THE EFFECT OF A TWO-WEEK LOWER BODY RESISTANCE TRAINING PROTOCOL ON AEROBIC CAPACITY (VO_{2PEAK}) IN SEDENTARY MIDDLE-AGED FEMALES

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ABSTRACT

Chad William Wagoner: The Effect of a Two-Week Lower Body Resistance Training Protocol on Aerobic Capacity (VO_{2peak}) in Sedentary Middle-Aged Females
(Under the direction of Claudio L. Battaglini)

This prospective study examined the effect of two-weeks of lower-body resistance training on cardiopulmonary capacity (VO_{2peak}) as well as its impact on muscle strength/size in sedentary middle-aged females (n=18). VO_{2peak} was assessed via a maximal cardiopulmonary exercise test (CPET), leg extensor strength via isokinetic dynamometry, and muscle size of the vastus lateralis (VL) (cross-sectional area (CSA)) using ultrasound. Both relative and absolute VO_{2peak} significantly improved by 10.8% (p=0.002) and 10.7% (p=0.003), respectively. leg extension peak torque (PT) significantly improved by 6.1% (p=0.027), and EMG amplitude significantly improved by 41.3% (p=0.001). VL CSA did not increase in response to training (p=0.456). No significant relationship was observed between VO_{2peak} changes and chosen strength variables (PT/Amplitude). In conclusion, the strength training appears to have had a positive effect on VO_{2peak}.and strength in middle-aged females, however future studies including a control group are warranted to confirm or refute the results of this current study.

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LIST OF ABBREVIATIONS

1-RM	One Repetition Maximum
BM	Body Mass
BP	Blood Pressure
cm	Centimeter
CPET	Cardiopulmonary Exercise Test
CSA	Cross-Sectional Area
EKG	Electrocardiogram
EMG	Electromyography
HR	Heart Rate
kg	Kilogram
PAR-Q	Physical Activity Readiness Questionnaire
PT	Peak Torque
RPE	Rate of Preceived Exertion
US	Ultrasonography
Ve	Minute Ventilation
VL	Vastus Lateralis
VT	Ventilatory Threshold
W	Watts

CHAPTER 1

INTRODUCTION

Sarcopenia can be defined as the loss of skeletal muscle as a result of the aging process (Roubenoff & Hughes, 2000). Studies have shown that a decrease in skeletal muscle mass can occur as early as 30 years old with the greatest decline be observed between the ages of 50 to 69 years old (Frontera, Hughes, Lutz, & Evans, 1991). It is well documented within the literature that muscle mass and strength continue to decline as individuals continue to age (W. J. Evans & Campbell, 1993). However, sarcopenia has been shown to be accelerated not only by aging, but also by sedentary lifestyles and disease (W. J. Evans, 2010). Specifically, it has been established that those whom do not participate in physical activity on regular basis have less skeletal muscle mass (W. J. Evans, 1995) and are more susceptible to decreased functional capabilities (Roubenoff & Hughes, 2000). Those who are diagnosed with illnesses, such as cancer, often suffer from "cachexia" (Fox, Brooks, Gandra, Markus, & Chiou, 2009), which is "a complex metabolic syndrome associated with underlying illness and characterized by loss of muscle with or without loss of fat mass" (W. J. Evans et al., 2008). Similar to inactivity, cachexia is considered an underlying contributor to sarcopenia (Rolland, Abellan van Kan, Gillette-Guyonnet, & Vellas, 2011).

Regardless of the mechanism behind sarcopenia, the loss of skeletal muscle is related to a decrease in the ability to perform functional tasks such as walking, carrying groceries, and rising up from a chair. Studies in the past have demonstrated that resistance training can lead to improved functional ability as shown by reduced rate of perceived exertion (RPE) during post-intervention testing of functional tasks (Hartman, Fields, Byrne, & Hunter, 2007) and faster times in a 5-Chair Stand test (Hanson et al., 2009). Similarly, in order to attenuate the loss of skeletal muscle, physical activity, specifically resistance training, can assist in this process leading to enhanced ease of daily activities and prevention of diseases such as diabetes, osteoporosis, and obesity (Rogers & Evans, 1993). In addition to its relationship with functional tasks, loss of muscle mass is considered a limiting factor in aerobic capacity, as seen by significantly lower VO_{2peak} values from cardiopulmonary exercise tests (CPET) (Fleg & Lakatta, 1988). Strong relationships have been reported in terms of the decline in leg strength and leg muscle mass in relation to VO_{2peak} values in sedentary males and females (Neder, Nery, Silva, Andreoni, & Whipp, 1999). With this relationship in mind, recent studies have sought out to determine the mechanism behind it. General consensus shows that the atrophy that occurs with aging, disuse, and disease results in the lower limbs not being able to generate enough force to withstand the resistance of the cycle ergometer (Neder et al., 1999). As a result, the CPET is concluded prematurely, producing a VO_{2peak} value that is not necessarily an accurate representation of the individual's peak cardiopulmonary capacity, bringing into question the aerobic exercise intensities that are prescribed based off this value.

To address this issue, researchers have begun to examine the influence that resistance training has on VO_{2peak} in individuals whom are impacted by significant losses of muscle mass (elderly, sedentary, and diseased individuals). It has been previously shown that older sedentary populations elicit similar increases in VO_{2peak} as a result of resistance training alone when compared to aerobic training alone, indicating that training adaptations from both modes are beneficial for an individual's aerobic capacity (Hepple, Mackinnon, Goodman, Thomas, &

Plyley, 1997). Furthermore, post-intervention one-repetition maximum (1-RM) scores from lower body exercises such as leg press, leg curl, and leg extensions have been reported to be strongly correlated with VO_{2peak} scores, displaying a significant relationship between resistance training and aerobic capacity in inactive elderly males and females (Vincent, Braith, Feldman, Kallas, & Lowenthal, 2002). In females alone, robust correlations have been reported when taking leg muscle mass (LMM) into account and comparing it to VO_{2peak} values as aging occurs (Neder et al., 1999). Indeed, the studies elicit a valid relationship between resistance training and its influence on aerobic capacity; However, the length of intervention for these studies fall between as little of eight weeks to as long as six months. They are ultimately examining the influence of physical hypertrophic characteristics of trained skeletal muscle, such as cross-sectional area (CSA) on VO_{2peak} rather than neuromuscular adaptations that has been reported to occur as early as 2 weeks of resistance-training (Moritani & deVries, 1979).

Neuromuscular adaptations in response to resistance training take place during the initial phases of a training program. Adaptations include larger motor neuron recruitment, greater frequency of motor neuron recruitment (rate coding), and greater muscle activation. Greater muscle activation in concentric, eccentric, and isometric contractions of the vastus lateralis (VL), vastus medialis (VM), and the biceps femoris (BF) has been seen in older sedentary females in as little as one week of training (Hortobagyi & Vita, 2000). Likewise, 1-RM, muscle thickness and functional capacity of older females have been shown to improve in as little as six weeks of resistance training, indicating that neuromuscular improvement took place as well as hypertrophic adaptations in response to short term resistance training (Pinto et al., 2014). In terms of aerobic capacity, few studies have shown improvements in maximal oxygen uptake as a result of neuromuscular adaptations. For instance, one study revealed that as little as four weeks of resistance training increased both 1-RM scores on a leg press exercise as well as maixmal oxygen uptake values in college-aged females (Kim, Dear, Ferguson, Seo, & Bemben, 2011). An important limitation of this study was that maximal oxygen uptake values were estimated based off of submaximal cardiopulmonary testing. With this in mind, we are unaware of any studies that have observed the impact of short-tetm resistance training on changes in aerobic capacity in an older population of sedentary females. As noted by Neder et al. (1999), there is an inability to produce force on a cycle ergometer during a CPET test by sedentary females. In turn, this premature cessation of a CPET on a cycle ergometer may produce a oxygen uptake value that may not accurately represent their true aerobic capacity due to muscular weakness in the lower extremities. This also may be the case observed in women with breast cancer due to their low levels of physical activity during and post treatment, which stimulated the development of this current study. The results of this study in apparently healthy sedentary women with similar ages as those women with breast cancer may prove that this reduced muscular capacity impact oxygen uptake assessment on a cycle ergometer and can potentially be attenuated with short term resistance training. If proven correct, this attenuation of muscular weakness may implicate more accurate assessments of cardiopulmonary capacity and thus improving our ability to prescribe cycling exercise for sedentary more accurately.

Purpose Statement

The purpose of this study will be to examine the effect of a two-week lower body resistance training protocol on VO_{2peak} in sedentary middle-aged females. A secondary purpose of this study will examine the effect of a two-week lower body resistance protocol on muscle strength, activation and size of the Vastus Lateralis (VL). Lastly, a tertiary purpose will evaluate the relationship between changes in VO_{2peak} and muscular peak torque/activation from baseline to the completion of the two-week resistance training protocol.

<u>Research Questions</u>

RQ1. Will two weeks of lower body resistance training elicit greater VO_{2peak} responses from to pre to post-training in sedentary middle-aged females?

RQ2. Will two weeks of lower body resistance training elicit greater peak torque values of the VL in sedentary middle-aged females post-training?

RQ3. Will two weeks of lower body resistance training elicit greater activation of the VL from pre to post-training?

RQ4. Will two weeks of lower body resistance training greater muscle size of the VL in sedentary middle-aged females?

RQ5. Is there an association between the changes in VO_{2peak} values from pre to post training with the changes in peak torque values from pre to post training?

<u>Hypotheses</u>

H_1: Subjects will elicit greater VO_{2peak} values from pre to post-training as a result of the two-week lower body resistance training protocol.

H_2: Subjects will elicit significantly greater torque as a result of neuromuscular adaptations in comparison to pre-training values.

H_3: Subjects will exhibit greater VL muscle activation in comparison to pre-tests values.

H_4: Subjects will not exhibit greater muscle size in the VL in comparison to pre-training values.

H_5: VO_{2peak} and peak torque/EMG amplitude values from pre to post testing will elicit a strong positive relationship.

<u>Operational Definitions</u>

- *Sedentary:* Classified as not having participated in regularly scheduled exercise more than once a week for the previous 6 months.
- *CSA:* The area of the VL that represents the muscle size as determined by cross-sectional ultrasound scans.
- *Familiarization:* Session that occurs two days prior to the pre-testing session in order to familiarize the subjects with protocols being implemented and equipment being used.
- *Pre-Training:* Events that occur before the resistance training protocol of two-weeks. This includes the initial screening / familiarization session as well as the second visit (pre-testing session).
- *Post-Training:* Events that occur at least two days after the two weeks of resistance training has been completed (i.e., post-testing session).
- *VO_{2peak}:* A subject's highest volume of oxygen consumption attained during a graded cardiopulmonary exercise test (CPET).
- *1-RM:* one repetition maximum; exercise used to assess the maximum amount of weight that can be lifted with proper form one time.
- *EMG:* Technique used to assess and evaluate the activation of the VL via electrical signals that is brought about by physiological processes; i.e., during a maximal voluntary contraction (MVC).

- *Peak Torque:* The greatest amount of torque produced during the isokinetic load range in leg extension muscle action at 60°/second.
- *Learning Effect:* Phenomenon that occurs after the initial testing session; i.e., subjects know what to expect the second time and greater changes are observed.

<u>Delimitations</u>

- All subjects will be female between 35-65 years of age.
- All subjects will not have regularly participated in any exercise program for the past 6 months prior to the study, deeming them as sedentary.
- All subjects will be familiarized with facilities, exercises, and testing protocols being used prior to taking baseline measurements in order to reduce the learning effect.
- All subjects will be recruited from the central North Carolina area via flyer, email, face to face, and phone call.
- All subjects will be cleared by a physician for exercise participation prior to participating in the study.

<u>Assumptions</u>

- All subjects will follow the pre-assessment guidelines prior to testing sessions.
- All subjects will give their maximal effort during testing sessions.
- Subjects will not participate in any other forms of exercise or diet while participating in the study.
- All subjects will honestly report medical history and any discomfort that occurs throughout the study.

Limitations

- The results of this study may only apply to those whom are women, sedentary, apparently healthy and between the ages of 35-65 years old. Results may not be applied to females of all ages and males.
- It is possible that subjects will not adhere to pre-assessment guidelines entirely as researchers will not be with them during the hours prior to testing.
- Due to the selected age range and gender, menstrual cycle could affect study results in those whom were pre-menopausal.

Significance of the Study

This study will assist fitness professionals in providing a short-term protocol that will help elicit a more accurate VO_{2peak} response assessed on a cycle ergometer in order to prescribe aerobic exercise of different intensities. No study has ever looked at a resistance training protocol this short while simultaneously testing its relationship on the cardiopulmonary system. Most studies of this nature have looked at the effects of resistance training on aerobic capacity on more of a long term basis, but rather leg muscle mass (LMM), cross sectional area (CSA), and strength values from 1-RM. Further, it is of interest to utilize this protocol, or one of similar nature, in other populations as well, such as breast cancer patients. Despite a paucity of data, a common occurrence during a CPET for most patients undergoing cancer treatment is a cessation of the graded exercise bout due to the inability of the lower limbs to produce enough force to withstand the resistance on the cycle ergometer, rather than truly maxing out their cardiopulmonary system. This phenomenon is similar to that as mentioned by Neder et al. (1999) in sedentary individuals. Recent data published by E. S. Evans et al. (2015) has shown that sedentary females and breast cancer patients are similar in terms of their anthropometric characteristics and cardiopulmonary capacities. For these reasons, the present study has initially chosen to pilot this protocol in sedentary females with hopes of continuing to implement in a breast cancer population in the future.

CHAPTER II

REVIEW OF LITERATURE

For organizational purposes, Chapter II was divided into the following sections: SECTION I. Physiological effects of aging, disuse, and disease on skeletal muscle; SECTION II. Skeletal muscle and functional capabilities; effects of resistance training; SECTION III. Skeletal muscle and aerobic capacity; effects of resistance training; SECTION IV. Overview of neuromuscular physiology; SECTION V. Short-term adaptations to resistance training. Results discussed from the articles within this section have been selected to provide a history and proper rationale for the study at hand.

Physiological effects of aging, disuse, and disease on skeletal muscle

Aging

With aging comes the inevitable loss of skeletal muscle mass. It has been estimated that by the age of 65, individuals will have lost up to 25 to 30% of their skeletal muscle mass as a result of the natural aging process, contributing to losses of strength and functional ability (Brooks, Fahey, & Baldwin, 2005). Specifically, Frontera et al. (1991) were able to show through a cross-sectional research design that an 8% decline rate in overall strength can occur as early as the third decade of life, and the greatest decline in skeletal muscle mass will likely occur between the ages of 50 and 69. Further, it has been reported this process can begin as early as the age of 25 (Lexell, Taylor, & Sjostrom, 1988). Those who are subject to an excessive loss of skeletal muscle mass are more prone to become diagnosed with sarcopenia. Sarcopenia can be defined as a loss of muscle mass (degree of muscle impairment) large enough to significantly hinder one's ability to perform physical and functional tasks (Rolland et al., 2011). It has been hypothesized that both muscle atrophy and hypoplasia, the loss of muscle fibers, play a role in this aging process of losing skeletal muscle (Brooks et al., 2005). Additionally, further mechanisms that have been reported to contribute to skeletal muscle loss include motor unit remodeling (Doherty, Vandervoort, Taylor, & Brown, 1993) and a dropout of the alpha motor neuron (W. F. Brown, 1972). These concepts, as well as supplementary contributors to the age-related loss of skeletal muscle, will be discussed in detail within this section.

Research as early as 1972 has been conducted in order to formulate a reason as to why individuals lose skeletal muscle mass as a result of aging. W. F. Brown (1972) was one of the first studies to establish that older individuals exhibited a significantly lower amount of motor units for a given muscle when contracted. The explanation for the loss of motor units was not discovered. However, it was apparent that with increasing age, a significant drop in motor units was observed in the thenar muscle for individuals at 60 years of age and above (W. F. Brown, 1972). Other early studies, such as Lexell, Henriksson-Larsen, Winblad, and Sjostrom (1983), set out to provide an explanation for skeletal muscle loss from a different perspective. Specifically, Lexell et al. (1983) chose to examine the vastus lateralis of young and older men with a histochemical technique to determine if muscle fiber loss played a role in skeletal muscle loss; and if it did, was it predominantly a drop out of Type I fibers, or Type II. Analysis of the results indicated that not only did older males show smaller cross-sectional area and total number of fibers in the vastus lateralis than their younger counterparts, but also 60% of the fiber reduction was attributed to the loss of Type II muscle fibers (Lexell et al., 1983). In order to confirm that skeletal muscle loss was highly associated with the loss of Type II fibers, Lexell et al. (1988) was able to show through cross-sectional analysis that muscle fiber size was poorly associated with muscle cross-sectional area, whereas the numbers of muscle fibers was highly associated. Doherty et al. (1993) was able to take these two theories and ultimately connect them to provide a plausible explanation for the age-associated loss of skeletal muscle. With the use of spike-triggered averaging, Doherty et al. (1993) was able to determine that not only did older individuals provide a lower value for the estimated number of motor units in the biceps, but they also noticed a remodeling of the alpha motor unit. Essentially, with aging, Type II motor units (alpha I) are reinnervated into forming Type 1 motor units (alpha II), causing Type 1 muscle fibers to continuously become activated and Type II muscle fibers dropping out due to their inactivation (Brooks et al., 2005). Overall, there is a multitude of factors that contribute to the loss of skeletal muscle mass with aging. Older individuals seem to have a dropout or a remodeling of alpha motor neurons that lead to a decreased activation of Type II muscle fibers. This decreased activation leads to a drop out of Type II muscle fibers as a whole or even an inhibition of contractile properties due to intramuscular fat and connective tissue accumulation within the skeletal muscle (Lexell et al., 1988).

With the physiological mechanisms underlying skeletal muscle loss established, more recent literature has set out to establish the trend of decreased strength with age and its association with the loss of skeletal muscle. Roos, Rice, Connelly, and Vandervoort (1999) set out to explore the differences in strength as assessed by isometric strength testing in young and older individuals. When compared to each other, older individuals showed a 48% decrease in maximal voluntary contractions (torque) during the isometric strength testing, as well as slower contractile speeds (Roos et al., 1999). Despite these differences, Roos et al. (1999) discovered that older individuals were still able to fully activate their muscle, indicating that the loss of strength did not appear to occur as a result of an inhibition of the central nervous system. Rather, it was a peripheral issue. Specifically, the results indicate that age-related muscle weakness may be more related to the number of muscle fibers present as well as the majority of these muscle fibers being of the Type 1 category (Rice, Cunningham, Paterson, & Lefcoe, 1989). Similarly, V. A. Hughes et al. (2001) examined knee extensor strength through isokinetic testing at 60°/sec while simultaneously observing muscle mass through creatinine excretion over a period of 10 years. Results of the study indicated that as age increased, strength of the knee extensors significantly decreased, muscle mass of the knee extensors was positively related to changes in knee extensor strength, and females had a larger percent change in strength in the lower body than did males (V. A. Hughes et al., 2001). Not only does this study back up the claims that the age-related muscle size is strongly correlated with the age-related strength loss; but it seems as if females experience a greater decrease, putting them at a greater risk of developing sarcopenia and functional impairment. With these studies in mind, the trend of losing skeletal muscle mass and strength with the aging process alone is well established. However, issues such as sedentary lifestyles and disease can, in essence, accelerate the loss of the skeletal muscle and strength.

Disuse / Sedentary Lifestyle

The terms “sedentary” and “physically inactive” are distinct yet related to one another. Individuals whom are physically inactive typically are more susceptible to sedentary lifestyles. Tremblay, Colley, Saunders, Healy, and Owen (2010) define “physically inactive” as the amount of time one is not engaged in activity at a pre-determined intensity and “sedentary” as low levels of activity, typically less than or equal to 1.5 METS. In addition to the natural aging process, inactivity plays a significant role in the loss of muscle mass and strength. Decreased physical activity resulting in sedentary lifestyles and disuse of skeletal muscle typically produce muscular adaptations of muscle cross sectional area and muscle fiber reductions (Brooks et al., 2005). Kasper, White, and Maxwell (1990) were able to show a significant decrease in overall muscle mass and fiber cross sectional area in the soleus muscle during a period hind-limb suspension. Indeed, this study was completed in animals. However, the results of the study provided a good indication about the influence of reduced physical activity on skeletal muscle.

Lack of physical activity and sedentary lifestyles have been shown to be strongly associated with an increase in mortality rate in older men (Hakim et al., 1998). Hakim et al. (1998) were able to show that older men whom walked less than one mile per day were nearly twice as likely to experience an earlier onset of mortality. Additionally, Hakim and associates discovered that of those who did experience mortality at an earlier stage in life, 13.4% of those died of cancer.

Despite the significant association provided, the section at hand is focused on the relationship of decreased physical activity and its influence on skeletal muscle mass and strength. Kuta, Parizkova, and Dycka (1970), were able to show early on that there was an association between physical activity level and muscular strength. Through field-based dynamometry, results indicated that knee flexor strength of men within the “no exercise” group was significantly less than that of those were had regularly exercised or had been physically active for 15 years prior to the study (Kuta et al., 1970). Not only did Kuta et al. (1970) show that lack of physical activity decrease muscular strength, but regular physical activity can assist in maintaining muscular strength and attenuating the loss that occurs as a result of the natural aging process. Further, females have been shown to elicit greater strength decreases with sedentary lifestyles when compared to males (Rantanen, Era, & Heikkinen, 1997). With the use of validated physical activity scales, handgrip dynamometry, and isometric / isokinetic strength testing, Rantanen et al. (1997) provided data that indicated a greater loss of strength in inactive females when compared to inactive males during post testing. Moreover, baseline data provided significant correlations between strength scores and activity levels of females. Specifically, those that started the study classified as “sedentary” produced lower strength scores at baseline than did the females that started the study classified as “active” (Rantanen et al., 1997). Similarly, Kostka, Rahmani, Berthouze, Lacour, and Bonnefoy (2000) were able to provide evidence for strong links between physical activity and muscle function, specifically, quadriceps strength. For example, increased quadriceps power, as obtained by dynamometry, was seen in those whom were regularly engaged in sports activity, as gauged through completion of a questionnaire (Kostka et al., 2000). In addition, lack of muscle mass has been shown in women who were considered to not have been regularly engaged in physical activity, ultimately leaving them prone to issues such as osteopenia and osteoporosis (Walsh, Hunter, & Livingstone, 2006).

Regardless of gender, the evidence appears convincing that lifestyle choice plays a significant role in the loss of muscle strength and muscle mass in addition to the natural aging process. This phenomenon appears to have a greater impact on females as well. As briefly mentioned throughout, a lack of physical activity has an impact on the increased rate of mortality (Hakim et al., 1998) as well as increased susceptibility to diseases (Walsh et al., 2006). As it will be discussed in more detail in the next section, diseases, such as cancer, that can result in earlier decades of life with decreased physical activity (Sesso, Paffenbarger, & Lee, 1998), is another factor in which the age-related to loss to skeletal muscle mass and strength can be accelerated.

Cancer: Effects on skeletal muscle loss and strength

Cancer patients undergoing treatment (chemotherapy, radiation, etc.) occasionally experience excessive weight loss. For many professionals within the oncology field, this excessive weight loss is termed "cachexia". Cachexia has been said to occur by many proposed mechanisms such as energy intake and substrate metabolism (K. C. Fearon & Moses, 2002). However, only until recently has there been a definition that is widely accepted among the medical community. Ultimately, cachexia can be defined as "a multifactorial syndrome characterized by an ongoing loss of skeletal muscle mass that cannot be fully reversed by conventional nutritional support and leads to progressive functional impairment" (K. Fearon et al., 2011). Additionally, the loss of skeletal muscle mass can occur with or without the loss of fat mass (K. Fearon et al., 2011). The loss of skeletal muscle during cancer treatment remains an important issue today due to its relation with morbidity. It is a prominent cause of cancer reoccurrence as well as mortality (K. C. Fearon & Moses, 2002). In the last decade, researchers have sought out the specific mechanisms behind the occurrence of cachexia in order to develop counter-acting protocols to prevent the significant loss of skeletal muscle mass, and in the same context, skeletal muscle strength.

A review by Costelli and Baccino (2003) indicated that a potential mechanism behind cachexia in cancer patients is the Ubiquitin-Proteasome System, in which proteins are broken down. The authors claimed that it is likely that this system holds primary responsibility over the onset of cachexia due to its enhancement in response to cancer. Despite this, more recent literature has indicated that pro-inflammatory cytokines (i.e., IL-6 & TNF-α) play a more prominent role in the loss of muscle mass (K. C. Fearon & Moses, 2002). Further, C. L.

Battaglini, Hackney, and Goodwin (2012) have proposed a hypothetical model entitled Exercise Anti-Cachectic Hypothetical (EACH) in order to demonstrate this process. The model depicts the role of exercise training on skeletal muscle through the up-regulation of anti-inflammatory cytokines as well as androgenic hormones as an acute response. The up-regulation that occurs has induced protein synthesis within the skeletal muscle and has inhibitory effects on pro-inflammatory cytokines that often rise as a result of cancer and cause sarcopenia, decreased quality of life, and increased morbidity. This model is supported by observing these responses to exercise training in breast cancer patients (C. Battaglini et al., 2007) and leukemia patients (C. L. Battaglini et al., 2009).

With the mechanism behind cachexia now widely accepted, it is important to recognize that along with muscle mass, cancer can repress muscular strength as well, which can hinder functional capabilities and quality of life of the patients. Monga et al. (1997) examined the neuromuscular fatigue in prostate cancer patients undergoing radiation therapy via isokinetic and isometric strength testing. Despite the statistical procedures indicating non-significant differences between pre and post treatment measurements, it was clear that the patients did indeed lose muscular strength and as well as a decrease in their neuromuscular efficiency, indicating greater impact of fatigue (Monga et al., 1997). More recent research examining muscular strength in cancer populations has sought out to explore other factors that may play role in its loss in response to cancer treatments, such as physical activity (Yee et al., 2014). Vardar-Yagli et al. (2015) explored the associations among physical activity, comorbidity, functional capacity, and their influence on muscular strength in early stage breast cancer patients. Results indicated that the isometric strength of the rectus femoris in breast cancer patient was strongly correlated with physical activity as assessed by the IPAQ total walking score, as well as comorbidity (Vardar-Yagli et al., 2015). This study displayed the importance of remaining physically active for breast cancer patients. Not only did being physically active elicit greater strength scores, it left the patients at a lower risk of comorbidity. By training, breast cancer patients can increase their strength and attenuate the risk of developing other diseases as well as the reoccurrence of the breast cancer itself.

Skeletal muscle and functional capabilities; effects of resistance training

Functional Ability

With the loss of skeletal muscle mass and strength, early to recent literature have discovered significant associations between this epidemic and the ability to perform activities of daily living (i.e., functional tasks). Functional tasks include, but are not limited to, carrying groceries, standing up from a chair, and walking. Sarcopenia and its influence on functional ability has been an area of interest to many researchers. With the assistance of the NHANES III study to determine functional impairment, Janssen, Heymsfield, and Ross (2002) discovered that those deemed with Class II sarcopenia, as determined by bioelectrical impedance, were strongly associated and more likely to develop the inability to perform functional tasks. Additionally, more recent research has exhibited that those with sarcopenia elicit slower gait and walking speeds (Tanimoto et al., 2013). Given that resistance training can diminish or even reverse the effects of sarcopenia, it would be ideal to suggest that older and sedentary individuals should participate in resistance training programs to attenuate the risk of functional impairment (Frontera, Meredith, O'Reilly, Knuttgen, & Evans, 1988).

With a reduction in muscle mass, typically a reduction of muscle strength occurs as well. Strong relationships between isometric lower limb strength and time to complete functional tasks have been displayed in earlier literature (M. Brown, Sinacore, & Host, 1995). M. Brown et al. (1995) were able to show that older individuals whom acquired lower overall muscle strength in the lower limbs, produced greater time trials in order to complete 5 chair stands and produced slower gait speeds. M. A. Hughes, Myers, and Schenkman (1996) found similar results in the chair rise and strength measures in older individuals when compared to younger participants. It's apparent that with a reduction in isometric strength in the lower limbs, the ability to rise from a chair becomes increasingly difficult and almost impossible for some individuals (M. A. Hughes et al., 1996). Older individuals lose their ability to generate the strength and power required for this task. Some literature even claims that muscle power, rather than muscle strength, is the main contributing factor to this decreased functional ability (Foldvari et al., 2000). The reasoning behind this involves the idea that most functional tasks involve the ability to generate force at a greater velocity, rather than just generating force in itself (Bassey et al., 1992). Foldvari et al. (2000) discovered through regression analyses that older individuals that produced lower peak power outputs on the leg press were also more prone to functional disability. Peak power output was the only variable, besides physical activity, that was an independent predictor of functional disability. Overall, the impact that skeletal muscle mass/strength loss has on functional ability is detrimental. However, attenuations can be accomplished with proper training

Effects of resistance training (Functional Ability)

With the decrease in skeletal muscle mass and strength naturally occurring with aging, a plausible method to attenuate this loss is resistance training. Despite the current study not specifically observing the influence of 2 weeks of resistance training on functional capabilities, the topic is relevant to discuss due to resistance training having positive influences on aspects other than aerobic capacity. In the elderly, strength gains and increases in the cross-sectional area of elbow flexors and leg extensors have been observed simultaneously in response to 12 weeks of resistance training (A. B. Brown, McCartney, & Sale, 1990). Indeed, the cited study was conducted in elderly males. However, middle-aged women, both pre and post menopausal, have experienced positive adaptations to resistance training in forms of increased upper and lower body strength and improved body composition with 8 to 12 weeks of training (Benton, Kasper, Raab, Waggener, & Swan, 2011; Kemmler, Lauber, Engelke, & Weineck, 2004). Similarly, in response to a training program consisting of both aerobic and resistance training, breast cancer patients have been reported to significantly improve both body composition and muscular strength (C. Battaglini et al., 2007).

With it well established that resistance training can improve muscular strength in both aging populations (middle-aged and elderly) and diseased populations such as cancer, the influence that it has on functional capabilities in these same populations has become an important area of research. Functional tasks such as stair climbs, chair stands, and walking have been examined in accordance with resistance training programs to examine the effect that the training has on these activities of daily living. Additionally, studies have implemented different training protocols and have observed similar improvements in task such as chair stands and various walking tests (Hanson et al., 2009; Henwood & Taaffe, 2006; Pinto et al., 2014). Hanson et al. (2009) put participants through 22 weeks of resistance training. As a result, both sedentary males and females collectively improved upon their functional capabilities. Hanson and his associates reported significant improvements in the rapid walk, get up and go, and 5-chair stands functional tests. In a study conducted by Henwood and Taaffe (2006), participants were subjected to 8 weeks of resistance training at high velocity. Training consisted of chest press, leg press, leg curls, leg extensions, rows, and bicep curls. Post-training, it was observed that the participants had significantly improved on their functional capabilities, which was observed through the completion of a chair rise exercise. Further, the stair climb ability of the participants was approaching significance during post-testing. Similarly, Pinto et al. (2014) was able to see improvements in functional capabilities, as measured by 30-second sit to stands and 8-foot up and go tests, in as little as 6 weeks of resistance training. It should be noted that this took place in sedentary females, a similar population as to what the current study will be looking at.

In addition, similar results have been observed in breast cancer patients. Despite the lack of resistance training research within oncology, the results of the two studies discussed below are promising for the field of exercise oncology. For example, recent research has shown that in as little a 8 weeks of traditional resistance training, breast cancer patients have improved their functional capabilities in terms of increasing the number of repetitions in an arm curl test and increasing the number of chair stands they can complete in 30 seconds regardless of their age (Benton, Schlairet, & Gibson, 2014). In the same study, Benton et al. (2014) discovered an increase in overall quality of life in their cancer patients as well. An earlier study on the effects of resistance training on breast cancer patients' functional capabilities reported significant improvements in the 12-minute walk (Schwartz, Winters-Stone, & Gallucci, 2007). Overall, it is apparent that resistance training has an overall positive impact on functional capability and skeletal muscle in general when it comes to sedentary and diseased populations.

Skeletal muscle and aerobic capacity; effects of resistance training

Aerobic Capacity

Age-related declines in aerobic capacity, regardless of training status, have been well documented within past literature as indicated by a meta-analysis published by Fitzgerald, Tanaka, Tran, and Seals (1997). This decline is similar to that of the age-related loss of skeletal muscle mass and strength. The inhibitory influence that skeletal muscle mass/strength loss has on an individual's aerobic capacity includes the inability to produce the amount of force required to withstand the resistance on during a cardiopulmonary exercise test (CPET) (Neder et al., 1999). Ultimately, this results in an earlier cessation of the test and VO_{2peak} values that are not necessarily a true representation of the individual's aerobic capacity. Many studies have examined the relationship between skeletal muscle mass and VO_{2peak} values. Fleg and Lakatta (1988) conducted one of the first studies to establish this relationship. The researchers measured creatinine excretion in older and younger individuals to estimate skeletal muscle mass and compared this value to their VO_2max values. Essentially, the authors discovered that with advancing age, the loss of skeletal muscle mass plays a significant role in the reduction of aerobic capacity (Fleg & Lakatta, 1988). In 2005, with more advanced technology, Fleg et al. (2005) found similar results as in 1988. The authors found that with advancing age, a reduction in fat free mass independently predicts VO_{2peak} as individuals continue to age. The significance of the two studies is that each was conducted in a different population. In 1988, Fleg and Lakatta tested sedentary individuals leaving a limitation as to if this phenomenon actually occurred in other populations. In the 2005 study, Fleg et al. debunked this statement by reporting a similar relationship in healthy and active individuals, both male and female.

With Fleg and Lakatta (1988) establishing this relationship between skeletal muscle and aerobic capacity, more recent literature has made good use of advances in technology to further examine the relationship. Specifically, studies have observed reductions in lean mass in accordance with aerobic capacity with more reliable body composition methodology, such as skinfolds (Jackson et al., 1995), underwater weighing (Toth, Gardner, Ades, & Poehlman, 1994), and DEXA scans (Proctor & Joyner, 1997). Additionally, researchers have been able to examine the influence that physical activity and disease has on this relationship. Ultimately, multiple researchers have been able to establish a "cascade of events" that leads to this reduction in aerobic capacity. As aging occurs, reductions are observed physical activity. The reduction in physical activity, as we know from recent literature previously discussed, accelerates the reduction in lean mass, which in turn reduces an individual's aerobic capacity (Jackson et al., 1995). Proposed mechanisms include the inability of the quadriceps to produce an optimal power output when compared to reductions in aerobic capacity (Kostka et al., 2000). In diseased individuals, such as those with chronic heart failure, bed rest during treatment and recovery decreases their lean muscle mass where similar associations have been observed in measured VO_{2peak} values as with healthy individuals with decreased muscle mass (Cicoira et al., 2001; Mancini et al., 1992). Declines in aerobic capacity with age and physical activity level have been well established. This relationship has lead researchers on a path to attenuate this decline with not aerobic training, but with resistance training.

Effects of resistance training (Aerobic Capacity)

Early research has been able to establish a positive relationship between aerobic capacity and endurance performance variables with resistance training, despite a few studies that have reported mixed results (Keeler, Finkelstein, Miller, & Fernhall, 2001). For instance, O'Bryant, Byrd, and Stone (1988) took a group of college-aged males and tested the impact that periodized resistance training had on endurance performance variables on a cycle ergometer, specifically power output. The researchers discovered, that along with increases in strength, the participants significantly increased their power output on the cycle ergometer (O'Bryant et al., 1988). Even though this study did not specifically look at the VO_2 of the individuals, its results helped establish a relationship between resistance training and endurance performance. Similarly, studies in years to follow examined parallel relationships such as the effects of weight training on walking endurance, whose results were analogous to those of O'Bryant et al., (1988) (Ades, Ballor, Ashikaga, Utton, & Nair, 1996).

With it well established that aerobic capacity declines with aging, and their initial weight training studies in older men providing evidence that resistance training does indeed improve the overall size of skeletal muscle as well as functionality of the individual, Frontera, Meredith, O'Reilly, and Evans (1990) set out to explore how resistance training impacted the aerobic capacity (VO_{2peak}) of older men. As one of the first and most highly cited studies on this particular subject matter, Frontera et al. (1990) discovered that resistance training did indeed have a significant and positive impact on VO_{2peak} in older men. In particular, participants were assigned to 12 weeks of resistance training. Muscle fiber area was assessed by muscle biopsy and VO_{2peak} was assessed by cycle ergometry. As a result of resistance training, not only did absolute VO_{2peak} increase from pre to post, but positive correlations between activity of the vastus lateralis and VO_{2peak} were observed, leading the researchers to conclude that with aging, resistance training is a viable method in not only increase skeletal muscle function, but an individual's aerobic capacity as well (Frontera et al., 1990).

As a result of Frontera et al. (1990) findings, many other researchers have commenced on researching the same relationship, but in different populations. Vincent et al. (2002) examined this relationship between resistance training and aerobic capacity in elderly males and females, rather than just elderly males. In their study, Vincent et al. (2002) studied the effects of high-intensity resistance training and low-intensity resistance training on aerobic capacity. Results indicated that both high and low intensity resistance training significantly improved VO_{2peak} with no differences between the two groups (Vincent et al., 2002). Ultimately, the study indicated that regardless of resistance training type, a positive influence can still be observed in VO_{2peak} in both male and female elderly individuals. The previous study combined the results of both males and females. However, it is important to know how females' VO_{2peak} will respond to resistance training alone. Ferketich, Kirby, and Alway (1998) did just that by exposing elderly females to a combined training program of resistance and aerobic training. Despite the combination of training, the participants produced greater increases in strength and VO_{2peak} post-training when compared to the endurance only group and control group (Ferketich et al., 1998).

More recent research has explored the effects of resistance training on VO_{2peak} in special female populations such as those whom are postmenopausal and breast cancer patients. Postmenopausal participants have been reported to significantly improve aerobic capacity in response to both high intensity resistance training as well as circuit weight training (Brentano et al., 2008). Those with breast cancer have reported similar results, despite participating in a resistance-training program combined with walking (Rahnama, Nouri, Rahmaninia, Damirchi, & Emami, 2010). These results show that there is indeed a relationship between VO_{2peak} and strength training in a female population. In being able to prescribe aerobic exercise of different intensities off of an individual's VO_{2peak}, the accuracy of this value becomes even more important. With many studies indicating that strength training can increase VO_{2peak} in similar populations (female, sedentary, breast cancer), resistance training comes across as a viable method to help improve the accuracy of aerobic exercise prescription. However, the studies discussed in this section contain training protocols that last from 8 weeks to as long as 24 weeks. To exercise professionals wanting to prescribe aerobic exercise, a protocol of these lengths is time consuming and not efficient. Early research has reported strength gains in response to resistance training as early as 2 weeks, without increases in cross-sectional area indicating an increased efficiency in neuromuscular aspects of skeletal muscle (Moritani & deVries, 1979). With this in mind, it is logical to test this relationship with a shorter protocol targeting neuromuscular adaptations to increase VO_{2peak} on a cycle ergometer. Before short-term adaptations to resistance training are discussed, an overview on neuromuscular physiology is provided.

Overview of Neuromuscular Physiology

An overview of neuromuscular physiology begins with an explanation of resting membrane potentials and their excitability in concurrence with an action potential. Membrane potentials are regulated by the sodium-potassium pump (Na-K pump). In the resting state, muscle cell resting membrane potentials carry a slightly negative charge. This is due to an increased permeability of the muscle cell to K ions, resulting in more K ions diffusing out of the cell than Na ions diffusing in (Brooks et al., 2005). In turn, the membrane potential of a muscle cell leads to an action potential that helps stimulate muscular contractions. Action potentials are rapid changes within the muscle cell's net charge. Essentially, a rapid excitation occurs in which the inside of the muscle cell becomes positively charged and the outside becomes negatively charged. This is the opposite charge of the membrane when it is at rest. The physiological mechanism that brings about an action potential is a product of the membrane's increased permeability for Na rather than K (Brooks et al., 2005). This has also been referred to as the "all or nothing principle". Ultimately, as the membrane's permeability for Na increases, at a certain point a threshold is reach. At this point, a point of excitability occurs inside the muscle cell due to a rapid influx of Na. As a result of the rapid influx, an action potential is generated.

Action potentials are brought about by excitatory post-synaptic potentials (EPSP) and inhibited by inhibitory post-synaptic potentials (IPSP). Excitatory post-synaptic potentials involve the release of acetylcholine. Acetylcholine increases the membrane potential's permeability for Na, gradually getting it closer to the voltage threshold where an action potential will always take place. The excitatory events can occur via spatial or temporal summation. Spatial summation involves EPSP's nerve endings surrounding a single soma and releasing an abundance to neurotransmitter to bring about and action potential; whereas temporal summation involves a repeated stimulation of a pre-synaptic nerve ending to bring about an action potential (Brooks et al., 2005). Once the action potential takes place, it only lasts about close to 1 millisecond (Brooks et al., 2005). The rapid inhibition is a result of inhibitory post-synaptic potentials increasing the muscle cell's permeability for chlorine (Cl), decreasing the cell's membrane potential.

The neuromuscular junction is the final point located on the skeletal muscle where action potentials, carried by motor neurons, are sent from the central nervous system (Brooks et al., 2005). Specifically, action potentials final destination is the motor end plate where terminal branches sit on the skeletal muscle fibers. However, before this can occur, the action potential must be generated through a series of events. As action potentials reach the terminal axon, calcium channels within the plasma membrane open, resulting in the release of acetylcholine, which in turn results in the passing of Na and K passing through the newly opened channels. With the passing of these ions, depolarization of the motor end plate occurs. This can also be termed the “end plate potential”. As the motor end plate is depolarized, an excitatory response from the plasma membrane results and the action potential is then sent via the t-tubules to the muscle fibers to elicit a contraction.

Once the action potential reaches the skeletal muscle fibers, another series of events, primarily mechanical, occurs to elicit the power produced from the single action potential / muscular contraction. This can be termed the Excitation Contraction Coupling Process. After the action potential has reached the motor end plate, calcium is released into the sarcoplasm via the sarcoplasmic reticulum. The released calcium then acts upon the contractile protein troponin, resulting in another contractile protein, tropomyosin, relocating off of actin protein molecules, exposing the binding sites for myosin proteins. Myosin heads then bind to actin forming crossbridges. These newly formed crossbridges then pull on each other and create power strokes as a result of ATPase isoforms hydrolyzing adenosine triphosphate (ATP) to power the contraction. This process continues as long as ATP and calcium is present, and calcium is present as long as action potentials continue to be sent down the t-tubules.

As stated earlier, motor neurons carry the action potentials to the skeletal muscle fibers. And alpha motor neuron and all the muscle fiber it innervates can be classified as a motor unit (Brooks et al., 2005). Alpha motor neurons are classified as alpha I and alpha II. Alpha I motor neurons are typically seen in fast twitch muscle fibers. Their characteristics include fast conduction velocity, high recruitment threshold, low fatigue resistance, and they are large. Alpha II motor neurons are seen in slow twitch muscle fibers. Their characteristics are essentially just the opposite of alpha I motor neurons. Alpha II motor neurons have a slow conduction velocity, low recruitment threshold, high fatigue resistance, and they are smaller. In terms of the order of recruitment, motor neurons are typically recruited based on the amount of effort it takes to recruit one. In other words, easier motor neurons are recruited first. The easier of the two types are alpha II motor neurons. This can easily be described as the Size Principle. The Size Principle states that smaller motor neurons will be recruited first because they are easier to bring about (Brooks et al., 2005). With that said, it can be inferred that alpha II motor neurons are recruited followed by alpha I.

The above summary of neuromuscular physiology was provided in order to provide a brief background as to what occurs during a single muscle contraction. Specific to the study at hand, the length of the resistance training protocol will be primarily attempting to induce strength gains by enhancing the processes described above. In turn, with the strength gains, primarily due to enhanced neuromuscular efficiency and recruitment, that will be observed in the lower body just after 2 weeks of resistance training will ultimately influence the power that the participants will be able to generate on the cycle ergometer during the VO_{2peak} assessment, allowing them to cycle to higher training thresholds. The subsequent section will provide sufficient evidence of short-term neuromuscular adaptations to resistance training in terms of greater motor unit recruitment (number and size) as well as greater recruitment frequency (rate coding).

Short Term Adaptations to Resistance Training

It has been well established within past literature that neuromuscular adaptations play the primary role in initiating strength gains in response to a resistance-training regimen (Hakkinen, Pakarinen, & Kallinen, 1992; Moritani & deVries, 1979). The earliest and most commonly cited study that represents this physiological mechanism is that of Moritani and deVries (1979). In their study, males and females were subjected to eight weeks of isotonic resistance training of the elbow flexors. Throughout the eight weeks, strength and hypertrophy measurements were taken every two weeks. The first two testing sessions (weeks 2 and 4) showed significant increases in strength and muscle activation. However, there were not significant increases in the size of the elbow flexor muscles. From this data, Moritani and deVries (1979) were able to conclude that the primary mechanism behind early strength gains (weeks 2 and 4) were primarily due to the enhancement of neuromuscular recruitment. Further, specifically in females, similar results have been reported just after two weeks of resistance training (Hakkinen et al., 1992). In their study, Hakkinen et al. (1992) had female subjects participate in three weeks of resistance training. Isometric EMG measurements were completed after the second and third of week training. Indeed, Hakkinen et al. (1992) observed significant increases in force production and EMG after the third week of training; however, they also reported a significant increase after the second week of training as well. Based on these earlier conducted studies, strength gains early on in resistance training programs do indeed occur. Additionally, they can occur very rapidly; in as little as two weeks as reported by the two previously discussed studies.

More recent literature has explored general short-term effects of resistance exercise, training protocols lasting close to 6 weeks, and has observed positive increases in strength regardless of training volume (Candow & Burke, 2007; Radaelli et al., 2014). However, the more compelling aspect of the debate regarding short-term adaptations in response to resistance training falls under studies that have reported increases in force production with as little as two to three days of resistance training (Cramer, Stout, Culbertson, & Egan, 2007; Prevost, Nelson, & Maraj, 1999). Prevost et al. (1999) was able to show increases in torque production with two days of fast velocity isokinetic training on the knee extensors. Male participants were introduced to two days of training consisting of three sets of ten repetitions at a slow velocity (0.52 rad/s) and a fast velocity (4.17 rad/s). Despite the authors finding no significance in increases in mean torque at slow velocities, they did however discover that mean torque production to fast velocities significantly improved after training. In fact, Prevost et al. (1999) reported that the significant increases were similar to other studies that implemented longer training protocols. Given that these results are similar to data from studies of longer protocols, it can be inferred that neural adaptations play a vital role in the ability to generate torque. Furthermore, Cramer et al. (2007) was able to produce similar results with a similar study protocol with added creatine supplementation. Isokinetic leg extensions were performed at slow and fast velocities for both the supplement and control group. Results indicated that there were significant increases in peak torque for both groups, whereas the difference between the groups was not significant (Cramer et al., 2007). The data from this study indicated that three days of isokinetic resistance training on the leg extensors is sufficient to elicit smaller, but significant, strength gains, regardless of creatine supplementation.

As discussed in previous sections, past literature has explored and successfully developed a relationship between resistance training and its impact on aerobic capacity in elderly and females populations (Frontera et al., 1990; Vincent et al., 2002). Indeed, the neuromuscular adaptations that occur early on to a resistance-training program, especially in elderly and sedentary populations, are assumed. However, minimal studies have been published that have examined the relationship between the short-term adaptations (neuromuscular) to a resistance-training program and their influence on an individual's aerobic capacity. The studies that have been published have consisted of four to five week training protocols in healthy and sedentary females (Falatic et al., 2015; Kim et al., 2011; Myers, Schneider, Schmale, & Hazell, 2015). A recent study published the Journal of Strength and Conditioning Research looked at the influence that whole body aerobic resistance-training (circuit training) had on aerobic fitness and muscle strength in non-active females (Myers et al., 2015). The training protocol consisted of three days of training per week for a total of five weeks. Results from the study indicated that the circuit training did have a significant impact on the females' aerobic capacity and muscular strength in the hamstrings and chest (Myers et al., 2015). Despite the positive results, the training protocol still had an aerobic component to it. For our present study, our research team is interested in strictly resistance-training (no aerobic component) and its influence on aerobic capacity in sedentary females. With this in mind, another recent study published by the Journal of Strength and Conditioning Research examined the effects of kettle bell training, a form of resistance training, on aerobic capacity in college-aged females (Falatic et al., 2015). The researchers had their subjects participate in a four-week kettle program, training three days per week. The exercise performed was a kettle bell snatch for 20 minutes. Similar to the previous study, results indicated that the kettle bell training did indeed have a significant positive influence on the subjects' aerobic capacity (Falatic et al., 2015). However, the subjects were college soccer players, and they were still completing team workouts during their participation in the study. The lack of controlling for other physical activity could have played a role in the impact that the kettle bell training had on aerobic capacity. With that said, the results presented are questionable as to how they were truly produced from the study protocol. The one study that has examined short-term resistance training adaptations in response to traditional resistance training while simultaneously investigating the protocol's influence on aerobic capacity in females was conducted by Kim et al. (2011). In this study, college-aged females (sedentary) were subjected to four weeks of resistance training consisting of leg press and chest press exercises. Post-testing revealed that the training program brought about significant increases in the leg press exercises as well as VO_{2peak} values for the subjects (Kim et al., 2011). Overall, based on recent literature, there seems to be a potential relationship between short-term adaptations to resistance training and an individual's aerobic capacity. With the study at hand, we have chosen a gender, age range, and delimited to sedentary individuals in order to have the best chance possible of observing neuromuscular adaptations to a lower body resistance training in as little as two weeks while simultaneously observing increases in aerobic capacity.

CHAPTER III

METHODOLOGY

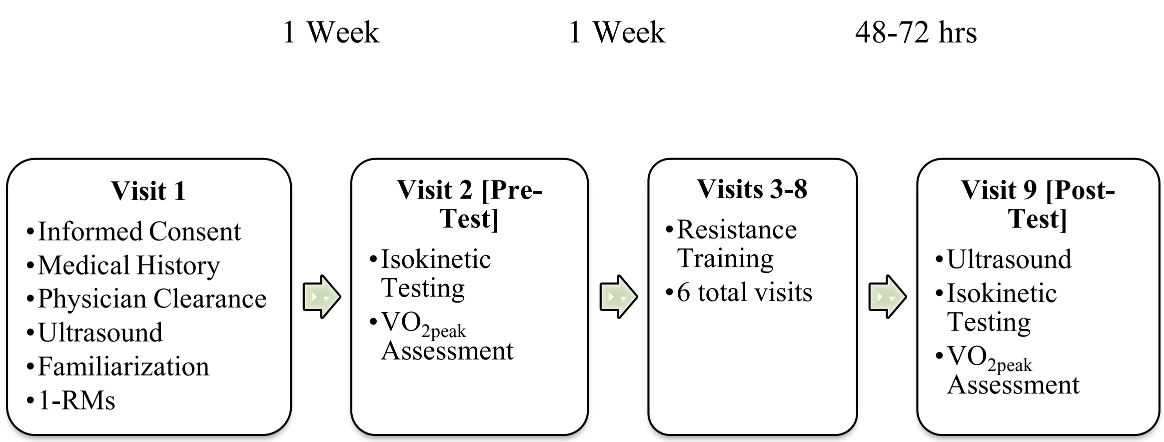
Subjects

Eighteen subjects were recruited for this single arm, repeated measures study. All recruited subjects were assigned to the intervention group. Recruitment for the study was completely voluntary, as subjects were made aware of the project via flyers, emails, phone calls, and face-to-face interaction with research team members. Recruitment sites included areas that fell within that of central North Carolina. Approval from the Institutional Review Boards in Exercise and Sport Science and School of Medicine (Biomedical) at UNC-Chapel Hill was obtained before commencing with the recruitment of subjects.

All subjects participating in the study were between 35 to 65 years of age and sedentary. The sedentary nature of the participants was determined by not having participated in regularly scheduled exercise more than once a week for at least six months prior to beginning the study. Interested subjects were enrolled in the study if they presented no cardiopulmonary and musculoskeletal disease that would preclude their participation in any aspect of the study as determined by a physician physical evaluation. Subjects were screened for exclusion based upon the criteria presented by the American College of Sports Medicine (ACSM) as contraindications to exercise testing (Pescatello & American College of Sports, 2014).

The subsequent paragraph is a brief overview of each visit the subjects attended throughout the course of the study. Visit one included the physical screening, informed consent, ultrasound assessment, familiarization of testing procedures described below, and 1-RM assessment. Visit two included the pre-intervention testing procedures of the VO_{2peak} assessment and the isokinetic EMG assessment of the VL, respectively. The next six visits took place over the course of two weeks with 48 to 72 hours separating each visit. These sessions made up the two weeks of lower body resistance training. The ninth and final visit included the post-intervention testing sessions of the ultrasound assessment, VO_{2peak} assessment, and the isokinetic EMG assessment of the VL, respectively. Figure 1 provides a visual timeline of the visits described above.

Figure 1. Study Timeline



Instrumentation

Anthropometric / Screening

Height was measured to the nearest 0.1 cm via a Portable stadiometer (Perspective Enterprises, Portage, MI USA), and mass was measured to the nearest 0.1 kg via a mechanical scale (Detecto, Webb City, MO USA). Ultrasound (US) images to assess cross-sectional area (CSA) of the VL were obtained by a brightness mode (B-Mode) portable ultrasound-imaging device (LOGIQ$^{e\ 5}$, General Electric Company, Milwaukee, WI, USA) along with a multi-frequency linear-array probe (12L-RS; 5-13 MHz; 38.4 mm FOV) (General Electric Company, Milwaukee, WI, USA) and hypoallergenic water-soluble gel (Aquasonic 100, Parker Laboratories, Inc., Fairfield, NJ, USA) in order to enhance signal. US images were analyzed with LogicView™ software (General Electric Company, Milwaukee, WI, USA).

A medical history questionnaire (Department of Exercise and Sports Science) was used to log the subjects' medical history, age, race, and relative physical activity level within the past year. This was utilized in conjunction with the physical examination and resting electrocardiogram (EKG) in determination of participation in the study. The resting EKG was accomplished by a GE CASE Cardiosoft V. 6.6 ECG diagnostic system (General Electric, Palatine, IL USA). Additionally, blood pressure was measured manually by auscultation via a Diagnostix 700 aneroid sphygmomanometer (American Diagnostics Corporation, Hauppauge, NY USA) and a Litmann stethoscope (3m, St. Paul, MN USA).

Cardiopulmonary

VO_2peak was assessed by a Parvo Medics TrueMax 2400 Metabolic System (Parvo Medics, Salt Lake City, UT USA) on a Lode electronically braked cycle ergometer (Lode, Gronigen, The Netherlands). Subjects' respiratory responses were obtained by use of a Hans Rudolph 7450 Series V2 Respiratory Valve (Hans Rudolph Inc., Shawnee, KS, USA). Rate of perceived exertion (RPE) was assessed via a Borg 6-20 Rate of Perceived Exertion (RPE) scale. Heart rate was monitored via a Pacer Polar heart rate monitor (Polar Electro Inc., Lake Success, NY USA).

One Repetition-Maximum (1-RM) / Strength Testing

A 1-RM for the leg press and leg extension exercise was completed on York 35 Degree Leg Press (York, PA USA) and a Body Solid GCEC340 Leg Extension machine (Forest Park, IL, USA), respectively, for purposes of prescribing the two weeks of resistance training that occurred. Strength testing took pace on a HUMAC Norm Dynamometer (Computer Sports Medicine Inc., Stoughton, MA, USA) in accordance with surface electrode (TSD150B 35mm, Biopac Systems, Inc., Santa Barbara, CA, USA) EMG.

Procedures

All subjects reported to the Exercise Oncology Research Laboratory (EORL) and the Neuromuscular Research Laboratory (NMRL) on a total of three separate occasions related to familiarization and testing purposes. The first two visits included a familiarization session and a pre-testing session. The final visit included the post-testing session. Before reporting for testing sessions, subjects were required to follow a set of pre-assessment guidelines and were questioned as to if they followed the guidelines upon arriving to the lab. These guidelines included maintaining a proper hydration status as assessed by an American Optical, Hand Held TS Meter (Keene, New Hampshire, USA) refractometer, being at least two hours fasted, no caffeine consumption at least eight hours prior, and no alcohol consumption at least twenty-four hours prior. In between the pre and post testing sessions, subjects reported to the Human Performance Center (HPC) at Fetzer Hall for a total of six sessions to take part in the two-week lower body resistance training protocol. All subjects within the study were required to undergo a physical screening by a physician in accordance with a 12-lead EKG, medical history questionnaire, and PAR-Q form. All visits took place in the EORL, HPC, or NMRL.

Visit One: Physical Screening, Ultrasound, Familiarization of Testing Procedures, 1-RM

The first visit to the laboratory included signing of the informed consent form, completion of the medical history questionnaire, PAR-Q, and a 12-lead resting EKG as part of the physical examination by a physician member of the research team. Height and weight was then obtained. Subjects then took part in the US assessment as well as the 1-RM testing of the leg press and leg extension exercises.

Ultrasound

For the US assessment, subjects lied supine for ten minutes on a table to allow for fluid shifts with their right lower limb in a relaxed position at full extension. Scanning sites for the CSA of the VL was determined by taking half the femur length as obtained by measuring the full length from the greater trochanter to the femoral condyle using a Gulick tape measure (AliMed, Dedham, MA, USA) (Kleinberg, Ryan, Tweedell, Barnette, & Wagoner, 2015). US transmission gel was then applied to the subjects skin and probe in order to enhance signal with the US imaging device. A probe support was used to ensure that the probe scans perpendicular to the VL along the transverse axis (lateral to medial). Three consecutive panoramic scans of the VL at a gain of 50dB and a depth of 5.0 cm (Mangine et al., 2014) were taken in order to assess CSA. The greatest CSA value obtained from the three separate scans was used for data analysis.

Familiarization

Subjects were then familiarized with the testing protocols so they would become aware and comfortable with the testing procedures. Initially, subjects were taken to the NMRL to be familiarized with the isokinetic EMG assessment. For the EMG familiarization, subjects were asked to sit in the dynamometer chair, and a member of the research team adjusted all harnesses to replicate the actual testing session. Subjects were then instructed on the isokinetic leg extensions that occurred during the testing session on the right leg (unilateral). Once procedures had been discussed, subjects performed three consecutive isokinetic leg extensions at 50% and three consecutive isokinetic leg extensions at 75% of their perceived maximal effort. Velocity was set at 60°/second. Subjects were then familiarized with the cardiopulmonary exercise test (VO_{2peak}) on a cycle ergometer. Subjects were fitted for a respiratory mask and seat height on the cycle ergometer was adjusted for proper cycling pedaling mechanics. Subjects were then taken up to 70-85% of their target heart rate (THR) determined by the Karvonen Formula using the same testing protocol used during the pre test CPET.

1-RM Assessment

The 1-RM assessment of the leg press and leg extension was conducted in order to approximate the max strength of the subjects, and took place in the HPC for purposes of defining initial exercise training intensity. An assessment was not performed on the leg curl exercise since the muscles primarily involved in cycling are the quadriceps. Rather, the leg curl was included to balance the resistance training with both the anterior and posterior portions of the lower limbs. Before the assessment, subjects were asked to assume position on the leg press machine and instructed on proper form. Proper form included lower back and hips pressed against the seat, legs parallel with feet hip width apart and toes slightly angled out, and a slow progression of allowing the hips and knees to flex as the weight is being lowered until the hips have come off of the seat (National Strength and Conditioning, 2008). For the leg extension, the knees were aligned with the axis of the machine, and subjects were asked to perform the exercise with their back against the back pad (National Strength and Conditioning, 2008) with hands grasping the handles.

Lower weight was applied to the machines to allow subjects to warm up as well as for the tester to have a feeling on what initial weight was used for the first attempt to max. The tester then asked subjects to rate their effort during the warm-up using a Rate of Perceived Exertion scale so to guide the tester on the initial load to be used to determine the 1-RM. The 1-RM value was determined for the leg press and leg extension exercises by increasing the workload each set until subjects were unable to lift the highest possible load 1 time with proper form. A 2-minute rest was provided between each set, and a 5-minute rest was provided between the two exercises. 1-RM values for the leg press and leg extension were used to establish training intensity for the two weeks (six sessions) of resistance exercise training.

Visit Two (Pre) and Nine (Post): Testing Sessions

The pre and post visits have been combined since procedures that will be discussed in this section were identical for both sessions with exception to visit nine, which will additionally include the second ultrasound assessment. Testing procedures occurred in this order: (1) Isokinetic strength testing and (2) the VO_{2peak} assessment. A rest period of a minimum of 10 minutes and a maximum of 15 minutes was utilized between the two tests to allow for proper recovery.

Isokinetic Strength Testing

Prior to beginning the strength test, subjects were allowed to warm up on a cycle ergometer for 5 minutes at 50 Watts. Subjects were then taken to the NMRL for the isokinetic leg extension assessment. Procedures were based off those conducted by previous studies in similar populations (Bottaro, Russo, & de Oliveira, 2005; Theou, Gareth, & Brown, 2008). Subjects were placed in the dynamometer chair with harnesses placed over the shoulders, waist, and right leg. The right knee was aligned with the dynamometer's center of axis of rotation at 90° as measured by a goniometer (Model G800, Whitehall Manufacturing, Industry, CA, USA). Muscle activation was examined using EMG surface electrodes that were placed on the muscle belly of the VL at 66% of the femur length. The EMG electrodes were placed parallel to the muscle fibers of the VL and a ground electrode was placed on the tibial tuberosity of the right knee. Once electrodes were in position, subjects were instructed to complete three warm-up isokinetic leg extensions at 50% as well as 75% of their perceived maximal effort at a velocity of 60°/second. Subjects then proceeded to complete three maximal isokinetic leg extensions at a velocity of 60°/second with two minutes of rest between each contraction. The greatest peak torque and subsequent EMG amplitude values that were recorded during the isokinetic load range were used for data analysis.

All signals were collected with a Biopac MP150WSW data acquisition system and AcqKnowledge software (Biopac Systems, Inc., Santa Barbara, CA, USA) at a sampling rate of 2000 Hz. Raw EMG and torque signals were stored on a personal laptop computer (MacBook Air, Apple Inc., Cupertino, CA, USA) and analyzed with Labview 2014 software (Version 14, National Instruments, Austin, TX, USA). A fourth order, zero phase shift low pass 50 Hz Butterworth filter was used to filter the torque and a zero phase shift bandpass (10 – 500 Hz) fourth order Butterworth filter was used for the EMG signals. Peak isokinetic torque was determined as the highest 100 millisecond epoch during the constant angular velocity of 60°/second (Iossifidou & Baltzopoulos, 2000). EMG amplitude was calculated using a root mean square (RMS) function during the entire isokinetic load range (Jenkins et al., 2015). The EMG amplitude values during the maximal isokinetic testing were normalized to baseline EMG signals as described previously [(MVC amplitude / baseline amplitude) X 100] (Pamukoff, Ryan, & Blackburn, 2014).

Cardiopulmonary Fitness Assessment

The final assessment was the cardiopulmonary exercise test for the assessment of VO_{2peak}. The test was performed on an electronically braked cycle ergometer using the Astrand Cycle Ergometer Maximal Test Protocol (Heyward, 2006). Subjects began the test by sitting quietly on the cycle ergometer for three minutes while the researchers collected resting metabolic data. The first stage of the test began at 50 watts and lasted for three minutes. Each stage after stage 1 will also lasted for three minutes. An increase of 25 watts was applied at the end of each stage. HR and RPE (6-20) were continually monitored and recorded during the last minute of every stage. Termination of the test was determined by the subjects' reaching volitional fatigue and signaling to stop the test, VO_2 plateau or decrease with increase in exercise intensity, or if an abnormal subject response to the test was observed and therefore the research team will terminate the test. Once the test had been terminated, a cool down period of light intensity (< 20 Watts) was implemented until baseline levels were reached. Criteria established for VO_{2peak} is that set forth by the American College of Sports Medicine (ACSM).

Visits Three through Eight: Lower Body Resistance Training Protocol

Over a period of two weeks, subjects reported to the HPC for a total of six visits for the lower body resistance training protocol with 48 to 72 hours between each visit. Each subject began the sessions by warming up on a cycle ergometer for five minutes at 50 Watts. Subjects were then lead through three resistance training exercises including the leg press, leg extension, and leg curl. Initially, intensity for the exercises was set at 65% of the subjects' 1-RM for sessions 1 and 2. For the leg curl exercise, a moderate intensity load was used to provide subjects with hamstring training to counterbalance the heavier training of the quadriceps muscle. Subjects completed 2 sets of 8-10 repetitions with a 2-minute rest (Vieira et al., 2015) between each set and the different exercises. On sessions 3 and 4, a 10% increase in load was implemented to stimulate training effects, which follows the recommendations of the American College of Sports Medicine (ACSM) in training intensities. Subjects followed the same number of sets and repetitions followed on sessions 1 and 2. Lastly, for sessions 5 and 6, another 10% of the previous load performed on sessions 3 and 4 was implemented. However, the number of repetitions that subjects attempted to lift ranged from 5 to 10. Training sessions lasted approximately thirty to forty-five minutes. Each resistance training session concluded with a five minute cool down session consisting of various static stretches. Stretches focused on the hip and knee extensors and flexors. Further, each stretch was held for thirty seconds and performed twice.

Data Analysis

Sample Size Calculation

Power calculations for the proposed study were completed using G*Power 3.1 software (67) based on data from Falatic et al. (2015) due to gender similarities, resistance training protocol length, and primary outcome variables of VO_{2max}. With a predicted 10% of performance improvement in VO_{2peak}, mirroring the results of the aforementioned study, the proposed study sufficiently achieved a power of 0.80 with enrollment of eighteen total subjects.

Statistical Analysis

Collected data for this current study was analyzed with SPSS Statistics version 20.0. The alpha level was set *a priori* for all statistical analyses at 0.05. Descriptive statistics were used in order to exhibit the study population characteristics (age, height, body mass, etc.). Paired samples t-tests were conducted in order to compare training effects from pre to post-intervention (VO_{2peak}, PT, peak EMG amplitude, and CSA of the VL muscle). Additionally, simple regressions were used to examine the relationship between the change values in VO_{2peak} and PT and the changes in VO_{2peak} and EMG amplitude.

CHAPTER IV

RESULTS

The purpose of the study was to examine the effect of two weeks of lower body resistance training on aerobic capacity in sedentary middle aged females as assessed via a maximal CPET on a cyce ergometer. A secondary purpose of this study examined the effect of the two-weeks of lower body resistance training on muscle strength, activation and size of the VLmuscle. A tertiary purpose evaluated the relationship between changes in VO_{2peak} and muscular peak torque/activation from baseline to the completion of the two-week resistance training protocol.

Subjects

The study included a total of 18 sedentary middle aged females. Subject characteristics are presented as means $\pm$ standard deviations in Table 1 below. A total of 17 participants completed six training sessions whereas one participant completed only five out of the six scheduled training sessions. The overall adherence rate to the lower body resistance training intervention was 99.1%. Additionally, data from only 17 subjects were available to assess peak torque from pre to post intervention, as one file was excluded due to a sampling error. The subjects' characteristics are presented in Table 1 below:

Table 1: Subject characteristics; n = 18 (mean $\pm$ SD)

Age (yr)	53.6 $\pm$ 7.2
Height (cm)	162.7 $\pm$ 7.4
Pre-Weight (kg)	78.0 $\pm$ 17.2
Post-Weight (kg)	77.7 $\pm$ 17.0
BMI ($kg*m^{-2}$)	29.4 $\pm$ 6.4
Leg Press 1-RM (kg)	108.9 $\pm$ 42.1
Leg Extension 1-RM (kg)	76.1 $\pm$ 25.9
Lower Body Composite (kg) *	185.1 $\pm$ 65.8
Post Menopasual (% of participants)	16 (88.9%)

Lower body composite = Leg Press 1-RM (kg) + Leg Extension 1-RM (kg)

Training Effects

Pre and post means, standard deviations, change scores, and standard errors of the mean change (SEM) of all primary variables are presented in Table 2 below:

Table 2: Primary Outcome Variables (mean $\pm$ SD)

Outcome Variables	***PRE***	***POST***	***CHANGE***	***SEM***
VO_{2peak} ($ml*kg^{-1}*min^{-1}$)	22.2 $\pm$ 4.5	24.3 $\pm$ 4.4*	2.1	0.58
VO_{2peak} ($L*min^{-1}$)	1.7 $\pm$ 0.4	1.9 $\pm$ 0.3*	0.2	0.04
Peak Torque (Nm); n=17	83.1 $\pm$ 25.4	89.0 $\pm$ 29.78*	5.9	2.84
EMG Amplitude (%)	4250.4 $\pm$ 3135.3	5177.3 $\pm$ 3348.2*	962.8	232.9
CSA (cm^2)	17.3 $\pm$ 4.9	17.4 $\pm$ 5.0	0.1	0.2

**** $p < 0.05$ from pre to post intervention***

Hypothesis 1, VO_{2peak} would significantly increase from pre to post intervention, was accepted based on our results. Significant increases in both, relative VO_{2peak} (p=0.002; 10.8%) and absolute VO_{2peak} (p=0.003;10.7 %) were observed. Hypotheses 2 and 3, there would be significant changes in PT (H_2) and overall EMG amplitude (H_3) of the VL from pre to post intervention were also accepted. Significant increases in PT of approximately 6.1% ($p=0.027$) and EMG amplitude of 41.3% ($p=0.001$) were observed. Hypothesis 4, there would be no significant changes in the overall CSA of the VL in response to the intervention was accepted as well as no significant difference in the CSA of the VL was observed ($p=0.456$). All four hypotheses were evaluated by conducting paired samples t-tests.

Relationship Between VO_{2peak} and Muscular Strength / Activation

Hypothesis 5 stated that there would be a significant positive relationship between changes from pre to post intervention in VO_{2peak} and PT as well as between VO_{2peak} and EMG amplitude. The correlations between VO_{2peak} and PT and between VO_{2peak} and EMG amplitude changes from pre to post intervention were analyzed using simple regressions. No significant relationships between changes in VO_{2peak} and PT ($r^2 = 0.002$; $p=0.855$) and VO_{2peak} and EMG amplitude ($r^2 = 0.003$; $p=0.839$) were observed. Figure 2 depicts relationships between VO_{2peak}/PT and Figure 3 between VO_{2peak}/EMG Amplitude for the 17 subjects included in the analyses.

Figure 2. VO_{2peak} Changes v. Changes in VL Torque Relationship

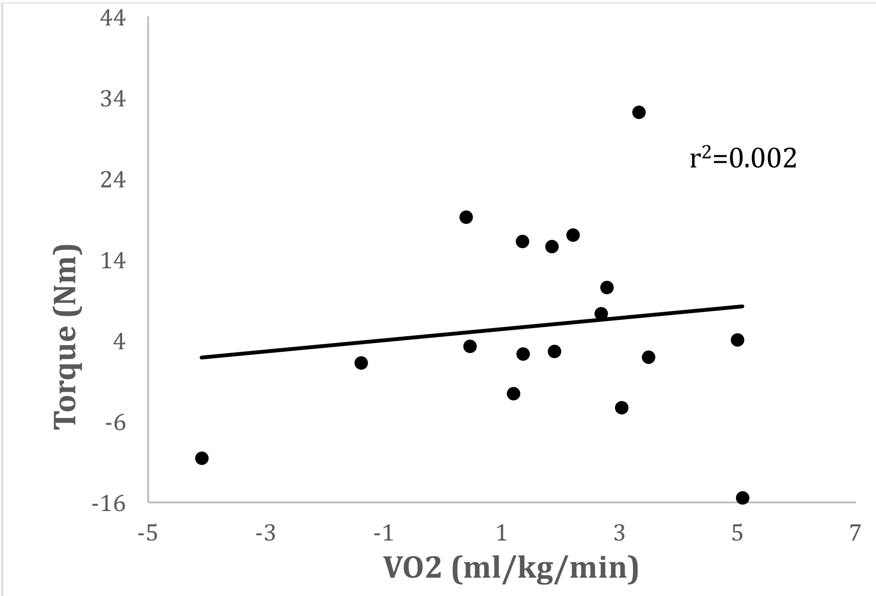
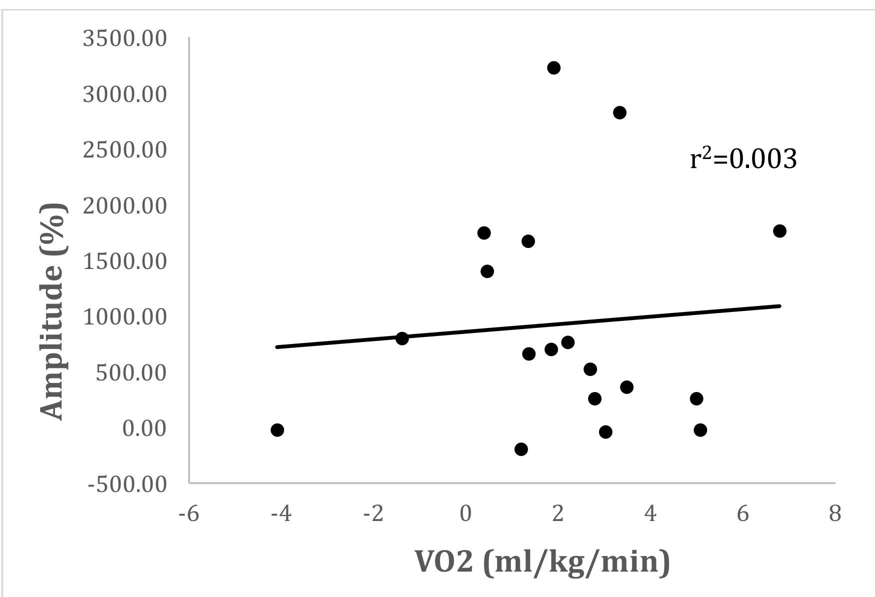


Figure 3. VO_{2peak} Changes v. Changes in EMG Amplitude Relationship



Exploratory Analyses

Exploratory analyses were conducted in order to compare selected CPET variables from pre to post. Table 3 provides a visual comparision of the chosen variables.

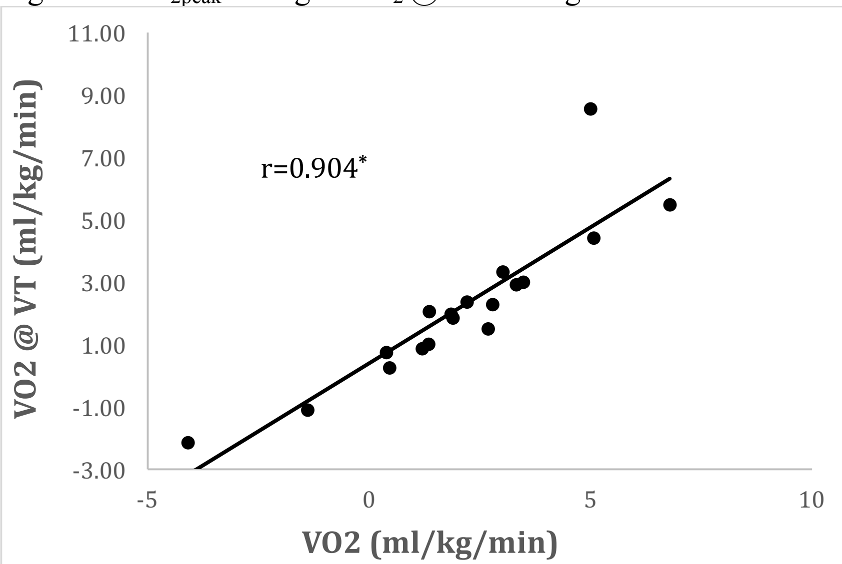
Table 3: Exploratory Results (mean ± SD)

CPET Variables	***PRE***	***POST***
METs	6.8 ± 1.5	7.3 ± 1.4*
Lactate (mmol)	7.7 ± 1.9	8.4 ± 2.1*
Peak Power (W)	116.7 ± 22.7	127.8 ± 20.8*
Ve (L/min)	64.06 ± 14.78	72.4 ± 14.9 *
VO_2 @ VT ($ml*kg^{-1}*min^{-1}$)	11.1 ± 3.1	13.3 ± 3.5*
Total Test Time (seconds)	765.7 ± 172.6	825.4 ± 163.8*

***** $p < 0.05$ *from pre to post intervention***

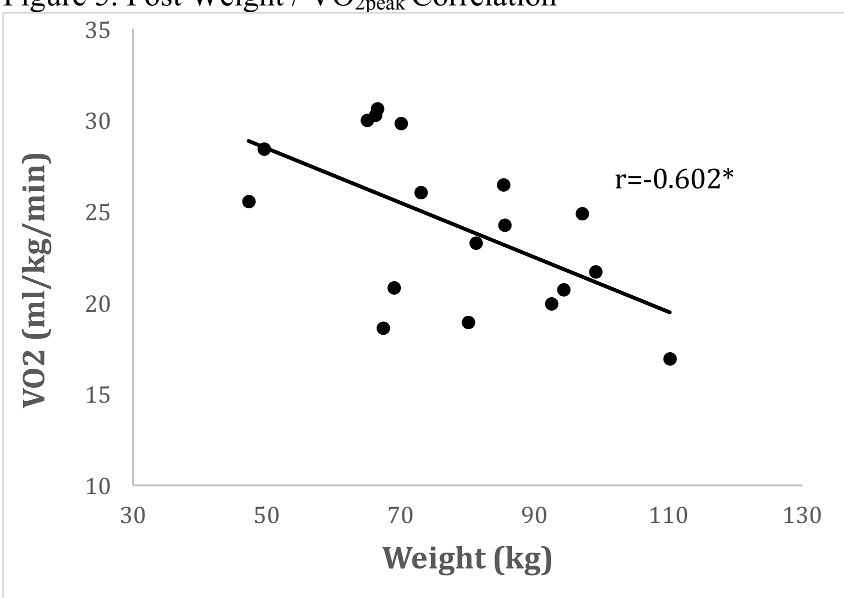
Additionally, correlations were conducted between changes in VO_{2peak} and changes in VO_2 at the subjects' ventilatory threshold (VT) as well as the subjects' post weight and post VO_{2peak} values as seen in Figures 4 and 5 below. All variables significantly increased from pre to post, and significant correlations were observed between changes in VO_{2peak} and changes in VO_2 at the subjects' ventilatory threshold (VT) ($p < 0.001$; $r=0.904$) as well as the subjects' post weight and post VO_{2peak} values ($p=0.008$; $r=-0.602$).

Figure 4. VO_{2peak} Change / VO_2 @ VT Change Association



**** Denotes a significant association (p < 0.05)***

Figure 5. Post Weight / VO_{2peak} Correlation



**** Denotes a significant association (p < 0.05)***

CHAPTER V

DISCUSSION

Overview

The purpose of this study was to determine the effect of two weeks of lower body resistance training on cardiopulmonary capacity in sedentary middle aged females, via CPET with indirect caolrimetry on a cycle ergometer. Though this has not been reported in previous literature, many older, sedentary, and even diseased (i.e., cancer) individuals report leg fatigue as being a primary reason for terminating a CPET on a cycle ergometer. As Neder et al. (1999) previously speculated, this is likely caused by the inability of the individual performing the CPET to generate an adequate amount of force in the lower limbs in order to withstand the resistance in the pedals. Ultimately, this would result in a VO_2 value that may not represent an accurate characterization of the individual's maximal cardiopulmonary capacity.

Knowing that strength gains in reponse to resistance training programs can be observed in those that are untrained as early as two weeks (Moritani & deVries, 1979), it is plausible that this approach could be utilized to improve an older, untrained, or diseased individual's cardiopulmonary capacity on a cycle ergometer, knowing that these populations suffer decreases in both leg muscle mass and strength (C. L. Battaglini et al., 2012; Frontera et al., 1991; Kuta et al., 1970). Previous studies have examined the relationship between leg strength and VO_2, however, the resistance training interventions varied significantly with intervention length lasting anywhere from four to twenty-four weeks in length (Brentano et al., 2008; Falatic et al., 2015;

Frontera et al., 1990; Kim et al., 2011; Myers et al., 2015; Vincent et al., 2002), with some even implementing circuit training methodologies. To our knowledge, this study is the first of its kind to examine a very short resistance trainig protocol (length of two weeks) on cardiopulmonary capacity in middle aged sedentary women. This study was done to better characterize cardiopulmonary capacity in this female population, by seeking to alleviate the loss of strength commonly observed in this population which may compromise the validity of a CPET for precise determination of aerobic training intesity prescriptions. Further, it is likely that the present study protocol be transitioned into other similar populations, such as breast cancer, where accurate aerobic exercise prescriptions are of importance as increased exercise intensity has been shown to highly beneficial on a long term basis (Martin, Battaglini, Hands, & Naumann, 2015).

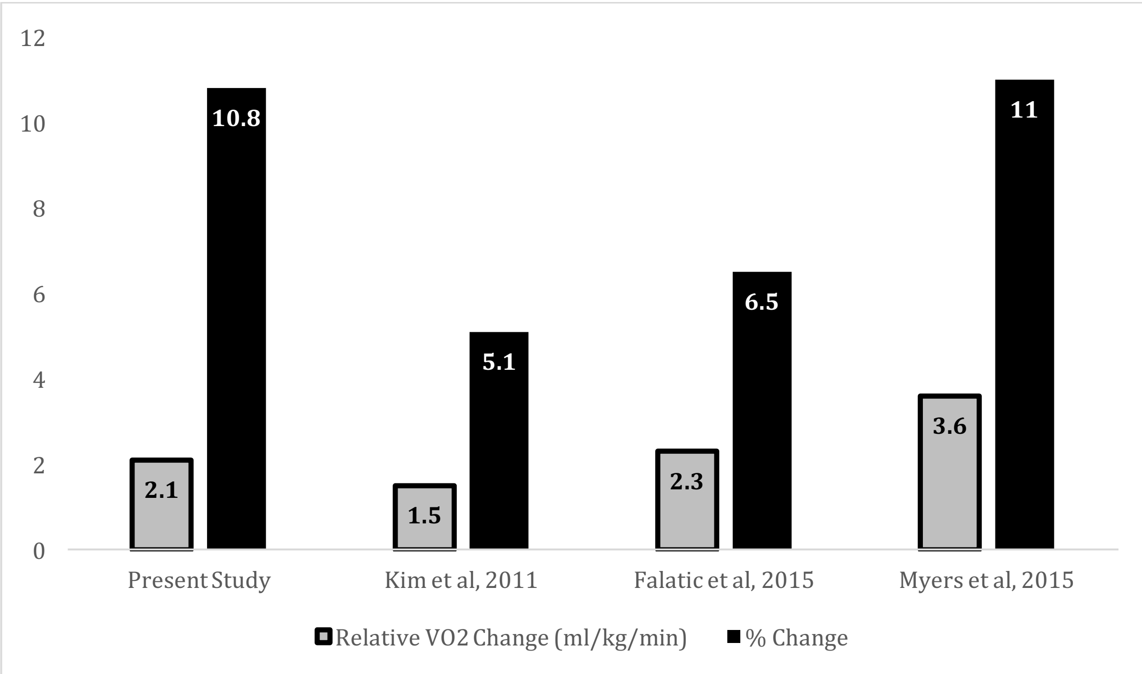
Cardiopulmonary Capacity

Significant changes in maximum oxygen uptake values from pre to post intervention were observed. The results of this study could be attributed to a multiude of factors including, but not limited too, a learning effect from pre to post intervention, or actual training effects in result of the lower body resistance training intervention. These concepts will be discussed in further detail below.

Despite this study being the first of its kind in observing the influence of only two weeks of resistance training on aerobic capacity, previous studies explored the same concept with different training protocols. Although a significantly shorter training protocol was used in the current study, observed changes in VO_2 were similar, if not greater, than previous studies that utilized longer interventions. For intance, Brentano et al. (2008) produced similar increases in maximum oxygen uptake in post menopausal women to the current study. However, it should be noted that the form of training that took place for six months was circuit weight training. With that said, their results can not be attributed strictly to resistance training, given that the study protocol could have produced some aerobic stimlus independent of the resistance training alone. Frontera et al. (1990) examined the influence of twelve weeks of resistance training in older men. Similar to the study at hand, Frontera observed an approximate 1.9 ml/kg/min significant increase in VO_2 in response to the intervention. The current tudy was able to produce a similar increase in VO_2 of 2.1 ml/kg/min. Though previous studies such as Vincent et al. (2002) observed greater increases in both elderly males and females in response to both low and high intensity resistance training, 4.5 and 3.5 ml/kg/min, respectively; it is hard to accept the practicality of the training protocol to the intent proposed by the current study. When considering it's practical application, a 6-month long protocol, such as the one shown in Vincent's study as well as Brentano, that produces similar changes in VO_2 as our two-week protcol would clearly indicate that an excessively long intervention is not necessary in order to elicit a more accurate representation of a middle to older aged individual's aerobic capacity. Rather, two weeks of training could provide a feasible approach to training the lower limbs, while simultaneously eliciting increases in aerobic capacity similar to those studies implementing longer and impractical protocols.

When comparing the two week protcol used in the current study to those previous studies who examined the same relationship with protcols shorter than those discussed above (4-5 weeks), the changes observed in aerobic capacity in the current study was strikingly similar if not greater. A visual comparison is provided in Figure 6 below.

Figure 6. Comparisons Among Previous Literaure (VO_{2peak})



To our knowledge, only three studies have examined the relationship between short-term resistance training and aerobic capacity. The earliest of those, conducted by Kim et al. (2011), included a four week traditional training protocol in sedentary college-aged females, consisting of various free weight exercises (i.e., leg press). Ultimately, the study did not produce a significant increase VO_{2peak} values. This could potentially be attributed to the age of participants, as previous literature has indicated that older individuals obtain a diminished ability to produce the required amount of force when undergoing a CPET on a cycle ergometer (Neder et al., 1999) whereas college-aged individuals have yet to experience a significant drop in lower body muscle mass and strength. More recently, a study conducted by Myers et al. (2015) included a 5-week training protocol that produced a mean change of 3.6 ml/kg/min, a change that exceeds the present study, but utilized circuit weight-training in a similar manner as Brentano et al. (2008). As such, this approach results in the inability to strictly attribute strength training adapatations to improvements in aerobic capacity. Lastly, Falatic et al. (2015), though not traditional resistance training, was able to show similar increases in aerobic capacity in response to kettle bell resistance training in college aged female soccer players (2.3 ml/kg/min as compared to the 2.1 ml/kg/min). It should be noted that though all three studies did utilize female populations and two were deemed sedentary (Kim et al., 2011; Myers et al., 2015), the populations were that of college-aged females, rather than middle aged used in the current study.

As it can be derived from the comparisons made above to previous literature exploring the relationship between resistance training and aerobic capacity, our results show similar increases to those whom did not include circuit training protocols that could potentially impact cardiopulmonary capacity. However, the studies that were most similar in terms of the intervention length were not conducted in a middle-aged female population, so direct comparisons cannot be made. Therefore, the exact physiological mechanism as to why increases in VO_2 are observed as a result of resistance training can not yet be determined in this particular population. It is believed that those who resistance train are able to produce and exert more force in the lower limbs, as opposed to improving metabolically (Neder et al., 1999). In response to two weeks of training, an increase in neural activation would in turn activate more fibers, producing more muscular force, allowing for the participant to exert a greater power output while pedaling (Kostka et al., 2000; Oliveira et al., 2009). These types of increases within this time frame have been examined as early as 1979 (Moritani & deVries, 1979), which will be discussed below.

For reasons discussed in more detail later in the chapter, this training effect should be cautioned for this particular cohort. The resistance exercise could have had an influence on the increases in VO_2 post training. However, strong positive relationships were not observed between changes in VO_2 and changes in PT/EMG amplitude. For this reason, it could be argued that the changes in aerobic capacity that occurred were due to a learning effect. That is, the participants gradually became more comfortable on the cycle ergometer from pre to post intervention, despite being familiarized on Visit One. Surely, this can be a potential reason for the significant increases; however, previous literature has indicated that in both clinical and healthy populations, a learning effect is non-existent when performing CPETs on cycle ergometers (Barron et al., 2014; Cox, Hendriks, Binkhorst, Folgering, & van Herwaarden, 1989; Dideriksen & Mikkelsen, 2015; Heine et al., 2015). Indeed, no study listed was conducted in sedentary middle-aged females. Regardless, they provide a strong argument in that the learning effect did not exist and that the changes observed in the subjects' aerobic capacity could have potentially been a result of the two-week intervention. Conversely, without the utilization of a control group, the claim of the resistance training truly improving aerobic capcity can not be definitively established.

Muscle Strength, Activation, and Size

When discussing the changes in muscular strength, EMG amplitude, and muscle size (CSA) observed from the present study, our results lead us to accept hypotheses two, three, and four that stated PT and EMG amplitude would siginificantly increase whereas CSA would not in response to the training intervention. In doing so, PT and EMG amplitude significantly increased from pre to post intervention whereas CSA of the VL did not.

Previous studies examining short-term resistance training (no greater than 5 weeks) have observed similar increases in muscular strength and neural activation, some reporting in as little as two (Prevost et al., 1999) and three days (Cramer et al., 2007). The earliest of those, briefly mentioned above, was that of Moritani and deVries (1979). Significant strength gains were observed in their study just after 2 weeks, as was the present study. Additionally, the strength gains were attributed to strictly neuromuscular improvements, as there were strong correlations between the amount of muscle activation (neural factors) and force produced without an increase in muscle size (hypertrophic factors). Specifically, it was conlcuded that muscle activiation accounted for 90% of the strength gains observed in the first 2 weeks of training. In the present study, though not as strong of a relationship as Moritani and deVries observed, changes in muscle activation as indcated by EMG amplitude (mV) were signifcantly correlated with changes in PT (r=0.600), leading us to believe that increases in force ouput of the VL were mostly in part due to an increased neural drive to the muscle when contracting. In regards to the previously mentioned studies that took place over the course of two to three days, the results of the current study is in agreement with the previously published literature. Cramer et al. (2007) reported a 6% increase in overall PT in response to three days of isokinetic training as did the current study. Additonally, Prevost et al. (1999) reported a 22% increase in leg extensor peak torque values after just two days of training.

Indeed, Cramer et al. (2007) demonstrated similar strength imrpovements as the present study whereas Prevost et al. (1999) showed a significantly greater increase. It is important to note that both, Cramer and Prevost studies trained and tested their subjects on isokinetic dynamometers. With this is mind, it is possible that subjects experienced a greater learning effect from pre to post intervention, resulting in an increase in PT values, which was aknoweldged by Prevost and colleagues study, since in their study no familiarization period before training was administered. In the present study, a familiarization was conducted for the isokinetic strength testing while the training consisted of traditional free-weight resistance training as opposed to isokinetic training. As a result, subjects would not have been exposed to continual isokinetic movements, strengthening the argument that no learning effect took place.

It should be noted that though the previously mentioned studies reported increases in strength with simultaneous increases in neural activation, the training was focused on the elbow flexors in young males and females or via isokinetic training instead of traditional resistance training in a middle aged female population. Hakkinen et al. (1992) observed strength changes in the leg extensors in response to three weeks of training in middle aged females. Similar to the present study's results, subjects were able to elicit greater force output in response to two weeks of training. Additionally, the results of the present study support these findings in that neither study observed increases in overall CSA of the leg extensors muscles, rather, only an increase in the overall activation of the muscles being recruited. Overall, with the present study showing similar results as those that have utilized two to three day protocols and those that have used up three week protocols, exhibiting strong relationships between force output and neural activation in the trained muscle, the argument that the significant increase in strength gains for the present cohort were primarily due to neural improvements in the leg extensors strengthens (i.e., increased rate coding and alpha motor neuron recruitment).

However, as with the changes that occurred in the subjects' aerobic capacity, the absence of a control group brings into speculation the adaptations that potentially occurred from the training, such as a learning effect in spite of familiarization to the test. Although recent reviews involving resistance training in clinical populations such as cancer have highlighted a need for better familiarization procedures when it comes to strength testing (Hanson, Wagoner, Anderson, & Battaglini, 2016), other recent publications have reported high test-retest reliability when utilizing isokinetic strength testing at 60°/second (Fagher, Fritzson, & Drake, 2016); yet none to our knowledge have been conducted in sedentary middle-aged females. With this in mind, a definitive conclusion in terms of a physiological mechanism can not be made in regards to the increases in strength that were observed post intervention.

Relationships Between Aerobic Capacity and Peak Torque / Muscle Activation

Based on the results of the present study, it can be concluded that there was no observed relationship between the changes in aerobic capacity and the changes in the observed strength variables (PT and EMG amplitude). Previous literature has reported contradictory results when compared to the present study. Vincent et al. (2002) reported significant positive correlations, ranging of 0.40 to 0.54, between changes in VO_{2peak} and changes in 1-RM values from the leg press, leg curl, and leg extension exercise. As briefly mentioned above, this study was conducted for a total of six months, significantly longer than the present study. Similarly, Brentano et al. (2008) reported significant correlations between VO_{2peak} and lower dynamic strength (r=0.73) as assessed by 1-RM and VO_{2peak} and isometric strength (r=0.59) in response to six months of training.

Surprisingly, many studies that have chosen to explore the influence of different modes of resistance training, including those lasting only four to five weeks, have elected not to report correlation data between the strength measures performed and the changes in aerobic capacity. This makes it difficult to compare the results of the current study's to other short-term resistance training studies in regards to changes in VO_{2peak} values in response to resistance training. Nonetheless, it is apparent that this study's results do not match up with the two studies mentioned above. Based on the regression analyses in the present study, it can be inferred that the observed increases in VO_{2peak} could be atttibuted to a learning effect, rather than the training itself, as increases in PT and EMG amplitude accounted for less than 1% of the increases $VO_{2peak.}$ However, a lack of specificity in the chosen strength test for the present study could have played a vital role in the absence of a relationship between VO_{2peak} and stength variables. In particular, a primary movement in cycling is the pushing motion (leg extension) of the lower limbs while pedaling, ultmately engaging many lower body muscles. Agonist muscles involved in cycling include the gluteus maximus, vastus lateralis, rectus femoris, and the biceps femoris (Hautier et al., 2000). For the present study's isokinetic strength testing, the only muscle evaluated was that of VL. Additionally, though the strength test did require maximal right leg extensions, the extensions performed were likely not indicative of a true cycling motion, as the subjects were postitioned in a way to isolate the quadricep muscles, removing any influence of the hip flexors and hamstrings.

Comparing the strength testing methodology utilized from the present study with that from Vincent et al. (2002) and Brentano et al. (2008), the difference in the relationships observed with the changes in VO_{2peak} and overall strength begin to make sense. Both Vincent and Brentano elected to perform a 1-RM on the leg press exercise. The leg press ecompasses many of the muscles listed above that are involved in the cycling motion. Furthermore, rather than a "kicking" motion that was used to perform leg extensions in the present study's isokinetic strength test, the leg press induces a "pushing" motion, allow for greater extension of the knees and hips. With this in mind, it is true the data from the present study could indicate a learning effect rather than a training effect; but when evaluating the methodology used for strength testing, it's quite possible that the specificity was not adequate in assessing training adaptations from the two week intervention.

Exploratory Analyses

Exploratory analyses were performed on variables related to the pre and post CPETs, given that the present study's primary purpose was to evaluate the effect of two weeks of resistance training on aerobic capacity. Of particular interest was the subjective assessment performed on the reasons for terminating the CPET. For the pre-intervention CPET, all eighteen subjects indicated that leg fatigue played a vital role in terminating the test. Interestingly, when asked why they decided to stop the post-intervention CPET, fourteen out of eighteen subjects indicated that breathing played an increased role in terminating the test, whether it being strictly having a harder time to simply breathe, or a mixture of leg fatigue and breathing difficulty. Regardless, this subjective analysis could possibly indicate a significant impact of the lower body resistance training.

Coincidently, subjects also displayed significant increases in both lactate and peak power output from pre to post intervention. It is possible to speculate that with the decrease of leg fatigue that occurred during the post-CPET for the majority of subjects could have been attributed to the enhanced ability to further recruit type II fibers. With the greater amount of muscle activation that was observed from pre to post intervention, subjects may have possibly recruited more and larger muscle fibers, contributing to the increase in peak power and lactate that was observed, as it has been well established that Type II fibers both produce a greater amount of force and lactate as exercise intensity increases (Brooks et al., 2005). Subjects also significantly increased the total time of the CPET from pre to post intervention, which may be an indication of more motor units being recruited and taking turns during the exercise, allowing for fatigue to be delayed. This supposition could possibly be the case as an overall increase the neural-activation as observed post intervention. As the surface EMG measurement cannot discern between the actual number of the motor units recruited versus the frequency of motor units recruited during muscle contractions, the exact physiological mechanism cannot be determined. However, results from the present study leads speculation in that the greater muscle activation observed lead to a greater recruitment of muscle fibers, allowing the subjects to pedal longer.

Other exploratory variables to take note of include the significant increases observed in ventilation (Ve) and VO_2 observed at the subjects' ventilatory threshold (VT). Changes in VO_{2peak} were strongly correlated with changes in VO_2 at VT as well. In order to explain these increases and associations in response to two weeks of resistance of training, one must consider the physiological mechanisms behind ventilatory regulation during exercise. Ventilation is driven by both humoral and peripheral inputs. For the present study, peripheral inputs could have possibly be a greater contributor to the increase in ventilatory responses post intervention. Specifically, an increase in recruitment of Type II fibers increase lactate and H^+ ion accumulation, providing a chemical stimulus from the peripheral to the respiratory centers in the medulla oblongata (Brooks et al., 2005). Additionally, stimulation from the exercising muscles could provide a plausible explanation for the increases in ventilation and its association with the increases in VO_{2peak}. Peripheral mechanoreceptors including muscle spindles, golgi tendon organs (GTOs) and skeletal joint receptors send afferent signals to the respiratory centers in response to stretch (muscle spindles) and tension (GTOs) within the given muscles being exercised (Brooks et al., 2005). Given that the present study observed significant increases in muscle activation, it is possible that more mechanoreceptors were activated, driving Ve and in turn, contributing to an increase in $VO_{2.}$

Furthermore, a significant strong correlation was observed when comparing the subjects' post-weight and post-VO_{2peak} as opposed to a non-significant association that was observed between pre-weight and pre-VO_{2peak} values. Without their being a significant difference between the weight of the subjects' pre and post, the correlation observed with the post training values raises the question as to if the VO_2 values observed post training were more indicative of their cardiopulmonary system, as different variables of body composition have been associated with an individual's cardiorespiratory fitness (Nogueira et al., 2016).

It is difficult to know from the given study if the increase in the variables were primarily brought about by the two weeks of lower body resistance training, especially with the absence of a control group. However, the chosen exploratory variables provide reason to further investigate if the two weeks of lower body resistance training did indeed have a significant training effect on the subjects' aerobic capacity.

Conclusions

Although this study did not contain a control group in order to compare training effects, the results suggest that it is quite possible that two weeks of lower body resistance training may potentially improve the ability of sedentary midle aged women to achieve a higher and more precised indication of their aerobic capacity measured during a CPET in a cycle ergometer.The results support the hypotheses in that signifcant increases in VO_{2peak}, PT, and EMG amplitude were observed post-intervention, whereas an increase in CSA was not observed. Despite accepting these hypotheses, caution is warranted when attributing these increases to the actual training itself. For reasons previously listed (i.e., specificity of the chosen strength test) and exploratory analyses revealing improvements in other cardiopulmonary variables, the two weeks of resistance training could have provided a sufficient stimulus. However, the absence of a control group, this can not be definitively determined at this point in time. Regardless, the present study brings into question the accuracy of a CPET in regards to VO_2 values obtained on a cycle ergomter in sedentary middle aged women . The average increase of 2.1 ml/kg/min from pre to post training shows that the subjects were physically able to push to a higher threshold, indicating that the intial VO_2 was not perhaps a precise representation of their true cardiopulmonary capacity, which could lead to inaccurate exercise prescriptions.

Future Research

As this study was the first of its kind in terms of intervention length, multiple opporutnities for future research arise. Future investigations exploring the influence of short term resistance training on maximal oxygen uptake accessed via CPET should include a control group so more definite conclusions can confirm or refute the findings of the present study. Furthermore, specificity in terms of a chosen strength test that presents a more comprehnsive representation of the muscles involved in cycling while simultaneously being able to assess neuromuscular adapations should be of importance as well. Similarly, different resistance training protcols should be explored such as those that are more specific to cycling, in particular, giving consideration to resistance training on a cycle ergometer. Lastly, as this study did not assess body composition, future researchers should aim to explore the relationship between body composition and pre and post VO_{2peak} values, as a stronger relationship could indicate a more accurate representation of an individual's cardiopulmonary capacity.

APPENDIX 3.1: STUDY BROCHURE

VOLUNTEERS NEEDED FOR RESEARCH STUDY

Exercise and Sport Science
University of North Carolina at Chapel Hill

Subjects needed for study that is investigating the impact of 2 weeks of lower body resistance training on aerobic capacity in sedentary females

- **Searching for volunteers that are female adults between the ages of 35-65 years.**
- **Must not have participated in regularly scheduled exercise (< 2 times / week) within the past 6 months.**
- **Participation involves 9 total visits:**
  - **Visit 1 → approximately 2 hours (Familiarization)**
  - **Visits 2 & 9 → approximately 1 hour each (Pre and Post Testing)**
  - **Visits 3 – 8 → approximately 30 – 45 min each (Resistance Training)**
- **Subjects will undergo 2 cardiopulmonary exercise tests, 2 isokinetic/isometric strength tests, and 6 sessions of lower body resistance training.**

For more information contact Chad Wagoner at chadwago@live.unc.edu

IRB: 15-1129

APPENDIX 3.2: PRE-ASSESSMENT GUIDELINES

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL
Claudio Battaglini, Ph.D. FACSM.
Department of Exercise and Sport Sciences
105 Fetzer Hall, CB # 8700
(919) 843-6045 / Email: claudio@email.unc.edu

Pre-Test Guidelines

1. Avoid eating 2 hours prior to testing.
2. Void completely before testing.
3. Maintain proper hydration prior to testing.
4. Please wear appropriate clothing/shoes for testing (running shorts/shirt/shoes)
5. No exercise 12 hours prior to testing.
6. No alcohol consumption 48 hours prior to testing.
7. No diuretic medications 7 days prior to testing.

Source: Advanced Fitness Assessment and Exercise Prescription – Third Edition – Vivian H. Heyward

APPENDIX 3.3: PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

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

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

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

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

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

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

If you answered

YES to one or more questions

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

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

NO to all questions

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

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

DELAY BECOMING MUCH MORE ACTIVE:

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

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

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

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

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

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

NAME ____

SIGNATURE ____ DATE ________________________

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

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

APPENDIX 3.4: MEDICAL HISTORY QUESTIONNAIRE

Department of Exercise and Sport Science
Medical History

Subject:____________________________ ID: ____________ Telephone:_______________

Address:____

Occupation:______________________________________ Age:________________________

YES NO

Patient History

1. How would you describe your general health at present?
   Excellent______ Good_______ Fair______ Poor______
2. Do you have any health problems at the present time? _____ _____
3. If yes, please describe:____
____
4. Have you ever been told you have heart trouble? _____ _____
5. If yes, please describe:____
____
6. Is there any chance of you being pregnant at this time? Yes: _________No:_________
7. Is there any chance that you may become pregnant during span of the study?
   Yes: ________ No: ________
8. Have you had consistent menstrual periods for the last 3 months? Yes:_________ No:________
If no, when was your last period_______________________________________
9. Do you ever get pain in your chest? _____ _____
10. Do you ever feel light-headed or have you ever fainted? _____ _____
11. If yes, please describe:____
____
12. Have you ever been told that your blood pressure has been elevated? _____ _____
13. If yes, please describe:____
____
14. Have you ever had difficulty breathing either at rest or with exertion? _____ _____
15. If yes, please describe:____
____
16. Are you now, or have you been in the past 5 years, under a doctor's care for any reason? _____ _____
17. If yes for what reason?____
____
18. Have you been in the hospital in the past 5 years? _____ _____

19. If yes, for what reason?____
____
20. Have you ever experienced an epileptic seizure or been informed that you have epilepsy?
_____ _____
21. Have you ever been treated for infectious mononucleosis, hepatitis, pneumonia, or another infectious disease during the past year? _____ _____
22. If yes, name the disease:____
23. Have you ever been treated for or told you might have diabetes? _____ _____ 24. Have you ever been treated for or told you might or low blood sugar? _____ _____
25. Do you have any known allergies to drugs? _____ _____
26. If so, what?____
____
27. Have you ever been "knocked-out" or experienced a concussion? _____ _____
28. If yes, have you been "knocked-out" more than once? _____ _____
29. Have you ever experienced heat stroke or heat exhaustion? _____ _____
30. If yes, when?____
____
31. Have you ever had any additional illnesses or operations? (Other than childhood diseases)
_____ _____
32. If yes, please indicate specific illness or operations:_____________________________________
____
33. Are you now taking any pills or medications? _____ _____
34. If yes, please list:____
____
35. Have you had any recent (within 1 year) difficulties with your:
 a. Feet _____ _____
 b. Legs _____ _____
 c. Back _____ _____

Family History

36. Has anyone in your family (grandparent, father, mother, and/or sibling) experienced any of the following?
 a. Sudden death _____ _____
 b. Cardiac disease _____ _____
 c. Marfan's syndrome _____ _____

Mental History

37. Have you ever experienced depression? _____ _____
38. If yes, did you seek the advice of a doctor? _____ _____
39. Have you ever been told you have or has a doctor diagnosed you with panic disorder, obsessive-compulsive disorder, clinical depression, bipolar disorder, or any other psychological disease? _____ _____
40. If yes, please list condition and if you are currently taking any medication.
Condition Medication

____
____
____

Bone and Joint History

41. Have you ever been treated for Osgood-Schlatter's disease? _____ _____
42. Have you ever had any injury to your neck involving nerves or vertebrae? _____ _____
43. Have you ever had a shoulder dislocation, separation, or other injury of the shoulder that incapacitated you for a week or longer? _____ _____
44. Have you ever been advised to or have you had surgery to correct a shoulder condition? _____ _____
45. Have you ever experienced any injury to your arms, elbows, or wrists?_____ _____
46. If yes, indicate location and type of injury:____
____
47. Do you experience pain in your back? _____ _____
48. Have you ever had an injury to your back? _____ _____
49. If yes, did you seek the advice of a doctor? _____ _____
50. Have you ever been told that you injured the ligaments or cartilage of either knee joint? _____ _____
51. Do you think you have a trick knee? _____ _____
52. Do you have a pin, screw, or plate somewhere in your body as the result of bone or joint surgery that presently limits your physical capacity? _____ ____
53. If yes, indicate where:____
____
54. Have you ever had a bone graft or spinal fusion? _____ _____

Activity History

55. During your early childhood (to age 12) would you say you were:
    Very active ____ Quite active____ Moderately active____ Seldom active____
56. During your adolescent years (age 13-18) would you say you were:
    Very active ____ Quite active____ Moderately active____ Seldom active____
57. Did you participate in:
    a. Intramural school sports? _____ _____
    b. Community sponsored sports? _____ _____
    c. Varsity school sports? _____ _____
    d. Active family recreation? _____ _____
58. Since leaving high school, how active have you been?
    Very active ____ Quite active____ Active____ Inactive____
59. Do you participate in any vigorous activity at present? _____ _____
60. If yes, please list:

Activity Frequency Duration Intensity

____
____
____
____

61. How would you describe your present state of fitness?
Excellent_____ Good_____ Fair_____ Poor_____
62. Please list the type(s) of work you have been doing for the previous ten years:
Year Work Indoor/Outdoor Location (city/state)
____
____
____
____
____
63. Whom shall we notify in case of emergency?
Name:____
Phone: (Home)________________________ (Work)________________________
Address:____
64. Name and address of personal physician:____
____
____

All of the above questions have been answered completely and truthfully to the best of my knowledge.

Signature:____ Date:___________________

APPENDIX 3.5: DATA COLLECTION SHEET

Subject ID:_________

Visual 1

Height (in/cm):____________/____________ Weight (lbs/kg):__________/___________

RBP:___________________________ RHR:___________________________

Ultrasound Assessment

Half Femur Length (cm): ______________

Pre CSA (cm^2): _______________________ **Post CSA (cm^2):** ______________________

Cardiopulmonary Assessment (VO_2peak)

Mask Size: _______________ **Seat Height (in):**______________________

Pre

RHR(Before):_____________

RBP(Before):_____________

RHR(After):______________

RBP(After):_______________

Height (cm):______________

Weight (kg): ______________

VO_2peak:

___________(ml/kg/min)

_______________(L/min)

Lactate (mmol/L):________________

Post

RHR(Before):_____________

RBP(Before):_____________

RHR(After):______________

RBP(After):_______________

Height (cm): ______________

Weight (kg):______________

VO_2peak:

___________(ml/kg/min)

_____________(L/min)

Lactate (mmol/L):________________

Isokinetic / Isometric Strength Testing

Electrode Placement [66% Femur Length](cm): ____________________

Isokinetic Leg Extension (60°/sec) CW

Pre:
____________ (Basic Noise)
____
____
____

Post:
____________ (Basic Noise)
____
____
____

Isometric

Pre:
____

Post:
____

Gravity Correction

Pre:
____

Post:
____

APPENDIX 3.6: EXERCISE LOG

One-Repetition Maximum (1-RM)

Leg Press: ________________(lbs) ____________________(kg)

Leg Extension: __________________(lbs) ____________________(kg)

*All exercises for every session → 2-minute rest between each set and each exercise
**Leg curl will be completed with 2 sets of 8-10 repetitions for each session
***Exercise order → (1) Leg Press, (2) Leg Curl, (3) Leg Extension

Visits 1 (   ) & 2 (   )

2 sets; 8-10 repetitions

Intensity (65% 1-RM): ___________________(leg press [lbs])

___________________(leg extension [lbs])

____________________(Leg Curl [lbs])

Visits 3 (   ) & 4 (   )

2 sets; 8-10 repetitions

Intensity (10% increase from previous load): ___________________(leg press [lbs])

___________________(leg extension [lbs])

____________________(Leg Curl [lbs])

Visits 5 (   ) & 6 (   )

2 sets; 5-10 repetitions

Intensity (10% increase from previous load): ___________________(leg press [lbs])

___________________(leg extension [lbs])

____________________(Leg Curl [lbs])

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