screening visit, they wore a Fitbit pedometer for one week and then returned it on their baseline testing visit. Participants underwent baseline testing (visit 2), following their activity tracking, and testing lasted approximately seven hours. Upon completion of baseline testing, participants were then randomized into one of the two intervention groups or control. Researchers and subjects developed a schedule for the RT intervention. The first training day consisted of a five-repetition max test (5RM) in the leg press, bench press and, latissimus dorsi pull-down. The second training day consisted of a 10RM test with the exercises as the 5RM testing day. The mid-point (visits 16-17) and final week (visits 37-38) of the RT intervention consisted of 5RM and 10RM testing, as well. Visits 5-15, and 18-36 were full training days designated to the specific RT intervention. All

RM testing and training sessions were conducted at the ASU Sun Devil Fitness Center in downtown Phoenix and lasted approximately 60-75 minutes each. The final visit (visit 39) served as the post-testing day and took place at the same location pre-testing was conducted. All testing performed during the final visit (visit 39) was identical to the testing performed during visit two (baseline testing). In the end, the total testing time required for exercise training participants was approximately 36-45 hours. Regarding the control group, total testing time required for participants was approximately 15 hours. Further details about procedures during each visit are below.

Procedures

Pre-Screening - Following the response to recruitment flyers, all participants were sent an email which included screening questions (APPENDIX-B) and questions from the physical activity readiness questionnaire (PAR-Q) (APPENDIX-B) as part of the Qualtrics Online Survey System that established eligibility for participation. At the beginning of the pre-screening survey, limited consent, identifying information as well as screening related information were obtained from potential participants. Each participant was asked about their age, height, weight, and gender in addition to several “yes” or “no” questions related to smoking status, medication status, history of drug use (both recreational and performance enhancing drugs), exercise history, currently dieting, whether they recently (last 3 months) attempted weight loss, and if they took oral contraceptives. If the participant answered “yes” to taking oral contraceptives, they would be required to list the medication in order to screen for oral contraceptive medications that may interfere with outcome measures. Female participants were required to take a pregnancy test due to the radiation produced by some of the testing equipment. When any of the potential participants answered “yes” to any questions on the PAR-Q, they would not be permitted to participate unless they obtained a physician’s release. Identifying information such as a telephone number or email address was obtained to allow follow-up. Participants were then scheduled for a more complete screening and in-person consent visit where signatures were obtained.

Visit 1 (Consent and Screening Visit)

Upon the first visit, participants were provided an informed consent form which was thereby explained by the researcher. Prior to initiating testing procedures, the participants provided consent to partake in the study. Each participant reviewed and signed a paper copy of the informed consent form. Following consent, measures of height, weight, and BMI were assessed using a standard stadiometer and scale. Participants then read and completed a Physical Activity Readiness Questionnaire (PAR-Q) and a Medical History Questionnaire to screen for any prior or existing health conditions. Participants that possessed no contraindications to exercise testing and training proceeded with collection of baseline measures.

After participants were enrolled within the study, they were then given a Fitbit (Fitbit, San Francisco, CA) which is a pedometer device that measures walking steps. Following a week of wearing the Fitbit, participants returned along with the device to the laboratory. The pedometer data was then assessed to determine whether the participants daily physical activity levels exceed the exclusion cutoff point of 10,000 steps per day.

The participants were also instructed to wear the Fitbit following the week 12 post-testing visit to assess for changes in physical activity throughout the duration of the study.

Group Assignment

After completing the pre-testing visit and confirmation of eligibility, participants were then randomly assigned to one of three groups. Those who were randomized into the control group were advised to refrain from physical activity and any dietary changes for the duration of the 12-week intervention. The LLHV (<15RM) group followed a RT program where each exercise was completed until volitional fatigue and consisted of 3 sets and 15 repetitions. The HLLV (<5RM) group which followed a RT program where each exercise was completed until volitional fatigue and consisted of 3 sets of 5 reps.

Visit 2 (Baseline Testing Visit)

Measurements - Every measurement, except for RM testing, was assessed at the baseline visit and at the post-testing visit. The time of testing remained constant to reduce any impact of diurnal variations in clinical variables measured. All female participants were tested during the follicular phase of their menstrual cycle. Post-intervention testing was performed 72-hours following the last RT session to eliminate any acute/sub-acute effects of the last exercise bout.

Instrumentation

Knee Flexor and Extensor Isokinetic Peak Power (watts) - Knee extensor and flexor peak power was assessed using an isokinetic dynamometer (Biodex System 4 Pro™, Biodex Medical Systems, Inc., Shiley, NY). Prior to data collection, each participant was instructed to complete a warm-up phase which consisted of 5 minutes of submaximal cycling on a cycle ergometer (Monark Exercise AB, Vansbro, Sweden).

After completion of the warm-up phase, each participant was tested for concentric knee extension and flexion on the Biodex System 4 Pro dynamometer.

Following the warm-up phase, tests were performed unilaterally on the right side, unless there was a medical contraindication. Each participant was first familiarized with the isokinetic muscle function testing. After a brief familiarization period, each participant was seated and fitted into the Biodex dynamometer in a backwardly inclined (5º) position and secured with safety belts across the upper leg of the tested side, the hips, and shoulders. Participants were then positioned specifically so that the rotational axis of the dynamometer was aligned with the transversal knee-joint axis. In addition, the tibia was aligned and attached with a length-adjustable lever arm. Each participant had their specific seat setting, rotational axis and, length of lever arm, documented and saved to reduce the impact of variability in measures during post-testing.

To obtain viable measures, participants were instructed to extend and flex at the knee using their muscles to push and pull, respectively, as hard as they can against the moving bar. Participants extended and flexed the knee at the specific angular velocities of 150°/s, 120°/s and, 90°/s. Each test was repeated twice at each angular velocity and consisted of three bouts of extension and flexion. Between each test, subjects were given 30 seconds of rest. During the post-test visit subjects repeated the same exact protocol. Verbal encouragement was provided to elicit maximal efforts during pre- and post-testing visits. Values in peak power from knee extension and flexion were recorded for all testing sets.

The mechanical measuring capabilities of the isokinetic dynamometer eliminates potential error by variable human performance and establishes the first step in ensuring clinically relevant physiological function (validity), with acceptable consistency (reliability). Mechanically reliable instruments such as the Biodex provide assurance that every time an individual is assessed, changes in muscular function are due to performance differences rather than inconsistent measurement capabilities of the instrument. In addition, mechanically valid instrumentation ensures that observations of muscle function are an assessment of a variable the investigator expects to observe. In short, as soon as mechanical reliability and validity are established, it is upon the investigator to determine whether the observed changes in human performance are a direct result of an applied intervention or an implicit inconsistency in human performance.

Ultrasonography Measurement

Muscle Thickness (MT) - Prior to the knee extensor and flexor isokinetic peak power testing, subjects had images taken of the vastus intermedius (VI) and vastus lateralis (VL) muscles on the lateral portion of the right thigh using ultrasonography (US). Each participants' testing side was placed in a custom-built foam positioning device to eliminate any external rotation of the leg being measured. To achieve a natural knee angle of approximately 10º, a towel was placed underneath the knee. After establishing a comfortable testing position, the participant relaxed in that position for 20 minutes to normalize for the influence of gravity induced fluid shifts (i.e., fluid accumulating in the legs while standing). After the 20-minute relaxation period, the investigator established and marked multiple measurement sites with a washable marker along the quadriceps where ultrasound images were obtained. The investigator first measured the outer (lateral) quadriceps length from the greater trochanter to the lateral epicondyle of the femur. A site was then marked at 56% of the distance from the greater trochanter to the lateral epicondyle of the femur. Once the investigator marked the specific measurement sites, the US transducer head was placed on the lateral part of the thigh with a coat of water-based conductive gel directly on the skin at each site and images were saved of the VI and VL muscles.

Depth of the ultrasound transducer was adjusted as needed to accommodate the size of the patient imaged. Two images were captured at the second lateral site or “L2” (56% mark between greater trochanter and lateral femoral epicondyle) of the lateral thigh. Images were analyzed using Fiji which is a distribution of the popular open-source software ImageJ, which focuses on biological-image analysis (Schindelin et al., 2012). The best image was selected based on quality and each selected image was sharpened to clearly enhance any structures used to obtain measurements. Using the line tool within Fiji, each image was calibrated, and a scale was set for 2 centimeters, that way, each image measurement would be presented in centimeters. A horizontal line was drawn and measured along the femur or bottom of the image. This measurement was used to divide the image and determine the “x-coordinate” values of 10%, 50%, and 90%, respectively. After establishing the x-coordinate values, vertical lines were drawn from each x-coordinate (10 to 90%) beginning with the most vastus intermedius, then the vastus lateralis, then both muscles combined and finally finishing off with the subcutaneous fat. After values were obtained at each x-coordinate, a mean was calculated for each muscle thickness outcome.

Currently, the gold standard instrument used to measure quadricep muscles thickness is magnetic resonance imaging (MRI) (Morse, Degens, & Jones, 2007). However, the MRI is expensive and time-consuming, which limits the regular use by researchers and clinicians to measure quadriceps muscle size in a subject or patient population. Whereas, a feasible alternative method to clinically measure muscle size in real time is ultrasound imaging which is more readily available in clinical situations. This muscle thickness measurement technique was chosen because of its test-retest reliability displayed in a study by D’Lugos, Skotak, Kelly, Gaesser, and Dickinson (2016). D’Lugos et al. (2016) assessed the test-retest reliability of US strategies for measuring muscle thickness. Additionally, the authors of this study determined the influence of standing versus laying down supine and anatomical location had on reliability. Results of this study indicated that laying down supine appeared to demonstrate the highest test-retest reliability for all muscles, except lateral VI. Furthermore, US was chosen as a measuring method for this study because measurements of quadriceps muscle thickness have good reliability and repeatability (English, Fisher, & Thoirs, 2012), can be performed in a short amount of time, and are strongly correlated to quadriceps strength (Strasser et al., 2013). Measurements of muscle thickness using ultrasound images of the mid-thigh are strongly correlated to the gold standard MRI measurements of rectus femoris thickness (Thomaes et al., 2012), and whole quadriceps volume (Miyatani, Kanehisa, Kuno, Nishijima, & Fukunaga, 2002). The validity and reliability of using US techniques to measure muscle thickness of the quadriceps in overweight or obese adults requires further investigation.

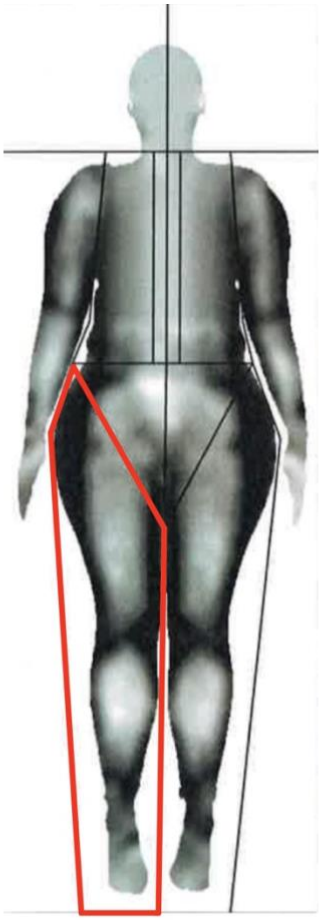
Figure 1. Example of an analyzed ultrasound image of the right vastus intermedius, vastus lateralis and subcutaneous fat.

Body Composition Testing (DEXA Scan)

In addition to ultrasound imaging, measurements of body composition were assessed utilizing dual-energy x-ray absorptiometry (DEXA) (GE Lunar iDXA). Body composition was assessed following an overnight fast (12 h) at baseline and during post-testing. In addition, DEXA scans were conducted more than 72 hours following the last exercise session post-intervention. Each subject's height and weight were measured on a stadiometer and standard scale, respectively. The DEXA exposes radiation to participants and any radiation carries potential risk. Therefore, prior to any scans, all pre-menopausal female participants underwent a urinary pregnancy test. Subjects were exposed to minimal radiation (1-4 micro-Sieverts) that is within an acceptable range as provided by the U.S. Food and Drug Administration (FDA). Radiation of 1-4 micro-Sieverts exposure is considered very minimal as compared to a typical chest-x-ray where patients could be exposed up to 30-40 micro-Sieverts.

As stated in the previous chapters, many experts consider to be the practical gold standard and criterion method for measuring body composition. The GE Lunar iDXA was chosen because of its ability to accurately measure fat mass and lean mass (Hind, Oldroyd, & Truscott, 2011). Additionally, DEXA was chosen because it is considered the gold standard for the quantitative assessment of total and regional body composition and bone mineral density in adults (Hind et al., 2011). Overwhelming literature delineates the validity and reliability of total and regional body composition quantitative values utilizing the DEXA in the standard frontal plane view (Smith-Ryan et al., 2017). Current DEXA software allows for both automatically and manually generated regions of interest (ROIs) to quantify regional body composition measures (e.g., arms, legs, and trunk) which includes, contralateral body comparisons (right vs left), and visceral adiposity measurements (Kaul et al., 2012). Studies in the past which utilized DEXA (Hart, Nimphius, Spiteri, Cochrane, & Newton, 2015), have assessed the regional quantification of fat mass (FM), and lean mass (LM) in the upper thigh and lower shank of the legs in the frontal (anterior) view.

Figure 2. Example image of a total body DEXA scan with segmental lines.



Highlighted lines represent right lower extremity segment used for measures of this study.

Post-Testing (Visit 3 or 39)

Following 72 hours after the last RT session, post-testing will be performed. The 72-hour delay from the final testing sequence is to eliminate any acute/sub-acute effects of the last exercise bout. The testing procedures stated in visit 2 (baseline) will be performed identically during visit 3 (post-test) or 39 (post-intervention).

Resistance Training Interventions

High-Load/Low-Volume (HLLV) – The high-load/low-volume RT intervention consisted of a 12-week progressive regimen based on each subject’s 5RM and 10RM testing outcomes during weeks one and six. The HLLV group completed two different total body training days (i.e., Day 1, Day 2) three days per week for a duration of 12 weeks. Day one (D1) consisted of seven exercises and emphasized the lower body. Whereas, day two (D2) consisted of eight exercises and emphasized the upper body. Each training week consisted of three training sessions and subjects completed both D1 and D2 training days. Additionally, each training week alternated training days (i.e., Week 4: D1, D2, D1; Week 5: D2, D1, D2). Subjects completed three sets of five repetitions with loads that approximated to 89% of the subjects 1RM (3 x 5 at ~89% 1RM) for each exercise until volitional fatigue. In addition, subjects rested approximately one minute or ninety seconds between each working set. If necessary, loads were decreased (~5–10% 1RM) between sets to ensure repetitions were performed within the participant’s assigned repetition range.

Low-Load/High Volume - The low-load/high-volume RT intervention also consisted of a 12-week progressive regimen based on each subject’s 5RM and 10RM testing outcomes during weeks one and six. The LLHV group completed the same two training days (D1 and D2), weeks and, exercises as the HLLV group. However, subjects in the LLHV group completed three sets fifteen repetitions with loads that approximated to 67% of the subjects 1RM (3 x 15 at ~67% 1RM) for each exercise until volitional fatigue. In addition, subjects in the LLHV group rested for the same duration between sets as did the HLLV group. If necessary, loads were decreased (~5–10%) between sets to ensure repetitions were performed within the participant’s assigned repetition range.

Exercises

The exercises selected for this study consisted of a mix between free weight and machine exercises. For lower-body muscle groups, each subject performed leg press, dumbbell step up, barbell lunge, knee extensions and knee flexions. For the upper body, each subject performed barbell bench press, latissimus dorsi-pulldown, barbell overhead press, seated cable row, barbell incline bench press, bicep curl, triceps extension and abdominal crunch. According to the ACSM, to maximize strength and hypertrophy, a combination of multi- and single-joint exercises were used for each of the major muscle groups (Garber et al., 2011). In addition, a combination of free-weight and machine-based exercises were chosen to reduce the risk of injury in the RT naïve population.

Statistical Analysis

To examine the influence of the two different intervention effects, the primary outcome measure will be knee extensor peak power (watts). The secondary outcome within this study will be thigh muscle thickness (cm). This data was analyzed utilizing SPSS software (version 25). Each outcome was tested for normality using the Shapiro-Wilk test due to the small sample size. One-way ANOVA was used to analyze baseline differences in subject characteristics. A linear mixed-model ANOVA was used to analyze all pre- and post-data to examine and determine main effects between the groups, time (pre- and post), as well as, group x time interactions. Due to the sample and sex discrepancy within each group, sex was controlled for as a covariate. Furthermore, the tertiary outcome of this study was to determine a correlation between thigh muscle thickness and DEXA thigh segment analysis. Utilizing bivariate linear correlations and Pearson correlation coefficients, correlations between changes in variables were examined. Each of the *p*-values were calculated based on a two-tailed hypothesis and the alpha level was set to 0.05.

CHAPTER 4

RESULTS

Baseline Characteristics

At the conclusion of this study, twenty-one subjects had completed the interventions as well as, baseline and post-testing (4 Control, 11HLLV, 6 LLHV). Due to the COVID-19 pandemic, recruitment for this master's thesis was terminated along with all research activities at Arizona State University. Table 1 below, outlines participant baseline demographic information. No significant differences were observed between subject demographics at baseline (*p* > 0.05).

Table 1. Demographic information by group at baseline (means ± SD)

	Control (n = 4)	HLLV (n = 11)	LLHV (n = 6)	*p* value
Age (years)	38.5 ± 12.9	34.1 ± 10.9	35.7 ± 10.2	0.791
Sex (M/F)	2M, 2F	5M, 6F	2M, 4F	0.982
Height (cm)	177.1 ± 13.5	172.7 ± 13.9	171.5 ± 9.3	0.780
Weight (kg)	86.7 ± 10.4	94.8 ± 25.5	103.3 ± 20.8	0.518
BMI (kg/m$_2$)	27.6 ± 1.6	31.3 ± 5.5	35.7 ± 10.6	0.209
Body fat (%)	39.5 ± 7.9	41.1 ± 6.5	43.2 ± 7.2	0.701

M and F represent male and female respectively
HLLV represents High-Load/Low-Volume
LLHV represents Low-Load/High-Volume

Isokinetic Knee Extensor and Flexor Peak Power

A Shapiro-Wilk's test was used to determine normality and all assumptions were met (P>0.05). According to a mixed-model ANOVA analysis, there were no significant differences found between intervention groups when analyzing measures of peak power in knee extensor and flexor using isokinetic dynamometry (P > 0.05). Table 2 below displays the isokinetic knee extensor and flexor peak power outcomes between groups at baseline and following the 12-week periods. Minimal differences were observed in both training groups. The HLLV group had nonsignificant decreases in measures of isokinetic knee extensor peak power at 150, 120 and, 90°/s. Furthermore, the HLLV group also had a nonsignificant decrease at 120°/s in isokinetic knee flexion. Overall, no main effects or interaction effects were observed in any of the peak power measurements.

Table 2. Changes in peak power (*w*) of knee extensor and flexor as measured by isokinetic dynamometry at baseline and following either 12-week intervention or control period (means ± SD).

Variable	Control n=4		HLLV n=11		LLHV n=6		Fixed Effects		
	Baseline	Post-12 Weeks	Baseline	Post-12 Weeks	Baseline	Post-12 Weeks	Group	Visit	Group x Visit
KF 150°/s	130.7 ±	166.0 ±	159.6 ± 85.6	172.8 ± 72.4	151.3 ± 31.4	200.8 ± 41.1	0.472	0.103	0.352
(*w*)	54.3	70.1							
KF 120°/s	127.2 ±	153.2 ±	169.3 ± 64.3	167.0 ± 59.7	160.2 ± 35.1	176.5 ± 37.9	0.113	0.337	0.322
(*w*)	45.6	37.4							
KF 90°/s	109.2 ±	127.5 ±	140.7 ± 58.6	144.0 ± 51.3	133.3 ± 29.4	143.3 ± 29.6	0.095	0.334	0.619
(*w*)	41.5	31.2							
KE 150°/s	218.7 ±	254.0 ±	247.5 ± 99.5	234.5 ± 97.7	238.5 ± 62.9	286.0 ± 64.6	0.640	0.431	0.211
(*w*)	96.4	98.6							
KE 120°/s	196.0 ±	233.2 ±	247.1 ± 86.9	229.3 ± 91.3	241.5 ± 70.1	257.5 ± 63.4	0.420	0.653	0.340
(*w*)	68.4	85.4							
KE 90°/s	158.2 ±	186.7 ±	199.9 ± 75.2	197.3 ± 63.0	205.1 ± 60.1	209.0 ± 41.2	0.206	0.580	0.599
(*w*)	46.5	69.5							

Isokinetic Peak Power is represented in watts (*w*)
KF represents Knee Flexion
KE represents Knee Extension
HLLV represents High-Load/Low-Volume
LLHV represents Low-Load/High-Volume

5RM and 10RM Strength Testing Outcome

Although the 5RM and 10RM strength testing outcomes were not a primary outcome of this study, these results provide support and context to the isokinetic peak power results. See table 3 below for 5RM and 10RM strength testing outcomes at baseline and following both RT interventions. A repeated measures ANOVA was used to determine significant differences between time (visit), groups, and group by volume by time. The results of the repeated measures ANOVA indicated that each RM test significantly increased following both HLLV and LLHV 12-week RT interventions ($P < 0.05$). The HLLV group had a percentage increase of 64.2, 76.5, 30.9, 36.7, 23.5 and 34.1 % in the 5RM leg press, 10RM leg press, 5RM bench press, 10RM bench press, 5RM latissimus dorsi pull-down, and 10RM latissimus dorsi pull-down, respectively. The LLHV group had a percentage of 50.3, 59.5, 28.9, 41.7, 19.3 and, 17.4 % in the 5RM leg press, 10RM leg press, 5RM bench press, 10RM bench press, 5RM latissimus dorsi pull-down, and 10RM latissimus dorsi pull-down, respectively. However, there were no significant interactions for group by volume by time ($P > 0.05$).

Table 3. Changes in 5RM and 10RM strength testing measures (lbs.) at baseline and following both 12-week resistance training interventions.

Variable	LLHV (n = 6)		HLLV (n = 11)					
					Time		Group x Volume x Time	
	Baseline	Post 12-Weeks	Baseline	Post 12-Weeks	F	Sig.	F	Sig.
5RM Leg Press (lbs.)	205.4 ± 45.2	308.9 ± 62.1	255.7 ± 33.4	419.9 ± 45.9	22.173	0.00034	0.045	0.834
10RM Leg Press (lbs.)	163.2 ± 34.7	260.3 ± 56.1	201.1 ± 25.6	354.9 ± 41.4				
5RM Bench Press (lbs.)	88.7 ± 10.8	114.3 ± 13.9	99.1 ± 8	129.7 ± 10.3	63.173	0.00003	0.302	0.591
10RM Bench Press (lbs.)	70.7 ± 8.7	100.2 ± 13.6	83.6 ± 6.4	114.3 ± 10				
5RM Lat Pull-Down (lbs.)	105.1 ± 8.9	125.4 ± 9.4	120.5 ± 6.6	148.8 ± 6.9	54.602	0.000003	1.124	0.307
10RM Lat Pull-Down (lbs.)	92.2 ± 6.8	108.2 ± 11.2	101.1 ± 5.1	135.6 ± 8.2				

Load is represented in pounds (lbs.)
RM represents repetition maximum
HLLV represents the High-Load/Low-Volume group
LLHV represents the Low-Load/High-Volume group

Quadriceps Ultrasound Muscle Thickness

All muscle thickness measures passed normality assessed by Shapiro-Wilks testing ($P > 0.05$). Table 4 below displays and compares ultrasound muscle thickness outcomes at baseline and following the 12-week periods. There was a significant group effect for vastus intermedius (VI) ($P = .008$). The significant group effect for the VI within the control group was due to a lower initial (1.5 ± 3cm) and post-testing muscle thickness measures (1.5 ± 4cm) compared to the HLLV (2 ± .5cm) and LLHV (2.03 ± .6cm) groups. However, following a mixed-model ANOVA, no other significant differences were observed between intervention groups when analyzing ultrasound muscle thickness ($P > 0.05$). Minimal nonsignificant increases in muscle thickness and decreases in subcutaneous fat were observed in both intervention groups.

Table 4. Changes in muscle thickness (cm) of the Vastus Intermedius, Vastus Lateralis, and Subcutaneous Fat as measured by ultrasound at baseline and following either 12-week intervention or the control period (means ± SD)

Variable	Control n=4		HLLV n=11		LLHV n=6		Fixed Effects		
	Baseline	Post-12 Weeks	Baseline	Post-12 Weeks	Baseline	Post-12 Weeks	Group	Visit	Group x Visit
Vastus Intermedius (cm)	1.5 ± .4	1.5 ± .3	2.1 ± .7	2 ± .5	1.9 ± .5	2.03 ± .6	0.008*	0.765	0.811
Vastus Lateralis (cm)	2.4 ± .4	2.4 ± .5	2.4 ± .5	2.7 ± .4	2.4 ± .6	2.66 ± .4	0.796	0.390	0.786
VIVL (cm)	3.9 ± .8	3.9 ± .7	4.5 ± .9	4.7 ± .7	4.3 ± 1	4.68 ± .8	0.071	0.463	0.806
Subcutaneous Fat (cm)	1.3 ± .6	1.3 ± .3	1.8 ± .8	1.7 ± .8	1.9 ± 1.3	1.82 ± 1	0.140	0.876	0.963

VIVL represents the combined measures of the vastus intermedius and vastus lateralis
HLLV represents High-Load/Low-Volume
LLHV represents Low-Load/High-Volume

Right Lower Extremity DEXA Scans

All measures of the right lower extremity were tested for normality using the Shapiro-Wilks test and all assumptions were met ($P > 0.05$). See table 5 for outcomes in right lower extremity composition changes at baselines and following the 12-week periods. There were no group, visit (time), or group by time interactions for right lower extremity DEXA measures using a mixed-model ANOVA. Minimal changes were observed within the two intervention groups meanwhile the control group remained the same.

Table 5. Changes in measures of right lower extremity DEXA response to 12-week RT intervention within and between groups (means ± SD)

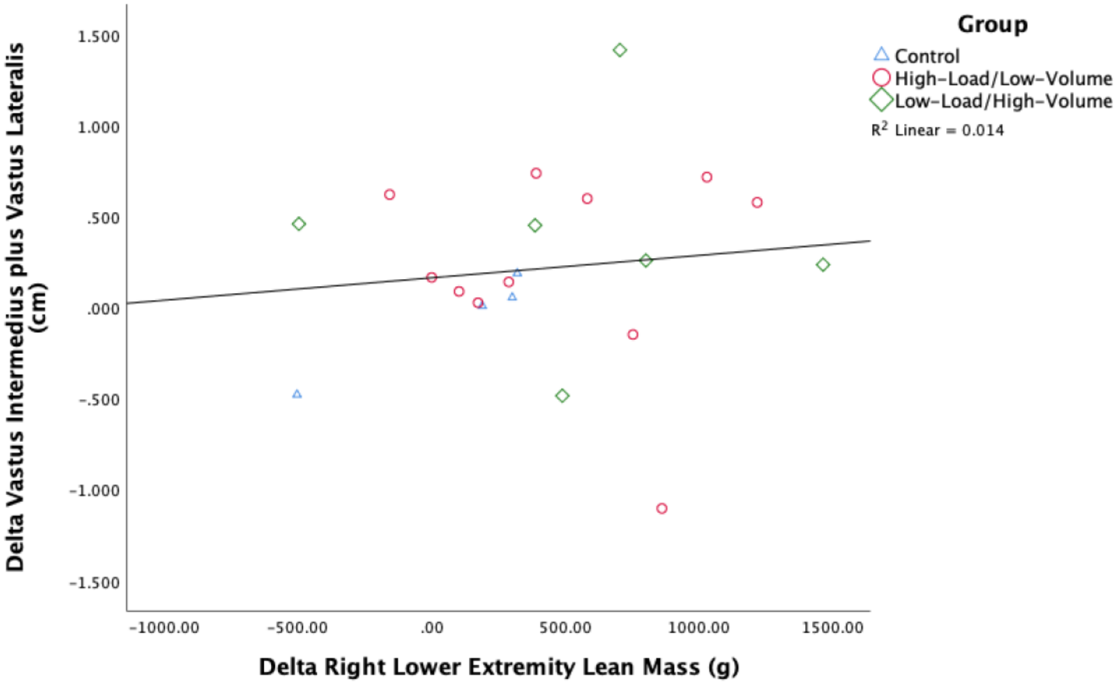
Variable	Control n=4		HLLV n=11		LLHV n=6		Fixed Effects		
	Baseline	Post-12 Weeks	Baseline	Post-12 Weeks	Baseline	Post-12 Weeks	Group	Visit	Group x Visit
Region Fat (%)	36.6 ± 12.3	36.6 ± 11.6	37.9 ± 9.4	36.9 ± 9.4	39.9 ± 9	39.1 ± 9.2	0.154	0.650	0.956
Lean Tissue Mass (kg)	14.3 ± 1.7	14.4 ± 1.8	16.2 ± 3.6	16.8 ± 3.4	16.6 ± 2.4	17.3 ± 3.1	0.144	0.634	0.978
Fat Tissue Mass (kg)	5.4 ± 1.5	5.4 ± 1.5	6.3 ± 1.9	6.4 ± 2.1	6.9 ± 2.2	7.1 ± 2.7	0.152	0.853	0.996
Total Mass (kg)	14.8 ± 1.8	15 ± 1.8	16.8 ± 3.7	17.4 ± 3.4	17.1 ± 2.3	17.9 ± 2.9	0.147	0.624	0.980

HLLV represents High-Load/Low-Volume
LLHV represents Low-Load/High-Volume

Correlations

Figure 3 below displays the correlation between changes in vastus intermedius plus vastus lateralis and changes in right lower extremity lean mass. Using a Pearson's correlation, there was no significant positive correlation found between changes of vastus intermedius plus vastus lateralis (VIVL) muscle thickness measures and changes of right lower extremity lean mass (g) DEXA measures (*r* =.119, n =21, p = .608). The coefficient of determination (r_2 = .014) value suggested that only 1.4% of the variation in changes of vastus intermedius plus vastus lateralis muscle thickness can be explained by the changes in right lower extremity lean mass. No other correlations were observed.

Figure 3. - Correlation between Delta Vastus Intermedius plus Vastus Lateralis (cm) and Delta Right Lower Extremity Lean Mass (g)



CHAPTER 5

DISCUSSION

The primary aim of this study was to assess the effects of HLLV versus LLHV RT protocols on isokinetic knee extensor and flexor peak power in RT naïve, physically inactive, overweight or obese adults. After the 12-week intervention it was determined that neither of the RT groups were superior to the control group for measures of isokinetic peak power.

It was hypothesized that the HLLV group would have significantly greater isokinetic knee extensor and flexor peak power compared to the LLHV group which would be greater than control following the 12-week RT intervention. However, there were no significant differences by group nor by visit. In addition, there was no significant interaction for group by visit. Furthermore, non-significant increases were observed in both control and the LLHV group with nonsignificant decreases in the HLLV group. The unexpected increases in peak power within the control group could be due to the study being underpowered. It was found that the HLLV group had a decrease in all isokinetic dynamometer designated speeds except for knee flexion at 150°/s, which had a nonsignificant increase (13.2 watts). The decrease in isokinetic peak power observed within the HLLV group could be due to the slow exercise velocity which accompanies heavy RT (Kawamori & Haff, 2004). In contrast, the LLHV group had nonsignificant increases in isokinetic peak for each designated speed. This is due to the fact that low-load RT is usually performed with higher velocities, which can increase the rate of force development (Kawamori & Haff, 2004).

These results are similar to a study by Van Roie, Bautmans, et al. (2013) which displayed that only the low-load resistance training group increased speed of movement using isokinetic dynamometry of the knee extensors. The main difference between this study and the Van Roie, Bautmans, et al. (2013) study was that the high-load group performed 1 set of or 10-12 repetitions at ~80% 1RM compared to 3 sets of 5 repetitions at ~90% 1RM. Regarding low-load RT, the Van Roie, Bautmans, et al. (2013) study's participants performed 1 set of 10-12 repetitions at 40% 1RM with no maximal effort, or, 1 set of 10-12 repetitions at 40% 1RM, preceded by 60 repetitions at 20-25% 1RM, without rest compared to this study's participants which performed 3 sets of 15 repetitions at ~65% 1RM. While there were greater velocity outcomes observed in the Van Roie, Bautmans, et al. (2013) study, there were also much lighter loads used within each RT intervention protocol.

Table 3 demonstrated the changes in 5RM and 10RM in the strength testing outcomes measured during baseline and following both 12-week RT interventions. Both HLLV and LLHV saw significant increases in strength following the 12-week RT interventions. However, there were no significant differences between groups. These results indicated that although both groups saw significant increases in strength, there were no significant interactions between groups and volume following the 12-week RT interventions. These results do not coincide with the results obtained for isokinetic knee extensor and flexor peak power, where there were no significant differences in peak power observed between groups nor were there significant interactions observed for group by visit. Isokinetic dynamometry may not detect improvements in the population examined within this study due to the principal of specificity in RT. The principal of specificity derives from observations of adaptations from specific types of exercise training. For example, if the objective is to maximize muscular power, one must RT with high velocities whereas if the objective is to maximize muscular strength, one must RT with high-load and low-volume. Thus, the results from 5RM and 10RM strength testing suggest that RT with high loads and low loads will result in strength increases; However, one RT protocol is not significantly superior to the other for developing strength and power in sedentary, overweight, or obese populations.

The difference between developing muscular strength and power is the component of speed. According to Kawamori & Haff (2004), enhancing muscular power can be done using a variety of RT methods. Heavy or high-load RT, such as the HLLV RT protocol used within this study, is normally performed at a relatively slow velocity because of the large external resistance that must be overcome. In contrast, low-load RT protocols are executed at higher velocities due to less external resistance that must be overcome. Although the use of high-load RT has been supported to increase muscular power, low-load (<60-80% 1RM) RT protocols are superior in enhancing muscular power due to the higher rates of force development (RFD). Therefore, to maximize the development of muscular power, especially in untrained, overweight or obese adults, practitioners should incorporate low-load, high-velocity RT protocols.

This study's secondary aim was to assess the effects of LLHV versus HLLV RT protocols on measures of ultrasound muscle thickness in the right leg of RT naïve, physically inactive, overweight, or obese adults. The significant group interaction was determined (P = 0.008) for vastus intermedius muscle thickness. This outcome was due to the significantly low baseline and post-testing VI values within the control group. Furthermore, this outcome could have been due to the “L2” site, chosen from D’Lugos et al. (2016), which did not display the vastus intermedius very well.

The secondary hypothesis stated that significantly greater muscle thickness changes would occur in the LLHV group compared to the HLLV group, which would both be greater than control. This study's results display nonsignificant increases of muscle thickness in both groups following the 12-week RT interventions with no significant differences between groups or visit, nor were there any significant interactions between groups by visit. Also, both intervention groups had nonsignificant decreases in subcutaneous fat thickness following the 12-week RT intervention.

The muscle thickness results of this study are similar to a study by B. J. Schoenfeld et al. (2015) which found significant increases in muscle thickness measures following 8 weeks of either high- or low-load RT. Similar to this study, B. J. Schoenfeld et al. (2015) found no significant differences in muscle thickness between groups. However, the main difference between this study and B. J. Schoenfeld et al. (2015) study was again the RT protocol for both high and low-load RT. Within the B. J. Schoenfeld et al. (2015) study, the high-load RT group performed 3 sets of 8-12 repetitions between ~70-80% 1RM until momentary concentric muscular failure whereas this HLLV group within this study performed 3 sets of 5 repetitions at ~90% 1RM until failure. Likewise, the low-load group within the Schoenfeld et al., (2015) study performed 3 sets of 25-35 repetitions at ~45-55% 1RM until failure in comparison to this study which used 3 sets of 15 repetitions at ~65% 1RM until failure. In addition, Schoenfeld et al., (2015) examined differences within well-trained men whereas the population within this study was sedentary, RT naïve, and overweight or obese. Although Schoenfeld et al., (2015) utilized a high-load RT protocol, it was not as high in intensity compared to this study. Therefore, those within the high-load RT group within Schoenfeld et al., (2015) study performed a RT protocol which was closer to this studies low-load/high-volume RT protocol.

Finally, this study aimed to assess the relationship between changes of ultrasound quadricep muscle thickness and lean mass of the right lower extremity segment via DEXA scans following the 12-week RT intervention. It was hypothesized that changes in vastus intermedius plus vastus lateralis muscle thickness and changes in right lower extremity lean mass measured by DEXA would result in a significant positive correlation. Upon completion of the Pearson correlation there was no significant correlation observed between changes in vastus intermedius plus vastus lateralis muscle thickness and changes in right lower extremity lean mass measured by DEXA.

CHAPTER 6

CONCLUSION

In conclusion, the results within this study indicate that 12-weeks of resistance training utilizing HLLV or LLHV did not have any significant effects on measures of knee extensor and flexor peak power assessed by isokinetic dynamometry. In addition, no significant interactions were seen on ultrasound measures of muscle thickness nor right lower extremity DEXA outcomes. Finally, there was no positive significant correlation observed between changes in muscle thickness and changes in right lower extremity lean mass assessed via DEXA.

This study had a few limitations. First, this study originally estimated that a sample of 33 subjects ($n = 33$) would be sufficient to have an 80% statistical power ($\alpha < 0.05$). However, due to the COVID-19 pandemic, recruitment for this master's thesis was terminated along with all research activities at Arizona State University. A sample of 21 subjects ($n = 21$) was ultimately used for this study. Secondly, the "L2" site chosen did not adequately represent the vastus intermedius and vastus lateralis in the overweight/obese population. Research in muscular hypertrophy, which uses muscle thickness as an outcome, uses multiple sites to determine changes in muscle thickness. However, this study only used one site.

Research on various RT loads and their effects on muscular power and hypertrophy are necessary, especially in untrained, sedentary obese populations, because prescribing proper RT protocols can attenuate the detrimental outcomes of sedentary behavior and aging. Long-term studies are necessary to understand the impact of different RT loads on lower extremity power and hypertrophy in sedentary overweight or obese adults. In addition, future research should consider the use of multiple measurement sites when determining changes of muscle thickness and how changes in MT can correlate to DEXA body composition scans.

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APPENDIX A

ARIZONA STATE UNIVERSITY INSTITUTIONAL REVIEW BOARD APPROVAL

ASU Knowledge Enterprise Development

APPROVAL:CONTINUATION

Siddhartha Angadi
Exercise Science and Health Promotion
602/827-2254
sangadi@asu.edu

Dear Siddhartha Angadi:

On 12/30/2019 the ASU IRB reviewed the following protocol:

Type of Review:	Continuing Review
Title:	Resistance Training and Vascular Health Study
Investigator:	Siddhartha Angadi
IRB ID:	STUDY00006617
Category of review:	
Funding:	Name: Graduate College (GRAD), Funding Source ID: GPSA
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• Flyer with QR code, Category: Recruitment Materials; • Informed Consent, Category: Consent Form; • Flyer, Category: Recruitment Materials;

The IRB approved the protocol from 12/30/2019 to 5/10/2020 inclusive. Three weeks before 5/10/2020 you are to submit a completed Continuing Review application and required attachments to request continuing approval or closure.

If continuing review approval is not granted before the expiration date of 5/10/2020 approval of this protocol expires on that date. When consent is appropriate, you must use final, watermarked versions available under the “Documents” tab in ERA-IRB.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

APPENDIX B

1. PHYSICAL ACTIVITY READINESS QUESTIONNAIRE
2. MEDICAL HISTORY QUESTIONNAIRE

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

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

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

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

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

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

If you answered

YES to one or more questions

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

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

NO to all questions

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

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

→

DELAY BECOMING MUCH MORE ACTIVE:

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

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

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

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

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

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

NAME ____

SIGNATURE ____ DATE ____________________________

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

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

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THE GOLD STANDARD IN EXERCISE SCIENCE AND PERSONAL TRAINING

MEDICAL HISTORY QUESTIONNAIRE

The following questions are designed to obtain a thorough medical history. The information you provide will help us to make the best determination about your eligibility for a particular study. Please answer all questions and provide as much information as you possibly can. This questionnaire, as well as any other medical information you provide, will be kept confidential and will not be shared with any unauthorized person or organization unless you specifically request us to do so.

Name: ____

Date Completed: ___________________________________

Name: ____

Street Address: ____

City, State, Zip: ____

Telephone number: Home ( )__________ Work ( )______________

Date of Birth: __________ Age: _____
mm-dd-yy

Sex: M _____ F _____

Personal Physician's Name: __________________________Phone___________

Address:____

____

Height: estimated __________ in

Weight: estimated __________ lb

Personal Health History

Have you ever been hospitalized or had surgery? Yes _____ No _____

Please list all hospitalizations and surgeries to the best of your recollection

Hospitalized for Disease/Operation	Duration	Age when Hospitalized

List any disease or illness you have had not listed above (e.g., hepatitis, severe infection, broken bones, blood clotting / bleeding issues, etc.)

____

____

____

____

Are you allergic, sensitive, or intolerant of any foods or nutritional supplements, products, or substitutes? Yes___ No___

If yes, please describe: ____

Are you allergic, sensitive, or intolerant of any medications? Yes___ No___

If yes, please describe:____

Are you allergic, sensitive, or intolerant of local anesthetic (pain killing medications; e.g., Novocaine, Lidocaine or Xylocaine)? Yes___ No___

If yes, please describe: ____

Have you ever received an injection of a local anesthetic (pain killing medication; e.g., Novocaine, Lidocaine, or Xylocaine). Yes___ No___

Are you allergic, sensitive, or intolerant of latex? Yes___ No___

Are you allergic, sensitive, or intolerant of any kind of tape or adhesive? Yes___ No___

Are you currently seeing a doctor or other health care provider for any reason?

Yes _____ No _____

If yes, please explain:

Have you ever been diagnosed with osteoporosis or other bone disorder?

Yes ____ No____

If yes, please explain:

Do you have, or have you ever had any of the following conditions?

Memory problems or confusion	Yes _____	No _____
Recurring headaches	Yes _____	No _____
Recent changes in your vision	Yes _____	No _____
Numbness of an arm or leg	Yes _____	No _____
Weakness of an arm or leg	Yes _____	No _____
Difficulty in speaking or slurred speech	Yes _____	No _____
Fainting or dizziness	Yes _____	No _____
Difficulty in walking (staggering)	Yes _____	No _____
Shortness of breath	Yes _____	No _____
Lung or Respiratory Disease	Yes _____	No _____
Rheumatism or arthritis	Yes _____	No _____
Heart disease	Yes _____	No _____

Epilepsy Yes _____ No _____

Tumors Yes _____ No _____

Mental illness Yes _____ No _____

Bleeding or blood clotting disorders Yes _____ No _____

Risk for infectious diseases Yes _____ No _____
(AIDS, IV drug use, blood transfusions, hemophilia, hepatitis)

Skin: rashes, lumps, moles, itching, eczema Yes _____ No _____

Nose, sinuses: frequent colds, sinus trouble Yes _____ No _____
nose-bleeds, deviated septum

Neck lumps, swollen glands, pain or stiffness Yes _____ No _____

Breasts: lumps, nipple discharge, pain or discomfort Yes _____ No _____

High blood cholesterol Yes _____ No _____
Date of last reading ______ Value ______

Stomach: chronic indigestion, ulcer, hiatal hernia, Yes _____ No _____
heartburn, trouble swallowing, vomiting.

Intestine: constipation, diarrhea, change in bowel Yes _____ No _____
habits, irritable bowel disorder, colitis, polyps.

Rectum: hemorrhoids, bleeding, polyps Yes _____ No _____

Liver, gallblader: hepatitis, gallstones Yes _____ No _____

Urinary: frequent urination, urgency, burning, Yes _____ No _____
pain, blood in urine, infection, kidney stones

Incontinence: Loss of bladder or rectal control Yes ______ No _____

Have you ever had any form of cancer, skin or other? Yes _____ No _____

If yes, what kind: _______________________________

Do you have diabetes mellitus (high blood sugar)? Yes _____ No _____

If yes, when and what kind of treatment did/do you receive:

Insulin _____ Diet _____ Pills _____ No treatment _____

Have you ever had or been told that you had high blood pressure?

Yes _____ No _____

If yes, when and what kind of treatment or medicine did/do you receive:

____

Do you have any chronic illnesses or medical conditions? Yes _____ No _____

If yes, please explain:

____

____

____

____

List all the prescribed medications you are currently taking:

Medicine	Reason for Medication

List all the over-the-counter medications you are currently taking:

Medicine	Reason for Medication	Is it doctor recommended?

Specifically, are you currently taking any pain medications, such as Tylenol or Advil, on a regular basis? Yes _____ No _____ If yes, how much and how often do you consume these medications?

____

____

<u>Are you currently taking any blood thinning medications including, but not limited to Coumadin, Plavix, Xarelto, Pradaxa, Eliquis, Savaysa, Lovenox, Arixtra, heparin, aspirin, or any other NSAID?</u>

Yes _____ No _____

If yes, please describe:

<u>Medication</u>	<u>Amount</u>	<u>How often</u>	<u>Doctor Recommended</u>

<u>Dietary Information</u>

Are you currently taking any vitamins, minerals or health food supplements (e.g., fish oil, ginko biloba) at least once per week on a regular basis? Yes _____ No _____

If yes, please describe:

<u>Supplement</u>	<u>Amount</u>	<u>How often</u>	<u>How long</u>	<u>Doctor Recommended</u>

Would you be willing to stop your vitamins, minerals or health food supplements if needed while participating in a study? Yes _____ No _____

Have you had a weight loss or gain in the last 6 months? Yes _____ No _____

If yes, how much? _____lbs. Gain _____ Loss _____ (check one)

How do you describe your appetite? Poor _____ Fair _____ Good _____

Do you have any food allergies/intolerance (e.g., shellfish/iodine)? Yes _____ No _____

If so, please explain:

____

____

____

Do you drink caffeinated beverages? (coffee, tea, soda) Yes _____ No _____

If yes, how many caffeinated beverages do you drink in an average day? ______/day

If required during a study, would giving up caffeine cause any problems for you?

Yes _____ No _____

Do you drink alcoholic beverages? Yes _____ No _____

If yes, how many alcoholic beverages do you consume in an average week? ______/wk

Would you be willing to forego drinking alcoholic beverages for the duration of a research study?

Yes _____ No _____

Smoking History

Do you currently use any products containing nicotine, for example cigarettes, electronic cigarettes, nicotine patches, cigars, pipe, chew, smokeless tobacco at present?

Yes _____ No _____

Did you use any of the above products in the past and quit permanently? Yes _____ No _____

When did you quit? (check one)
less than 1 year _____
1 to 5 years _____
more than 5 years _____

Exercise History

Do you participate in a regular exercise program? Yes _____ No _____

If yes, please describe the exercise that you usually participate in (e.g., walking, running, weightlifting).

____

____

____

____

If you are not currently participating in a regular exercise program, have you participated in one in the past? Yes _____ No _____

If yes, when was the last time you participated in the exercise on a regular basis?

Could you please describe the type of activity that you performed (e.g., walking, running, weightlifting).

____

____

____

____

How often did you exercise (days/week)? _______

At what intensity did you exercise? Light _______
Moderate _______
Hard _______

On days that you did exercise, how long did you usually exercise for (hours)?______

RTV Study Screening Questionnaire

Start of Block: Resistance Training Vascular Study Questionnaire

1 ASU Nutrition Professor Dr. Siddhartha Angadi and graduate student, Robert Santana, are inviting you to participate in this screening process, which will consist of questions specific to your health, demographics, and scheduling availability. You have the right to skip any question(s) you are uncomfortable answering, or to stop this survey at any time. Your participation in this survey and the research study is completely voluntary, and you may choose to withdraw from the study at any time without consequence. Your responses to this survey, and participation in this research study will be strictly confidential. If you meet the inclusion criteria for the study, you will be contacted to schedule an in-person appointment at Arizona State University (Downtown Phoenix campus). This initial appointment should last approximately 60 minutes.

Page Break

2 Do you wish to participate in the pre-screening process?

○ Yes (1)

○ No (2)

Skip To: End of Survey If Do you wish to participate in the pre-screening process? = No ***Rationale:*** *To obtain consent to ask screening questions.*

Page Break

3 How old are you?

○ Between 18-55 years old (1)

○ Less than 18 years old (2)

○ Greater than 55 years old (3)

Skip To: End of Survey If 1 = Less than 18 years old

Skip To: End of Survey If 1 = Greater than 55 years old

*

4 What is your height in inches?

____

*

5 What is your body weight in pounds?

____

End of Block: Resistance Training Vascular Study Questionnaire

---

Start of Block: Block 1

6 Do you smoke?

○ Yes (1)

○ No (2)

Skip To: End of Survey If 4 = Yes

Page Break

7 Did you previously smoke?

○ Yes (1)

○ No (2)

Skip To: 7 If 5 = No

Page Break

8 If you previously smoked, when was the last time that you smoked?

○ Less than 1 year (1)

○ Greater than 1 year (2)

Skip To: End of Survey If 6 = Less than 1 year

Page Break

9 Do you use recreational drugs?

○ Yes (1)

○ No (2)

Skip To: End of Survey If 7 = Yes

Page Break

10 Have you previously used recreational drugs?

○ Yes (1)

○ No (2)

Skip To: 10 If 8 = No

Page Break

11 If you previously used recreational drugs, when was the time that you used recreational drugs?

○ Greater than 1 year (1)

○ Less than 1 year (2)

Page Break

12 Are you currently using or have you used anabolic steroids in the last six months? (For example: Androsteindione, Testosterone, Testosterone analogues)?

○ Yes (1)

○ No (2)

Skip To: End of Survey If 10 = Yes

Page Break

13 Are you a man receiving Testosterone Replacement Therapy (TRT) or have you received TRT in the past 6 months?

○ Yes (1)

○ No (2)

Skip To: End of Survey If 11 = Yes

Page Break

14 Have you attempted to lose weight in the past 3 months?

○ Yes (1)

○ No (3)

Skip To: End of Survey If 12 = Yes

Page Break

15 Are you currently participating in or have participated in a structured weight lifting program in the last 3 months?

○ Yes (1)

○ No (2)

Skip To: End of Survey If 13 = Yes

Page Break

16 Have you been diagnosed with diabetes?

○ Yes (1)

○ No (2)

Skip To: End of Survey If 14 = Yes

Page Break

17 Are you taking oral contraceptives?

○ Yes (1)

○ No (2)

Skip To: 17 If 15 = No

Page Break

18 If you are taking oral contraceptives, which contraceptive are you taking?

____

Page Break

19 Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

○ Yes (1)

○ No (2)

Skip To: End of Survey If 17 = Yes

Page Break

20 Do you feel pain in your chest when you do physical activity?

○ Yes (1)

○ No (2)

Skip To: End of Survey If 18 = Yes

Page Break

21 In the past month, have you had chest pain when you were not doing physical activity?

○ Yes (1)

○ No (2)

Skip To: End of Survey If 19 = Yes

Page Break

22 Do you lose your balance because of dizziness or do you ever lose consciousness?

○ Yes (1)

○ No (2)

Skip To: End of Survey If 20 = Yes

Page Break

23 Do you have a bone or joint problem (for example, back, knee, or hip) that could be made worse by a change in your physical activity?

○ Yes (1)

○ No (2)

Skip To: End of Survey If 21 = Yes

Page Break

24 Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

○ Yes (1)

○ No (2)

Skip To: End of Survey If 22 = Yes

Page Break

25 Do you know of <u>any other reason</u> why you should not perform physical activity?

○ Yes (1)

○ No (2)

Skip To: End of Survey If 23 = Yes

Page Break

26 Please provide your email address and telephone number.

____

Page Break