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Effects of High-Velocity versus Low-Velocity Resistance Training on Resting Metabolic Rate and Functional Performance in Older Adults

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Effects of High-Velocity versus Low-Velocity Resistance Training on Resting Metabolic Rate and Functional Performance in Older Adults

Effects of High-Velocity versus Low-Velocity Resistance Training on Resting Metabolic Rate and Functional Performance in Older Adults

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by

Laura Morgan
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Abstract

The purpose of this study was to compare the effects of a 12-week high-velocity resistance training (HVRT) protocol to a traditional low-velocity resistance training (LVRT) protocol on resting metabolic rate (RMR) and other selected measures of muscular and functional fitness in older adults. Nineteen adults between the ages of 65 and 82 participated: 8 HVRT, 7 LVRT, and 4 controls (CTRL). Initially, no differences existed between groups except for age (*p* = .016). HVRT (75.6 years) was older than LVRT (69.6 years) and CTRL (69.3 years). The exercise intervention consisted of 2 days/week sessions for 12 weeks at 3 sets of 10 repetitions progressing to 80% 1RM for leg press, leg curl, leg extension, upper back, chest press, and shoulder press on Keiser pneumatic resistance machines. CTRL participants walked throughout the 12 weeks. Pre- and post-intervention strength, power (leg extension at 180°/sec), RMR, body composition, and functional fitness (30-sec chair stand and 8-ft up-and-go) were measured. Data were analyzed by a repeated measures analysis of variance (ANOVA) and effect sizes. All groups decreased RMR: LVRT by 11.4%, HVRT 15.6%, and CTRL 31.1% (*p* = .039 between groups). While CTRL lost 5.3% of FFM, HVRT increased 0.7% and LVRT 3.1% (*p* = .012). All groups increased in power but were not significantly different: CTRL by 3.0%, LVRT 8.7%, and HVRT 11.7% (*p* = .830). For total lower body strength, CTRL increased by 5.6%, LVRT by 42.3%, and HVRT by 44.6% (*p* = .016). No significant interaction between time and group was found for chair stand (*p* = .739) or up-and-go (*p* = .283). Overall, this study indicates LVRT and HVRT over a 12-week period at 80% 1RM produce similar changes in RMR, FFM, strength, and power.

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Dedication

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Chapter I

Introduction

Aging is a universal and multidimensional occurrence of the human existence. The number of adults ages 65 and older in the United States increased 15% from 2000 to 2010 and is projected to increase an additional 36% in the decade from 2010 to 2020 (US Department of Health and Human Services, Administration of Aging, 2011). Increased healthcare costs and decreased quality of life are realistic issues facing this population as seniors have an increased number of comorbidities, increased amount of prescribed medications, and increased risk of falls. The rapidly increasing number of older adults calls for extensive efforts to be focused on decreasing the impact on healthcare costs and increasing the quality of life for these individuals. Most experts agree that 85 years is the average life span of the humans species (Spirduso, 1995), which amounts to numerous years beyond retirement with increasing risk for high healthcare costs. Influenced by a variety of factors such as genetics and lifestyle, physiological aging occurs individually across the population and is not always parallel with chronological aging (Thompson, Gordon, & Pescatello, 2010). Physiological aging greatly affects an individual's quality of life and response to exercise; however, differentiating the effects of aging from the effects of deconditioning or disease is often difficult (Thompson et al., 2010). Quality of life and functional life expectancy become an issue for all individuals as they experience the numerous changes that occur as a result of the aging process.

At the heart of numerous healthcare organizations that work with older adults is an interdependent model of wellness called "The Six Dimensions of Wellness," developed by Dr. Bill Hettler, co-founder of the National Wellness Institute. The six dimensions include occupational, physical, social, intellectual, spiritual, and emotional health (Hettler, 1976). All of these dimensions influence independence and functionality of older adults. Therefore, a holistic approach to caring for seniors must be considered when working with this group in any capacity. But of particular importance to research and health professionals is the physical dimension of wellness and aging. For older adults, exercise in a one-on-one training, group setting, or instructor-supervised format is ideal for all dimensions of health, specifically for physical and social benefits.

A number of physical factors must be taken into account when working with the population of older adults as there are numerous biological changes that accompany aging: changes in the nervous system, cardiovascular system and capacity, anaerobic capacity, muscular strength and power, molecular composition of the muscle, energy expenditure, and body composition (Bortz, 1982; Busse, Maddox, & Buckley, 1985; Goran & Poehlman, 1992; Manini, 2010; Von Zglinicki, 2003). A superficial overview of some of these important components of the aging process are discussed in the literature review to highlight the significance of what occurs with aging and why exercise interventions are necessary. One of the most crucial physical occurrences with age the increase of fat mass (FM) and sarcopenia, the age-related decline of fat-free mass (FFM). Sarcopenia contributes to decreases in muscle strength and power and leads to decreased physical activity (PA). Notably, a positive feedback loop exists between PA and health. As health and strength is reduced by aging, PA is often reduced, which further reduces health status (Hunter, McCarthy, & Bamman, 2004). However, reduced PA causes decreased strength and overall health regardless of age. Increased PA is a valuable method of breaking this vicious cycle especially for seniors. Unfortunately, PA is virtually non-existent in individuals of all ages; Healthy People 2020 reported that 80% of adults do not achieve the recommended amount of PA (U.S Department of Health and Human Services, Healthy People 2020, 2012).

Determining beneficial training program specifics of frequency, intensity, duration, and mode of exercise for older adults is crucial to increase PA and improve their overall health status. Older adults are truly a unique population that requires special and specific research tailored to geriatric needs.

Another highly consequential physical change with age is energy expenditure or metabolism. Metabolic rate is the rate at which energy is expended or the total energy expenditure per unit time (Widmaier, Raff, & Strang, 2008). *Vander's Human Physiology* textbook lists a number of factors that affect metabolic rate, which includes age, sleep, height, weight, body surface area, gender, fasting, recent ingestion of food, infection or other disease, body temperature, environmental temperature, muscular activity, emotional stress, and circulating levels of various hormones such as epinephrine and thyroid hormones (Widmaier et al., 2008). Largely due to decreases in both FFM and PA, total energy expenditure (TEE) decreases with age (Levine & Kotz, 2005; Manini, 2010). TEE consists of basal metabolic rate (BMR), the thermic effect of food (TEF), and activity energy expenditure (AEE). AEE contributes 8.0-35.0% of TEE and can be further broken down into expenditure due to volitional exercise and non-exercise activity energy expenditure (Manini, 2010). BMR, or the metabolic cost living, is the minimum level of energy needed to sustain vital functions for which most of the energy is expended by the heart, muscle, liver, kidneys, and brain (McArdle, Katch, & Katch, 2010; Widmaier, et al., 2008). Due to the strict criteria for BMR, resting metabolic rate (RMR) is often measured instead. A less restrictive but closely-related measure, RMR values fall only slightly above BMR values measured under highly controlled laboratory conditions. BMR or RMR is variable to individuals, but comprises about 60-80% of TEE (Manini, 2010). Across the lifespan, TEE exhibits an inverted *U* pattern with a dramatic decline after the fifth decade and beyond (Manini, 2010). Composition and metabolic changes can be viewed as both inevitable effects of aging and the result of lifestyle changes of older individuals.

Resistance training (RT) is an important component of physical fitness and an imperative focus of research with older adults to counteract all of these age-related changes. “Traditional,” low-velocity resistance training programs (LVRT) have typically utilized a moderate-intensity, low-velocity protocol focusing on improving muscular strength and muscle mass. Although muscular strength is important to this population, many activities (such as standing from a chair, regaining balance, walking quickly, and climbing stairs) require not only muscular strength, but also muscular power (Hunter, McCarthy, & Bamman, 2004; Sayers, 2008). Samson et al. (2000) found that in adults ranging for age 20 to 90, muscular strength, muscular power, and functional ability were significantly correlated in both men and women and that these variables all decline with age. Although muscular strength and power are strongly associated with one another, there is one distinct difference: time. Muscular strength is the ability to produce force, and muscular power is the ability to produce force quickly. The main difference between the two is the emphasis on time or speed. However, the speed of movement during training sessions should be similar to functional tasks or activities of daily living. Research has shown that muscle power, specifically leg power, contributes more to functionality than muscle strength (Bean et al., 2002; Cuoco et al., 2004; Foldvari et al., 2000; Sayers, 2008; Sayers, Guralnik, Thombs, & Fielding, 2005; Suzuki, Bean, & Fielding, 2001). In addition to improving muscular strength and power, general RT also been shown to have a significant influence on body composition and RMR in younger and older adults (Bingham, Goldberg, Coward, Prentice, & Cummings, 1989; Campbell, Crim, Young, & Evans, 1994; Hunter, Wetzstein, Fields, Brown, & Bamman, 2000; Poehlman &

Danforth, 1991; Pratley et al., 1994; Ryan, Pratley, Elahi, & Goldberg, 1995; Williamson & Kirwan, 1997).

In contrast to LVRT, high velocity resistance training (HVRT)—which is often referred to as power training in the literature—is a specific RT modality that focuses on increasing contraction speed to improve muscular power in addition to muscular strength. HVRT has been shown to lead to greater hypertrophy, strength gains, and/or power production of the knee extensors (Coyle et al., 1981; Jones, Bishop, Hunter, & Fleisic, 2001), hip extensors (Jones, Bishop, Hunter, & Fleisic, 2001), and elbow flexors (Shepstone et al., 2005), as well as increase vertical jump performance of young men (Newton, Kraemer, & Hakkinen, 1999). However, HVRT is a relatively new exercise application to older adults. Over the past three decades, researchers have begun to investigate the impact and benefits of HVRT specifically for older adults, which are discussed further in the review of literature.

As sarcopenia, muscular strength and power, and energy expenditure are important issues for older adults, determining the beneficial RT programs for each of these variables is crucial. As previously mentioned, HVRT is a fairly new RT protocol for older adults, and the effects of a HVRT program on older adults' RMR have not been researched prior to the present investigation.

Purpose of the Study

The purpose of this study was to compare the effects of a 12-week, HVRT protocol to LVRT protocol on RMR and other selected measures of muscular and functional fitness in older adults.

Research Hypotheses

1. After 12 weeks of training, the HVRT group will have significantly greater increases in RMR than the LVRT group and the CTRL group, and the LVRT group will have significantly greater increases in RMR than the CTRL group.
2. After 12 weeks of training, the HVRT group and the LVRT group will have equivalent increases in FFM, and both exercise groups will have significantly greater increases in FFM than the CTRL group.
3. After 12 weeks of training, the HVRT group will have significantly greater increases in muscular power (as measured by average power of leg extension at 180°/sec) than the LVRT group and the CTRL group, and the LVRT group will have significantly greater increases in muscular power than the CTRL group.
4. After 12 weeks of training, the HVRT group and the LVRT group will have equivalent increases in muscular strength (as measured by the total of the three lower body estimated 1RMs and the total of the three upper body estimated 1RMs), and both exercise groups will have significantly greater increases in muscular strength than the CTRL group.
5. After 12 weeks of training, the HVRT group will have significantly greater changes in functional fitness (as measured by score on the chair stand and time of the 8-foot up-and-go) than the LVRT group and the CTRL group, and the LVRT group will have significantly greater changes in functional fitness than the CTRL group.

Limitations

1. This study utilized a small sample size.

2. There was not a true randomization of all groups. Participants volunteered to either be controls or exercise participants, and then participants were randomly assigned to either LVRT or HVRT.
3. The exercise participants were not required to be sedentary prior to the intervention, and the CTRL participants all participated in walking exercise.
4. The level of cooperation, participation, and effort of the volunteers varied by individual.
5. Individuals were encouraged to maintain their current diet and aerobic exercise habits, but the quantity and maintenance of these habits were not monitored.

Operational Definitions

To clarify specific terminology, the following definitions are given:

1. Low-velocity resistance training (LVRT) is defined as resistance training in which the concentric phase of each repetition is performed for 2 seconds, full extension/flexion is maintained for 1 second, and the eccentric phase of each repetition is performed for 2 seconds.
2. High-velocity resistance training (HVRT) is defined as resistance training in which the concentric phase of each repetition is performed as fast as possible, full extension/flexion is maintained for 1 second, and the eccentric phase of each repetition is performed slowly for at least 3 seconds.
3. One-repetition maximum (1RM) is defined as “the greatest resistance that can be moved through the full range of motion in a controlled manner with good posture” (Thompson et al., 2010, p. 90). Estimated 1RM for this study was determined by the following Wathen formula (Wood, Maddalozzo, & Harter, 2002):

   $1\ \text{RM}_{\text{est}} = \text{weight lifted (lbs)} / [(48.8 + 53.8e^{-0.075 \cdot \text{number of repetitions}}) / 100]$

4. Older adult is defined as people ages 65 or older (Thompson et al., 2010).
5. Basal metabolic rate (BMR) is defined as the “minimum level of energy to sustain vital functions in the waking state” and the metabolic rate when a person is “at mental and physical rest but not sleeping, at comfortable temperature, and has fasted for at least 12 hours” also called metabolic cost of living or basal metabolic energy expenditure (McArdle, Katch, & Katch, 2010, p. 193; Widmaier, Raff, & Strang, 2008, p. 584).
6. Resting metabolic rate (RMR) is defined as the metabolic rate closely related to but slightly higher than BMR.
    i. RMR as measured in this thesis was replicated with the same procedures for each test.
    ii. The pre-test criteria include: 24-hour abstinence from alcohol, 24-hour PA restriction, minimum of 8-hour fast from meals and snacks, from nicotine, from caffeine, and from any other stimulants and/or depressants, and maintenance of prescribed medications.
    iii. The test criteria include: use of the ParvoMedics TrueMax 2400 (Sandy, UT) computerized metabolic cart system with canopy system, the environment temperature at 68°F to 75°F, rest period of 15 minutes, participants in a recumbent position, and measurement lasting 30 minutes with the first 10 minutes disregarded.
7. Activity energy expenditure (AEE) is defined as the energy expenditure due to volitional exercise and non-exercise physical activity (Manini, 2010).
8. Total energy expenditure (TEE) is defined as the total of RMR, the thermic effect of food, and AEE (Manini, 2010).
9. Physical activity (PA) is defined as “any bodily movement produced by skeletal muscles that results in energy expenditure beyond resting expenditure” (Thompson et al., 2010, p. 2).

10. Exercise is defined as “a subset of physical activity that is planned, structured, repetitive, and purposeful in the sense that improvement or maintenance of physical fitness is the objective” (Thompson et al., 2010, p. 2).

Significance of the Study

In the United States alone, there are 40.4 million adults ages 65 and older, and that number is projected to increase 36% by 2020 (US Department of Health and Human Services, Administration of Aging, 2011). As the population of older adults is rapidly increasing, efforts are being focused on increasing the quality of life for this group and decreasing the impact on healthcare costs. Increased PA, specifically through resistance training, is a valuable method of increasing the health status of older adults, but older adults are the least physically active of all age groups (Thompson et al., 2010). Although RT for older adults has been a concern of research for over four decades, experts have yet to agree upon the best strategy to improve the health status of this population (Sayers, 2008). Determining the beneficial RT programs for improving RMR, muscular strength, muscular power, body composition, and overall functional fitness for older adults is crucial.

Chapter II

Review of Literature

Introduction

First, the general effects of aging on the nervous system, cardiovascular system, body composition, and strength changes are each briefly discussed to emphasize the importance of research on older adults. Second, the review concentrates on metabolic rate, including the history of metabolic research, RMR measurement, and age-related changes in energy expenditure. Third, the review of the literature turns to general exercise and RT effects on this population. RT is further broken down into the different modalities of LVRT, other variations of RT, and HVRT. Finally, the effects of RT on RMR are examined.

Physical Effects of Aging

A number of biological changes accompany aging. It is often difficult to distinguish among inactivity-related, disease-related, and true age-related changes. Some age-related alterations can be stopped or slowed by exercise, but unfortunately for some, exercise cannot control the inevitable loss of function.

Age-related neural changes. Aging disturbs sleep patterns and shortens rapid-eye-movement sleep (Bortz, 1982). As sleep patterns are disrupted in older adults, they are less able to perform daily activities and exercise. However, increased PA can help improve some sleeping patterns for older adults. Changes in both the structure and function of the brain and nervous system are common manifestations in the aging process (Bortz, 1982). Busse et al. (1985) found brain wave activity slows down with aging and that a relationship exists between this brain-wave slowing and mortality, vascular disease, and cognitive function. In the aging brain, the prefrontal and parietal regions (involved in executive functioning) show the greatest age-related declines

(Colcombe et al., 2004). Colcombe and colleagues (2004) found that highly fit, older individuals (average 66.2 years) had higher levels of activity in the prefrontal and parietal regions than non-fit individuals (average 67.9 years). The importance of the link between cognition and exercise in aging has been examined both in epidemiological and longitudinal studies over the years, but more clinical research is needed (Kramer, Erickson, & Colcombe, 2006). Furthermore, the maximum conduction velocity of nerves decreases with increasing age, which causes neuromuscular delay in older adults (Norris, Shock, & Wagman, 1953). Neuromuscular delay contributes to some of the age-related changes in muscular strength and power and can lead to increased risk of falls. Metter, Schrager, Ferrucci, and Talbot (2005) found that increased reaction time and decreased movement speed (indications of age-associated impairment of motor control systems) were both risk factors for mortality. Although all of these changes in the nervous system lead to decreased health in all individuals due simply to age, the magnitude and severity of the changes vary person to person.

Age-related cardiovascular changes. Although not greatly influenced by RT, cardiovascular health contributes to overall health status and *response* to all forms exercise including RT. Research has shown that maximal oxygen consumption (VO_2max), an important measurement of cardiovascular function, declines at a rate of about 1% per year after age 50, but that decline can be partially modified by habitual, aerobic PA (Astrand, 1960; Brandfonbrner, Landow, & Shock, 1955). A minimal level of cardiovascular capacity must be maintained to perform even RT exercise. The major cause of the universal decline in cardiovascular capacity due to age is the decrease in cardiac output. During rest, the decrease in cardiac output is a result of a decrease in stroke volume, as resting heart rate does not change with age (Spiroduso, 1995; Bortz, 1982); however, during exercise, especially in trained older adults, the decrease in maximal heart rate due to age (max heart rate decreases by about 5 to 10 beats per decade) limits VO_2max more than stroke volume (Spiroduso, 1995). If an older individual is untrained, both a lower stroke volume due to age and a lower max heart rate will impose limits on cardiovascular function. Blood pressure is an important measure of cardiovascular health that greatly influences the response to RT. With systolic pressure increasing more than diastolic pressure, arterial blood pressure also increases with age (Busse et al., 1985; Spiroduso, 1995; Lakatta, 1979). Hypertension is a silent health concern that is extremely prevalent in seniors; in 2009, 34% of older adults had *uncontrolled* hypertension (US Department of Health and Human Services, Administration of Aging, 2011). Hypertension can make RT exercises dangerous to perform especially if the Valsalva maneuver (forceful exhalation against a close airway, or holding one's breath) is performed during the contractions. Although systolic blood pressure increases with age, it appears that at least some of that increase is due to physical inactivity rather than age alone (Spiroduso, 1995; Lakatta, 1979). Fortunately, exercise (both aerobic training and RT) in combination with nutritional intervention can help to lower blood pressure. Cardiac output, heart rate, and blood pressure all contribute not only to overall health but also to individual exercise response.

Age-related composition changes. Physical dimension characteristics and composition— such as height, weight, FM, and FFM—are important indications of health and are dramatically influenced by aging. As height and weight change quickly in early years of life, age-related changes continue to develop with age in older adults (Spiroduso, 1995). In males, height increases until about age 25 and then begins to decrease slowly, and in females, height increases until about age 20 and then begins to decrease slowly with females losing height at a faster rate than males. For weight, males on average increase weight until about age 40 and then begin to decrease slowly, and females increase weight until about age 50, stabilize until about age 70, and then begin to decrease. Body composition—the combination of bone, fat, and muscle masses—continues to change absolutely and relatively with age (Blanchard, Conrad, & Harrison, 1990; Spiroduso, 1995). Total body mass is often divided into terms of FM, FFM, and bone mineral content (BMC). Body composition has genetic, environmental, lifestyle, and age-related influences. Although all age-related changes of the body and its composition are important, those changes that are actually modifiable are of extreme importance; such areas include nutrition, PA, and exercise. Throughout life, proper nutrition is important to develop muscle mass and control recommended FM, and elderly adults are often undernourished for a variety of reasons, including disease and decreased appetite. PA plays a key role in decreasing FM and developing and maintaining FFM and BMC.

For most individuals, FM continues to increase even as body weight levels off at approximately age 50 and declines in the seventh decade, and FFM begins to decrease after age 30 primarily due to inactivity (Bortz, 1982; Spiroduso, 1995). FM is distributed differently in older adults than younger adults and differences also exist between genders. Men experience greater intra-abdominal (subcutaneous) fat and increased fat around the organs of older adults (Schwartz et al., 1990; Spiroduso, 1995). Women experience maintained amounts of subcutaneous fat and increased internal body fat (Durnin & Womersley, 1974). Furthermore, for both sexes, the ratio of muscle mass and FM changes with aging as fat and connective tissue invade muscle fibers and partially replace muscle tissue (Allen, Anderson, & Langham, 1960). It is estimated that FFM decreases about 3.0 kg per decade after age 35, and the rate of loss for men and women is about 0.34 kg/year and 0.22 kg/year, respectively (Forbes & Reina, 1970; Forbes, 1976). Between the ages of 40 and 80, FFM is lost by about 5.0% each decade in men and 2.5% each decade in women (Rudman et al, 1991). Sehl and Yates (2001) found that the rate of most organ system losses is about 0.0-2.0% per year after the age of 30, with the musculoskeletal system averaging about 1.0-2.0% per year. Furthermore, bone density loss leads to osteopenia and osteoporosis and increases the risk of bone fractures of older adults, with women at higher risk than men. The age-related changes of BMC, FFM, and FM are all important focuses of research in relation to PA in older adults (Evans & Campbell, 1993; Kirkendall & Garrett, 1998; Marcell, 2003; Roubenoff, 2003).

Age-related strength changes. In addition to loss of total muscle mass, sarcopenia and FFM decreases consequently contribute to loss of both muscular strength and power (Metter, Schrager, Ferrucci, & Talbot, 2005). Older adults have less strength and less power than younger adults in lower extremities (Petrella, Kim, Tuggle, Hall, & Bamman, 2005) and upper extremities (Metter, Conwit, Tobin, & Fozard, 1997). Even in healthy older adults, muscular strength and functional mobility diminish with age, with strength in women decreasing more quickly than men between the ages of 55 and 80 (Samson et al., 2000). Additionally, older adults are more fatigable, as they are not able to sustain maximum concentric velocity during repeated contractions due to decreased strength and power (Petrella et al., 2005). A propelling influence on the aging process is the loss of the ability of cells, tissues, and organs to repair and maintain function, and therefore, the components of the aging muscle must be significantly changed (Von Zglinicki, 2003). Klein, Rice, and Marsh (2001) found that a decrease in cross-sectional area accounts for the majority of age-related muscle strength losses, but additional aspects (e.g. coactivation of muscles and specific tension) can explain decreased muscle strength in older adults.

Age-related changes in cross-sectional area and number of muscle fibers lead to sarcopenia. Research was initially in disagreement with the effects of age on type I (oxidative fibers) and type II (anaerobic fibers) due to muscle biopsy techniques and subjects' age ranges (Kirkendall & Garrett, 1998; McArdle et al., 2010). Now it is generally accepted that type I fiber cross-sectional area is not significantly affected by aging and that type II fiber cross-sectional area ("fast-twitch" fiber) is significantly reduced by aging (Kirkendall & Garrett, 1998; Larsson & Karlsson, 1978; Lexell, Henriksson-Larsen, & Winblad, 1983). Additionally, the number of muscle fibers decreases, beginning at about age 25 and totaling to about 25-40% decrease by age 80, depending on muscle group (Lexell, Henriksson-Larsen, & Winblad, 1983; Lexell, Taylor, & Sjostrom, 1988). Contributing to the loss of muscle fibers is the loss of neural input (Doherty, Vandervoot, Taylor, & Brown, 1993; Kirkendall & Garrett, 1998). Motor unit remodeling is a continuous process of muscle maintenance, and this mechanism gradually subsides in aging (McArdle et al., 2010). Doherty, Vandervoot, Taylor, and Brown (1993) showed that with age, motor units and contractile strength of muscles are significantly decreased even in healthy and active older adults; however, PA helps individuals to compensate for some of the losses of motor neurons by re-innervation. Fortunately, these losses of muscle fibers and motor units in older adults can be counteracted by muscle hypertrophy through increased PA (Aniansson, Grimby, & Hedberg, 1992).

Advancing age is accompanied by physiological changes in the body's tissues, organ systems, and composition (Chodzko-Zajko et al., 2009). No amount of PA can stop the process of aging. However, exercise and PA are key contributors to improving some of the losses in FFM, strength, power, functional fitness, and quality of life.

Age-related Energy Expenditure Changes

In addition to these body system and composition changes, aging greatly influences TEE. The age-related decline of RMR, the largest component TEE, is discussed next (Manini, 2010). But in order to successfully understand the influence of aging on TEE, the systematic measurement of metabolism and energy must be appreciated first.

History of energy expenditure research. Considered the founder of modern chemistry, Antonie Lavoisier conducted the first measurement of BMR in the late 18th century by measuring the rate of oxygen consumption, food consumption, environmental temperature, and muscular work in animals in a resting postabsorptive state (Henry, 2005; Hulbert & Else, 2004). In the late 19th century and throughout the 20th century, research on BMR became more commonly performed. BMR measurements were primarily used in a clinical context due to Magnus-Levy determining in 1895 that secretions from the thyroid gland stimulated the metabolic rate in humans (Henry, 2005). Proposed by Sarrus and Rameaux in 1838, the surface law suggested that heat production of different-sized subjects should be related to surface area rather than body mass, and numerous studies in the early 20th century found that heat production was more proportional relative to body surface area than body mass (Hulbert & Else, 2004). Kleiber (1932) hypothesized that body size not only directly influenced the metabolism but also influenced all other factors that contributed to metaboism and therefore developed an equation based on the three-fourths power of body to predict BMR. Scientists developed innovative apparati to calculate metabolic rate by measuring oxygen consumption, carbon dioxide production, and heat production.

Because all metabolic processes (of cells, tissues, and the body as a whole) result in heat, measuring the rate of heat production results in measuring metabolic rate or energy expenditure

(McArdle et al., 2010). Direct calorimetry is the direct measurement of the amount of heat produced by an individual body in an isolated environment (Simonson & DeFronzo, 1990). The concept behind direct calorimetry is similar to the bomb calorimeter with which food calorie amounts are measured during combustion (McArdle et al., 2010; Simonson & DeFronzo, 1990). In the 1890s, the Atwater-Rosa calorimeter was developed, and it consisted of an air-tight, insulated copper chamber in which a human subject lived, ate, slept, and exercised. Other direct calorimeters have been developed and utilized to measure heat production and related heat produced to energy input and energy expenditure; however, direct calorimetry is very expensive and time-consuming and involves large, cumbersome equipment. Therefore, indirect calorimetry was established as an alternative but comparable measurement of energy expenditure. Because all energy reactions in the human body are the result of oxidation, measuring oxygen consumption rather than heat production is a simpler, less expensive, yet accurate technique.

Indirect calorimetry can be assessed by either closed-circuit spirometry or open-circuit spirometry. Closed-circuit spirometry involves a prefilled spirometer of 100% oxygen from which the subject breathes, and rebreathing is restricted to only the gas in the spirometer (hence closed-circuit); oxygen consumption is quantified as the difference between the intimal volume and final volume of oxygen in the spirometer (McArdle et al., 2010). Although simple and accurate, closed-circuit calorimetry still requires bulky equipment and is difficult to use during exercise. In open-circuit calorimetry, atmospheric air which has a relatively constant percentage of carbon dioxide, oxygen, and nitrogen is used; expired air is collected and the volume and composition is measured and compared to inspired air (or atmospheric air; McArdle et al., 2010; Simonson & DeFronzo, 1990). Over the years of research involving indirect calorimetry, a variety of spirometers and apparati have been developed and utilized. When it comes to daily

TEE measurement, respiratory chamber calorimetry is the gold standard (Schoeller et al., 1986; Westerterp, Saris, van Es, & ten Hoor, 1986). Although it is the most accurate indirect calorimetry method for extended measurement of EE, the chamber still restricts free-living activity by the very nature of the equipment. Therefore, Lifson, Gordon, and McClintock (1955) developed the doubly-labeled water method in which water is labeled with the isotope D_2O^{18} to measure CO_2 production in the urine and saliva. These researchers found that their doubly-labeled water technique averaged only 7% CO_2 difference from a respiration chamber in 15 mice over a 24-hour period. Once the cost of the oxygen-18 isotope decreased due to scientific developments, the doubly-labeled water procedure was later validated for use in humans (Schoeller et al., 1986; Schoeller & Webb, 1984) even during high intensity exercise (Westerterp et al., 1986). Respiration chambers and doubly-labeled water are essential, valuable measurement methods in EE research, but still difficult measures to perform due to the time commitment required for both participants and researchers.

Common methods of indirect calorimetry for the measurement of RMR include the ventilated hood, portable spirometry, bag technique, and computerized instrumentation (McArdle et al., 2010; Simonson & DeFronzo, 1990). These techniques, specifically computerized systems in combination with either a ventilated hood or face mask, are excellent tools for laboratory measurement of RMR and exercise EE. Several computerized metabolic cart systems have been validated as accurate and reliable for the measurement of RMR (Bassett et al., 2001; Compher, Frankenfield, Keim, & Roth-Yousey, 2006; Crouter, Antczak, Hudak, DellaValle, & Haas, 2006) and exercise EE (Levine, 2005; Wilmore, Davis, & Norton, 1976). Although RMR measurement requires specialized equipment and a moderate time-commitment, RMR is a valuable component of health and important research variable.

Age-related changes in RMR. Of the three components of TEE, RMR is the largest contributor and has, therefore, been a major focus of research; the age-related decline in RMR has been widely reported in the literature (Fukagawa, Bandini, & Young, 1990; Johnstone, Murison, Duncan, Rance, & Speakman, 2005; Krems, Luhrmann, Strabburg, Hartmann, & Neuhauser-Berthold, 2005; Poehlman et al., 1992; Poehlman et al., 1993; Poehlman, McAuliffe, Houten, & Danforth, 1990; Poehlman, Melby, & Badylak, 1991; Tzankoff & Norris, 1977; Tzankoff & Norris, 1978; Van Pelt, Dinneno, Seals, & Jones, 2001; Van Pelt et al., 1997). Some researchers believe the drop in RMR is only due to loss in FFM, while others contend FFM loss does not fully account for the decrease in RMR. Early research by Tzankoff and Norris on BMR provided evidence supporting muscle mass-dependent decreases in RMR (Tzankoff & Norris, 1977; Tzankoff & Norris, 1978). Using creatinine excretion to assume muscle mass and anthropometric measurement to estimate FM, these researchers found an age-independent linear relationship between BMR and creatinine excretion (*r* = .64; Tzankoff & Norris, 1977). Tzankoff and Norris (1978) performed a longitudinal examination of the changes in BMR and non-muscle oxygen (O_2) consumption using data from the Baltimore Longitudinal Study. They found a 3.7% per decade decline in BMR and no change in non-muscle O_2 consumption with age until the decade preceding death, during which non-muscle O_2 consumption gradually increased. Although these authors were instrumental in metabolism research, more precise and appropriate FFM-determining methods are now commonplace.

More recent research has provided evidence that FFM is not the only explanation for the decline in RMR. Poehlman and colleagues (1993) examined the relationship between age-related decline in RMR in females and non-FFM factors, such as VO_2max, leisure time PA, thyroid hormone concentration, and nutrition. They found that for women aged 18 to 81, both FFM and

RMR showed a curvilinear decline with age, but the decline was only significant for women ages 50 or older ($p < .01$). The reported decline in RMR was primarily explained by the decline in FFM ($R^2 = 72\%$, $p < .01$), and no other tested variable contributed independently to the variance in RMR thereafter. Although FFM explained most of the change in RMR, 28% was left unaccounted. Unfortunately, none of the other measured variables were able to independently account for non-FFM RMR decline. Similarly, Fukagawa et al. (1990) investigated the relationship between RMR and FFM in young men, older men, and older women. The statistical difference between older men and older women disappeared when RMR was adjusted for FFM (1.03 ± 0.02 versus 0.99 ± 0.02 kcal/min, respectively, $p = .16$). When comparing the young and older men, RMR was significantly lower absolutely (1.24 ± 0.03 versus 1.04 ± 0.02 kcal/min, $p < .002$) and when adjusted for FFM (1.13 ± 0.02 versus 1.03 ± 0.02 kcal/min, $p < .002$). These researchers concluded that the age-related decline in RMR is due to FFM changes but also due to other factors, such metabolic activity of FFM.

Many researchers have developed studies to attempt to identify the other contributing factors to the age-related decline in RMR. Krems and associates (2005) sought to determine whether or not body composition solely contributed to the differences in RMR among young and older males and females ($n = 442$). When adjusted for FFM, FM, waist-to-hip ratio, and smoking status by covariance, adjusted RMR was lower by 377 kJ/day in older women and 587 kJ/day in older men when compared to younger women and men, respectively ($p < .01$). Although these researchers did not measure any additional contributing factors, their research adds to the evidence that FFM alone does not fully explain age-related RMR changes. Johnstone et al. (2005) examined the variation in RMR by looking at FFM, FM, age, sex, leptin, triiodothyrionine (T_3), and thyroxine (T_4; $n = 150$). FFM accounted for 63% of the variability in

RMR (*p* < .001), with FM accounting for an additional 6% (*p* < .01) and age 2% (*p* < .03). Therefore, 26% of the variation in RMR was unexplained and not associated with leptin or T_3. In men T_4 accounted for 25% of the residual variance but was not significantly associated with RMR in women. The previously discussed Poehlman (1993) study also measured T_3 in female subjects. Although they reported low but significant correlations between RMR and T_3 (*r* = .25, *p* < .01), the relationship was not significant, independent of FFM. The relationship between numerous hormones and RMR decline is common in the literature, but the associations tend to be small or insignificant.

In addition to hormone concentration, two of the most commonly researched variables in relation to age-related changes in RMR and FFM are physical activity and exercise. Poehlman and colleagues (1990) examined the associations among age, VO_2max, body composition, several hormones (insulin, glucose, glucagon, T_3, and T_4), energy intake, and RMR in sedentary and endurance-trained younger and older men (*n* = 68). When RMR was adjusted for FFM, a significant effect of endurance training on RMR was found, but no effect existed for age. Of all the variables measured, three independently accounted for 61% of RMR: FFM by 55%, VO_2max an additional 4%, and body weight another 2% (leaving 39% of the variance in RMR unaccounted). In a similar study using the same subjects in addition to 232 new volunteers, Poehlman et al. (1992) measured RMR, VO_2max, body composition, estimated energy intake, T_4, and T_3. After adjusting for FFM and FM, RMR was still correlated with age (*r* = -.29, *p* < .01). The relationship remained significant when either energy intake (*r* = -.26, *p* < .01), T_3(*r* = -.27; *p* < .01), or free T_3(*r* = -.43; *p* < .01) was added as a third covariate. When VO_2max was added as a third covariate, the relationship between RMR and age disappeared (*r* = -.10, *p* > .05).

The researchers concluded that VO_2max was the only one of the measured variables that was independently associated with the RMR decline.

Adding to the body of literature relating physical activity and RMR, Van Pelt et al. (2001) studied 137 healthy males aged 19-36 or 52-75. In both age groups, some were sedentary and the others were physically active and endurance trained. With age, RMR adjusted for FFM was lower for both sedentary (72.0 ± 2.0 versus 64.0 ± 1.3 kcal/hour, $p < .01$) and active (76.6 ± 1.1 versus 67.9 ± 1.2 kcal/hour, $p < .01$) men. The difference in adjusted RMR between sedentary and active older men was also significant (64.0 ± 1.3 versus 67.9 ± 1.2 kcal/hour, $p < .05$). In the active men, adjusted RMR was related to exercise volume, regardless of intensity ($r = .56$, $p < .001$) and estimated energy intake ($r = .58$, $p < .001$), and in subgroups of younger and older active men matched for volume or energy intake, adjusted RMR was not significantly different. These researchers found that the decline in RMR is still primarily associated with FFM decreases, but controlling for FFM, RMR decreases with age as a result of reduced exercise volume and energy intake. Furthermore, they concluded this decrease in RMR after controlling for age-related FFM changes can be prevented in those who maintain exercise volume and dietary intake with age. Some of the same authors also performed a similar study with women (Van Pelt et al., 1997). In this study, they used 65 sedentary and endurance-trained females aged 21-35 or 50-72. RMR adjusted for FFM was lower in older sedentary women as compared to younger sedentary (52.0 ± 2.0 versus 57.0 ± 2.0 kcal/hour, $p < .002$) but not significantly different between older and younger active women (57.0 ± 2.0 versus 59.0 ± 2.0 kcal/hour). Unlike the men in the other study, adjusted RMR was not associated with energy intake or exercise volume for either activity group. The authors concluded that for women, RMR controlled for FFM does not decline if they remain physically active.

Although there is a clear age-related decline in RMR and the decrease in muscle mass contributes to that decline, there are also other age-related factors, such as altered tissue metabolism and other factors discussed previously, which further decrease RMR in older adults (Allen, Anderson, & Langham, 1960; Forbes, 1976; Forbes & Reina, 1970; Fukagawa, Bandini, & Young, 1990; Rudman et al., 1991). These other age-related factors that decrease RMR in older adults need to be researched further, but research should still focus on RMR and FFM because FFM is a semi-modifiable component.

Older Adults and Exercise

Considering the vast array of changes that accompanies aging and the influence of exercise and PA on those changes, exercise should be an essential prescription for older adults. The American College of Sports Medicine (ACSM) recommends that older adults perform at least 5 days/week of moderate intensity aerobic activities, weight-bearing exercises, and flexibility exercises and 2-3 days/week of muscular strength and endurance exercises and balance exercises (Thompson et al., 2010). Numerous research studies have provided scientific evidence—to be discussed in length next— that RT can increase bone mass, muscle mass, muscle strength, muscular power, neuromuscular control, flexibility, balance, self-confidence, and self-esteem in older adults and can be performed at low risk for this population (Barry & Carson, 2004; Seguin & Nelson, 2003). Although it is commonly accepted that PA and exercise can safely and greatly benefit this population, older adults are the least physically active of all age groups (Thompson et al., 2010). Therefore, RT for older adults has been a concern of research for over three decades, but experts have yet to agree upon the best strategy to improve the health status for this group (Sayers, 2008). The response to a training program is determined by the specificity of the training (McArdle et al., 2010). The ultimate goal of the individual (whether that be the ability to play with grandchildren or the ability to go grocery shopping alone, etc.) determines what resistance training method will be most effective.

Generally, the relative adaptations to exercise for cardiovascular endurance, muscular strength, muscular endurance, and flexibility in older adults are comparable with those in younger adults, and exercise prescription for older adults should include aerobic, muscle strengthening, and flexibility exercises (Thompson et al., 2010). In contrast, not all of the research concerning older adults and exercise has confirmed that exercise positively effects health status of this population. Buchner et al. (1997) found that none of their 6-month exercise interventions (strength training, endurance training using bicycles, and a combination of strength and endurance training) were able to significantly affect gait, balance, or physical health status. Despite some disappointing effects of their exercise programs, all of the exercise groups had lower risk of falling, less outpatient clinic visits, and lower hospital costs than the CTRL group. Therefore, research needs to focus on the specific methodology and training in which older adults can achieve the greatest physical health benefits.

Endurance and muscular strength are the focus of health for people of all ages, but for older adults, muscular strength and power become even more crucial to perform activities of daily living and maintain functional independence. For muscle-strengthening activity, ACSM recommends a “progressive weight-training program or weight-bearing calisthenics (8-10 exercises involving the major muscle groups of 10-15 repetitions each), stair climbing, and other strengthening activities that use the major muscle groups” (Thompson et al., 2010; p.190). For older adults, special considerations such as intensity and duration need to be taken into account, and a conservative approach is often used with this population. Sarcopenia, loss of strength, loss of power, decreased energy expenditure, and increased FM all occur with age, but RT in older adults can significantly improve all of these factors. Improvement is possible for both LVRT and HVRT exercise interventions. Determining beneficial RT programs for older adults is crucial.

RT programs of various types can produce increases in strength, and the adaptation that leads to increased strength is often due to increases in cross-sectional area of the muscle or total muscle mass. However, some of the increases in strength are beyond what can be accounted for by hypertrophy, especially in older adults (Hunter, McCarthy, & Bamman, 2004). At the initial phases of training, these additional training-induced increases in strength are most likely due to increased motor unit activation in the neural system of the muscle (Aagaard, Simonsen, Anderson, Magnusson, & Dyhre-Poulson, 2002; Hakkinen et al., 1998; Hunter, McCarthy, & Bamman, 2004; Van Cutsem, Duchateau, & Hainaut, 1998). Aagaard and colleagues (2002) found that males who performed a 14-week progressive, heavy-RT protocol (4 or 5 sets of 3 to 10 repetition maximum loads) for the lower extremities (calf raises, squats, incline leg press, unilateral knee extension, and hamstring curls) induced 23% increased strength ($p < .05$) in the soleus muscle and increases in neural activity of the muscle. The neural improvements were evidenced by increased amplitude of V-wave by 55% (measurement of efferent neural drive from spinal motor neurons during maximal muscle contraction; $p < .01$) and of H-reflex by 19% (assessment of motor neuron excitability; $p < .05$). Van Cutsem, Duchateau, and Hainaut (1998) showed that a 12-week RT program (10 sets of 10 fast dorsiflexion contractions at 40% 1RM) caused a 19.6% increase in EMG activity ($p < .05$) with a 15.6% decrease in the time taken to reach maximal EMG value ($p < .01$). Additionally, an increase in the frequency of motor unit firing was observed (percentage of units firing double intervals increased from 5.2-32.7%). All of these results indicate that neural adaptations are likely to cause some of the increases in speed of contraction and in strength after HVRT. Regardless of the specific type of program, RT not only increases muscular strength and power, it also produces significant adaptations in nervous system activation in older adults.

Low-velocity Resistance Training. The effects of typical low-velocity resistance training programs on hypertrophy, functionality, and muscle power is discussed individually in this section, while the effects on muscular strength is mentioned throughout as it is a common measurement in a variety of research studies.

One of the primary emphases of RT is to prompt hypertrophy, or muscle growth. Several research studies have been able to show that older muscles can significantly hypertrophy (Hunter et al., 2004). Charette et al. (1991) implemented a 12-week LVRT intervention (3 days/week) for the leg and hip in older women (69.0 ± 1.1 years). The participants performed 3 sets of 6 repetitions of each of the seven lower limb exercises (leg extension, leg curl, leg press, hip abduction, hip adduction, hip extension, and hip flexion) at 65% original 1RM for the first 5 weeks, 70% first-retest 1RM for the next 4 weeks, and 75% second-retest 1RM. The women had significant increases ($p < .001$) compared with baseline values for all seven exercises (15.5 kg increase and 92.6 ± 12.6% change for leg extension, 7.7 kg and 115.3 ± 27.4% for leg curl, 16.8 kg and 28.3 ± 5.7% for leg press, 11.0 kg and 90.6 ± 13.2% for hip abduction, 8.1 kg and 33.9 ± 6.2% for hip adduction, 10.3 kg and 28.3 ± 3.7% for hip extension, and 11.0 kg and 95.8 ± 13.2% for hip flexion). The cross-sectional area of type II muscle fibers significantly increased (20.1 ± 6.8%, $p = .02$) as measured by manual planimetry (measuring the area of the planes for the specimen) of muscle biopsy.

Additionally, Pyka, Linsenberger, Charette, and Marcus (1994) found that over a year-long LVRT intervention consisting of twelve exercises, older adults (68.2 ± 1.0 years) in the exercise group were able to increase strength and hypertrophy. Muscular strength increased rapidly over the first 3 months and then plateaued for the rest of the year-long intervention (95.4 ± 10.0% for leg extension, 75.9 ± 12.2% for leg flexion, 53.1 ± 9.6 for leg press, 96.8 ± 12.4% for hip flexion, 96.8 ± 12.4% for hip extension, 91.4 ± 18.6% for hip abduction, 61.9 ± 7.0% for hip adduction, 54.5 ± 12.4% for back extension, 49.7 ± 7.6% for bench press, 32.0 ± 5.2% for military press, 49.9 ±10.2% for triceps press, and 77.8 ± 20.7% for upright row). Cross-sectional area was only measured at 15 weeks and 30 weeks; type I fibers increased by 29.4 ± 1% at 15 weeks and 58.5 ± 13.7% at 30 weeks compared to baseline ($p < .02$ and $p < .002$, respectively), and type II fibers did not increase at 15 weeks but increased 66.6 ± 9.5% by 30 weeks ($p < .0002$). Long-term LVRT can induce rapid changes in strength with hypertrophy of type I and type II fibers eventually. Furthermore, McCartney, Hicks, Martin, and Weber (1996) found that in men and women aged 60 to 80, a 2-year RT protocol increased the cross-sectional area of knee extensors by 8.7% ± 0.9% as measure by computerized tomography (CT scan). These individuals had never weight-trained before, and they performed unilateral military press, leg press, ankle plantarflexion, and bilateral bench press exercises on a multistation weight training machine 2 days/week for 22 out of the 24 months of the training intervention. The researchers also showed that muscular strength in the leg press increased 32.0% and in the military press by 90.0%. Pyka et al. (1994) most likely found more robust hypertrophy than McCartney et al. (1996) due to performance of muscle biopsy measurement, which is a more sensitive measure of muscle fiber size than is a CT scan.

There are sex differences in resistance-training hypertrophy for older adults. Bamman et al. (2003) found sex differences in 1RM strength gains and hypertrophy of all three fiber types (I, IIa, IIx) following at LVRT protocol for major muscle groups, performing 2 sets of 15-25 repetitions at 80% 1RM 3 days/week for 26 weeks. Both the older men and women increased their FFM (2.6 kg for men and 1.7 kg for women), reduced body fat (-2.9% for men and -3.1% for women), and maintained body weight. Men had a 40% average increase in myofiber size, compared to only 7% in women, and they had a 82% increase in strength, compared to only 58% in women (both relative to pre-training values). Although men typically have larger increases than women, long-term RT programs can induce hypertrophy in both of the sexes.

Another emphasis of RT is to increase power production in older adults. Traditional resistance can promote modest power increases in older adults. Jozsi, Campbell, Joseph, Davey, and Evans (1999) conducted a progressive RT program consisting of seated chest press, seated arm pull, seated unilateral knee extension, seated bilateral leg curl, and seated bilateral leg press 2 days/week for 12 weeks. The training enabled both younger and older men and women to significantly increase relative muscle power output for arm pull at 40 and 60% 1RM and leg extension at 40, 60, and 80% 1RM. Older individuals increased strength similarly to younger individuals in every exercise except for the left knee extension (35.0% for old men, 26.5% for young men, 29.3% for old women, and 28.1% for young women). Men increased more in strength for all exercises except for the leg press than women, independent of age. Older adults can achieve significant strength gains, but men may have higher absolute strength gains as compared to women.

Furthermore, another emphasis of RT is to increase functionality and PA levels of older adults. Functional fitness for older adults can be assessed by a variety of measures including gait velocity, static balance, agility and dynamic balance, and chair stands. Utilizing elderly people (87.1 years), Fiatorone and colleagues (1994) found that LVRT at 80% 1RM (hip extension and leg press) for 10 weeks improved functional fitness in terms of increased gait velocity (11.8 ± 3.8%) and muscular strength (113.0 ± 8.0%) as compared to a non-exercise CTRL group whose gait velocity actually decreased (1.0 ± 3.8%) and strength increased (3.0 ± 9.0%). Simons and Andel (2006) found that in 64 subjects (average 83.5 years) LVRT at 75% 1RM (leg extension, leg curl, leg press, lat pull-down, upper back, and chest press) and walking for 16 weeks were both able to improve functional fitness in terms of agility and dynamic balance compared to a CTRL group (18.5% and 8.9% decrease in time versus 16.7% increase in time, $p < .001$). Balance and agility was assessed by the AAHPERD Agility and Dynamic Balance Test, which consists of standing up from an armless chair, negotiating an obstacle course, sitting down again, and repeating the course once more. In contrast, Schlicht, Camaione, and Owen (2001) found that RT at 77.8 ± 3.4% 1RM (leg extension, inner thigh press, outer thigh press, glute press, leg press, and ankle press) for 8 weeks was able to improve maximal walking speed (17% versus 6% increase, $p < .05$) but not single-leg blind balance (1% versus 5% increase, $p > .05$) or timed 5-repetition chair stand (15% versus 13% decrease, $p = .082$) compared to CTRL. Overall, RT improves functional fitness, but the magnitude of the improvement is dependent on which measure of fitness is used and the RT program (specific exercises, length of intervention, and intensity).

There is still some debate whether late-life PA provides *all* the benefits thought to be a result of exercise, i.e. minimizing or even preventing disability and functional performance decline (Keysor, 2003). Keysor and Jette (2001) conducted a systematic review of literature concerning experimental and quasi-experimental aerobic and resistance exercise training programs. They found that late-life exercise does increase strength, aerobic capacity, flexibility, and physical function; however, late-life exercise does not effectively reduce disability. The authors did qualify their findings; the studies used in the review may have methodology limitations in their ability to quantify and examine disability. However, another explanation could be that the modes of exercise (aerobic and LVRT) could be poor effectors of disability, and another mode (such as HVRT) could better serve to improve the effects of late-life exercise.

Additional Resistance Training Modalities. The variables of RT (weight, velocity, repetitions, sets, frequency) can all be manipulated for different results. Some researchers have experimented with intensity of resistance training. For example, Fiatarone et al. (1990) found that a 8-week high-intensity (80% 1RM) RT protocol induced significant strength gains, as lower-extremity strength ranged from 61% to 374% over baseline. Furthermore the high-intensity intervention resulted in significant improvement in gait speed (48%) for the nine subjects (90.1 ± 1.1 years). Similarly, Nelson et al. (1994) implemented a year-long, high-intensity LVRT program for postmenopausal women (ages 50 to 70). These researchers showed that performing high-intensity exercises (hip extension, knee extension, lateral pull-down, back extension, and abdominal flexion) using Keiser pneumatic resistance machines for 3 sets of 8 repetitions at 80% 1 RM, 2 days/week resulted in increases in femoral neck bone and lumbar spine density, muscle mass, muscle strength, and dynamic balance. Maddalozzo and Snow (2000) also conducted a high-intensity LVRT program with free weights and tested its effects on bone mass, body composition, and muscle strength. They found that high-intensity training resulted in increased strength, lean body mass, and some increases in bone mass (significantly for men but not for women) and decreases in FM after 6 months of training.

Another RT program variation is superslow resistance training (SSRT), which lay publications once claimed to better enhance strength development due to the increased amount of time the muscle exerts tension (Keeler, Finkelstein, Miller, & Fernhall, 2001). Keeler and colleagues (2001) compared the outcomes of SSRT and LVRT programs for 3 days/week for 10 weeks on muscular strength and body composition. They found that both groups significantly increased strength on leg press, leg curl, leg extension, lateral pull-down, bench press, seated row, biceps curl, and triceps extension, but the LVRT group's improvement was significantly greater than the SSRT group for all eight exercises (39% versus 15%). There were no significant changes in body composition, which suggests the improvements were primarily neurological, but the researchers caution that their measure of hypertrophy (BodPod) may not have been sensitive enough to detect true, smaller changes in muscle mass. Although an array training components such as intensity or speed can be altered, research is an important tool to determine which alterations are truly advantageous and which are not.

High-velocity Resistance Training. For both the general population and older adults, it is important to consider the objective or goal of the training when stating one modality is superior to another. Harris, Stone, O'Bryant, Proulx, and Johnson (2000) showed that a combination of high-force LVRT and HVRT resulted in greater gains in strength, power, and speed than either high-force LVRT or HVRT alone for young (average age of 19) football players; the combination of high-force and high-velocity allowed participants to gain the benefits associated with each training method for overall, wider improvement of sport-specific performance. Although the combination of LVRT and HVRT was most effective for young athletes training for football, Henwood and Taaffe (2006) found that the test measurement and corresponding component (i.e. 1RM test for strength and 6-meter backwards walk for dynamic balance) determined whether HVRT, LVRT, or a combination training for 8 weeks was more beneficial for older adults. All three variations of RT were effective at increasing muscular strength. The average (of all six exercises) muscle strength change was 22.0 ± 12.5% for HVRT, 21.7 ± 11.0% for LVRT, 26.1 ± 14.4% for combined, and -1.8 ± 7.2% for CTRL (all conditions significantly higher than CTRL, $p < .01$). Adjusted for baseline value and gender and then compared to the CTRL group, HVRT, LVRT, and combined all significantly improved the leg curl (23.5 ± 1.1 kg versus 31.1 ± 1.1 kg, 30.4 ± 1.1 kg, and 30.1 ± 1.3 kg, respectively; $p < .001$), leg extension (36.0 ± 1.4 kg versus 44.9 ± 1.3 kg, 46.7 ± 1.3 kg, and 48.4 ± 1.6 kg, respectively; $p < .001$), and row (44.4 ± 2.0 kg versus 53.5 ± 1.8 kg, 54.2 ± 1.9 kg, and 63.4 ± 2.3 kg respectively; $p < .001$). For the biceps curl, the combined (26.8 ± 1.2 kg) and LVRT (24.9 ± 1.0 kg) were significantly higher as compared to CTRL (19.8 ± 1.0 kg), while HVRT (23.7 ± 1.0 kg) was not significantly different. However, for the leg press, the HVRT (78.4 ± 1.5 kg) was significantly higher compared to the CTRL (70.3 ± 1.6 kg), while LVRT (77.2 ± 1.5 kg) and combined (76.1 ± 1.8 kg) were not significant. For the chest press, there were no significant differences from the CTRL for any of the exercise groups ($p = .53$). Furthermore, for most power-oriented functional tasks (i.e. timed 5-repetition chair stand and stair climbing), HVRT alone was the most beneficial for older adults (for chair stand, HVRT: 11.9 ± 2.0 to 10.5 ± 0.3 seconds versus LVRT: 12.1 ± 2.3 to 11.4 ± 0.3, combined: 12.6 ± 2.0 to 11.6 ± 0.4, CTRL: 12.0 ± 1.9 to 12.0 ± 0.3 seconds). As muscular power may the strongest predictor of functional status in older adults and HVRT focuses more on increasing muscular power in addition to strength, HVRT could potentially be a beneficial RT protocol for older adults.

A variety of research studies have compared the effects of HVRT and LVRT in older adults. Comparing 10-week HVRT and LVRT protocols, Bottaro, Machado, Noqueria, Scales, and Veloso (2007) investigated the outcomes of the two types of RT (2 days/week) on functional performance, muscular strength, and muscular power in men aged 60-76. The HVRT group (or the power training group) performed 3 sets of 8-10 repetitions at 60% of 1RM as fast as possible, and the LVRT group performed 3 sets of 8-10 repetitions at 60% of 1RM with 2-3 seconds of contraction for 7 exercises (leg press, knee extension, knee flexion, chest press, seated row, elbow extension, and elbow flexion). The arm curl, 30-seconds chair stand, and 8-ft up-and-go tests of the Senior Fitness Test were the selected measures of functional performance. For the arm curl, HVRT improved by 50.3% and LVRT by 2.8% ($p < .05$). HVRT also significantly improved the chair-stand by 43.0% (17.8 ± 5.4 to 25.5 ± 5.6 stands) and up-and-go by 15.3% (5.8 ± 1.0 to 4.9 ± 0.6 seconds) compared to LVRT which improved chair stand by 6.0% (22.0 ± 3.7 to 23.3 ± 3.2; $p < .05$) and up-and-go by 0.8% (5.0 ± 0.7 to 5.0 ± 0.6 seconds; $p < .05$). For muscular strength, both groups significantly improved leg press (27.1% and 26.7%) and chest press (28.2% and 24.9%; $p < .05$), and there was no significant difference between HVRT and LVRT groups for leg press (174.3 ± 33.7 to 221.6 ± 41.9 kg versus 176.7 ± 26.1 to 223.9 ± 37.7 kg, respectively) and chest press (45.1 ± 6.5 to 57.8 ± 8.7 kg versus 50.2 ± 8.1 to 62.7 ± 8.5 kg). For muscular power, both groups significantly improved leg press power (31.0% and 7.8%) and chest press power (36.9% and 13.2%; $p < .05$), but there were significant differences between HVRT and LVRT for leg press power (613.6 ± 137.9 to 803.7 ± 164.7 watts versus 573.8 ± 107.5 to 618.7 ± 121.9 watts; $p < .05$) and chest press power (235.3 ± 57.9 to 322.2 ± 82.3 watts versus 233.9 ± 62.4 to 264.8 ± 59.2 watts; $p < .05$). This study demonstrated that HVRT and LVRT were equally effective in improving strength, but HVRT was more effective in increasing leg press power and functional fitness.

Additionally, Henwood, Riek, and Taaffe (2008) tested the effects of HVRT and LVRT on functional performance, muscular strength, and muscular power, but they used older men and women (ages 65 to 84). This 24-week exercise intervention (2 days/week; chest press, seated row, biceps curl, leg press, leg curl, and leg extension) included a 2-week conditioning phase performed at 65% 1RM and 70% 1RM. Then the LVRT group performed 3 sets of 8 repetitions at 75% 1RM with 3 seconds each for concentric and eccentric phases, and the HVRT group performed the first set of 8 repetitions at 45% 1RM, the second set of 8 repetitions at 60% 1RM, and the third set of at least 8 repetitions at 75% 1RM. A CTRL group performed no form of training. These researchers found that FFM increased for all groups (HVRT by 1.2 ± 0.2 kg, LVRT by 1.4 ± 0.3 kg, and CTRL by 0.6 ± 0.3 kg). Total strength (across all six exercises) significantly increased by 51.0 ± 9.0% for HVRT and 48.3 ± 6.8% for LVRT ($p < .001$) with no significant difference between the two exercise groups and no significant difference from baseline for CTRL (1.2 ± 5.1%). Average power of leg extension as assessed by force plate and velocity measurement was significantly greater in HVRT (170.1 ± 9.7 watts) and LVRT (174.4 ± 9.6 watts) compared to CTRL (133.4 ± 10.9 watts) following training ($p < .005$), but no significant difference existed between the two exercise groups for average power. Functional fitness assessed by a battery of 8 tests (floor rise to standing, stair climb, backwards 6-m walk, 5-repetition chair stand, and 400-m walk) increased significantly and similarly for both exercise groups with no statistically significant difference between the two exercise groups (chair stand time decreased by 1.5 seconds for HVRT and 1.3 seconds for LVRT and increased by 0.5 seconds for CTRL). Although there were similar improvements between HVRT and LVRT, the HVRT group expended less (by about 20%) total work per training session. Therefore, it is likely that if the HVRT group had performed equal amounts of work as the LVRT group, the HVRT would have had greater increases in strength, power, and/or functional fitness.

Fielding and colleagues (2002) examined the outcomes of 16-week (3 days/week) HVRT and LVRT exercise programs (3 sets of 8 repetitions for leg press, left knee extension, and right knee extension) at 70% 1RM for women ages 65 or older. For muscular strength, leg press increased by 35% for HVRT and 33 % for LVRT and knee extension by 45% for HVRT and 41% for LVRT with no significant difference between groups ($p = .52$ and $p = .22$, respectively).

For peak power, HVRT had significantly greater increases in leg press peak power compared to LVRT (267.0 watts versus 139.0 watts; *p* < .007), but there was no significant difference between HVRT and LVRT for knee extension peak power after training (30.0 watts versus 22.0 watts; *p* = .183). Similarly, Earles, Judge, and Gunnarsson (2001) investigated the effects of a 12-week (3 days/week) HVRT intervention (knee extension, hip extension, hip flexion, and plantar flexion) on men and women ages 70 and older, but rather than comparing HVRT to LVRT, this study compared to HVRT to a walking program (12-week, 6 days/week, 30 minutes). The HVRT group significantly increased leg press power by 22% (273.0 ± 115.0 to 337.0 ± 156.0 watts, while the walking group non-significantly decreased leg press power (277.0 ± 70.0 to 256.0 ± 88.0 watts). Leg press strength significantly increased in both groups: HVRT by 22% (6.24 ± 1.41 to 7.61 ± 1.73 N/kg) and walkers by 12% (6.28 ± 1.17 to 7.02 ± 1.50 N/kg) with no significant difference between groups. Functional fitness was assessed by the Short Physical Performance Battery, and the HVRT group increased total score from 10.6 ± 1.7 to 11.3 ± 1.0, while the walking group went from 11.0 ± 1.0 to 11.1 ± 1.0 with no significant difference between groups or significance in improvement of functional performance.

In contrast to HVRT improving power but not functional fitness, Miszko et al. (2003) found that there was no difference between the two exercise groups for average power but significantly greater changes in functional fitness test scores for HVRT compared to both LVRT and CTRL. In this study, participants performed either LVRT or HVRT at 80% 1RM (3 sets of 6 to 8 repetitions on seated row, chest press, triceps extension, leg press, leg extension, seated leg curls, plantar flexion, and squats) for 16 weeks (3 days/week). Both HVRT and LVRT significantly increased chest press (31.0 ± 12.9 to 34.8 ± 14.6 kg, 12.3% and 30.3 ± 15.8 to 34.6 ± 17.7 kg, 14.4%), respectively, compared to CTRL (29.4 ± 12.2 to 29.2 ± 13.6 kg, -0.6%).

Similarly, HVRT and LVRT significantly increased leg press (95.5 ± 33.2 to 107.7 ± 32.2 kg, 12.8% and 85.6 ± 45.20 to 105.3 ± 53.1 kg, 23.0%) compared to CTRL (75.6 ± 38.90 to 79.7 ± 37.5 kg, 5.4%). For average anaerobic power as assessed by a Wingate cycle test, HVRT increased by 6.2% (233.1 ± 80.0 to 247.5 ± 119.0 watts), LVRT increased by 8.0% (216.7 ± 100.0 to 234.1 ± 107.0 watts), and CTRL decreased by 11.9% (199.8 ± 64.0 to 176.0 ± 54.0 watts). For functional fitness as assessed by the Continuous Scale Physical Functional Performance test, HVRT increased total score by 15.3% (58.2 ± 13.0 to 67.1 ± 13.0), LVRT by 4.0% (55.5 ± 10.0 to 57.7 ± 10.0), and CTRL by 2.7% (55.5 ± 14.0 to 57.0 ± 18.0). For functional fitness, HVRT score was significantly greater than both LVRT and CTRL ($p < .05$), and LVRT was not significantly different from CTRL.

de Vos et al. (2005) sought to discover the optimal load to use in HVRT for older adults. These researchers assigned the participants to a HVRT group at either low-intensity (20% 1RM), medium-intensity (50% 1RM), or high-intensity (80% 1RM) 2 days/week for 12 weeks. They performed bilateral leg press, seated chest press, bilateral leg extension, seated row, and seated bilateral leg curl on Keiser pneumatic resistance-training machines. All three groups increased average peak power similarly (high: 14 ± 8%, medium: 15 ± 9%, low: 14 ± 6%) and significantly compared to the CTRL group (3 ± 6%). However, the researchers discovered a positive dose-response relationship between intensity and average strength ($r = .40$) and endurance ($r = .43$), so they concluded that applying heavy loads in HVRT may be the most successful way to improve strength, power, and endurance simultaneously in this population. Even at high loads and high velocity, there was a very low rate (0.3%) of adverse events for these older adults. In a similarly designed study by the same authors, Orr et al. (2006) examined the effects of HVRT at low (20% 1RM), medium (50% 1RM), and high (80% 1RM) intensities on balance. They found that

HVRT significantly improved balance in all of the groups as compared to the CTRL group, with low-intensity HVRT producing the greatest improvement in balance. The intent of the training program helps to determine at what load older adults should perform the HVRT protocol. For example for power production, a typical power curve (force versus velocity) reveals that the highest power occurs at approximately 70% 1RM (Bean et al., 2004).

Rather than using exercise machines, Bean et al. (2004) created a HVRT program that utilized a weighted vest, "emphasized *in*creased *v*elocity *e*xercise *s*pecific to *t*ask, designated by the acronym InVEST [*sic*]" that can be performed at home (p.800). The protocol required subjects to perform 3 sets of 10 chair stands, toe raises, pelvic raises, step-ups, seated triceps dips, and chest press with the concentric component performed as quickly as possible starting at 2% body weight, increasing by 1% each week. In this study, the CTRL group performed 3 sets of 10 chair-based exercises (unilateral knee extension, hip flexion, chairs stands, shoulder press, biceps curls, chest press, and triceps extension) with only body or limb weight performed at a LVRT velocity. The data indicated that the values for power fell along the typical power curve with the highest values at 70% 1RM for both group, but the InVEST group had significantly greater improvements in leg power at 75% to 90% of 1RM than the CTRL group following the intervention. The InVEST group also had significantly greater improvements of gait speed and chair stand time. The researchers intended to develop the InVEST training program to improve both balance and mobility as a home-use product.

Interestingly, Behm and Sale (1993) found that velocity-specific responses to RT are governed by the intended velocity rather than the actual velocity of the movement. These researchers had subjects attempt to perform dorsiflexion with both legs. However, one leg was only allowed to perform an isometric contraction as it was restrained by a "modified boot apparatus” that was specially designed for the experiment to prevent movement, and the other leg was secured to a Cybex isokinetic dynamometer that allowed the movement to occur at a set velocity of 5.23 radians/sec. The subjects (physical education college students) performed 16 weeks of training, 3-5 sets of 10 repetitions, 3 days/week and were instructed to move at maximal speed regardless of resistance for both the isometric and isokinetic contractions. They found that the training produced velocity-specific adaptations in both legs: increased peak torque, increased voluntary isometric rate of torque development and relaxation, and decreased time to peak torque. Although the results of the isokinetic training were consistent with previous research, the results of the isometric training were more consistent with the isokinetic studies than previous isometric studies. The researchers explained that the protocol for the isometric contraction (attempting ballistic movement with high force development) was uniquely different from previous studies involving low-velocity isometric contractions. The isometric condition was able to produce high-velocity-specific responses (similar to a true high-velocity movement) despite no actual movement.

Research can also assess the effects of HVRT and LVRT on other psychometric variables, such as quality of life, depression, and cognition. In a dissertation at the University of Arkansas, Leszczak (2010) investigated the effects of a 12-week (2 days/week) HVRT program incorporating weight-bearing exercises and ankle weights (standing hip flexion, standing hip extension, chair stand, and standing calf rise) compared to a non-exercising CTRL group. HVRT increased chair stand (10.0 ± 4.2 to 12.7 ± 4.3 stands; $p < .01$) but not significantly compared to CTRL (11.6 ± 2.0 to 10.4 ± 2.4 stands). Furthermore, neither the HVRT nor CTRL significantly changed for 8-ft up-and-go (8.6 ± 4.4 to 8.5 ± 4.9 seconds versus 6.7 ± 1.1 to 7.0 ± 1.5 seconds) or working memory as assessed by a Wechsler Adult Intelligence Scale III (14.81 ± 3.06 to

15.32 ± 3.21 versus 13.28 ± 4.46 to 13.57 ± 3.95 number of correctly completed questions). Katula, Rejeski, and Marsh (2008) performed a pilot study that investigated the effects of HVRT on quality of life for older adults as compared to LVRT. Controlling for baseline values, they found that the HVRT group had significantly more change in measures of self-efficacy, satisfaction with physical function, and satisfaction with life as compared to the CTRL group. The LVRT group only had a significant higher score for self-efficacy as compared to the CTRL. Although both training programs were able to increase self-efficacy, HVRT influenced more measures of quality of life for these older adults.

Overall, research seems to indicate that HVRT is a potentially effective RT program for older adults. Research HVRT interventions have examined a variety of durations (from 8 weeks to 2 years), frequencies (mostly 2 or 3 days/week), intensities (20% to 90% 1RM), and modes (body weight, free weights, ankle weights, and resistance machines). HVRT has been shown to be beneficial for increasing functional performance, self-efficacy, and muscular strength, as well as for another important senior-fitness measure which LVRT is less effective at improving, i.e. muscular power.

Exercise and RMR

As previously discussed, numerous changes occur in the aging individual including sarcopenia, decreased FFM, decreased strength, and decreased power, and a variety of RT programs including LVRT and HVRT have been found to effectively counteract some of these changes. However, it is also important to concentrate on positively influencing the aging process by investigating the effects of exercise on RMR in older adults and implementing effective programs. Research has shown that RT can acutely increase RMR. Experiments have shown that a single bout of LVRT significantly increases RMR in young men (Hunter, Seelhorst, & Snyder, 2003; Melby, Scholl, Edwards, & Bullough, 1993). Additionally, Williamson and Kirwan (1997) found that a bout of RT at 75% 1RM significantly increased RMR (284.0 ± 34.3 versus 274.9 ± 34.0 kJ/hr, *p* < .006) in older men (66.5 years), which corresponded to a 1,627 ± 193 versus 1,570 ± 193 kcal/day TEE (*p* < .0002). The increase lasted up to 48 hours post exercise. The acute increases in RMR are advantageous for older adults to maintain a desirable weight and contribute to the chronic, long-lasting effects of RT on RMR.

Regular exercise positively affects RMR in older adults, and endurance training alone is often able to increase RMR. For example, Poehlman, Melby, and Badylak (1991) compared RMR of young and older men, sedentary and physically active (i.e. runners). Overall, older men had a lower RMR (unadjusted for body size) than younger men. Adjusting for FFM and percent body fat, RMR in sedentary young men (1.20 ± 0.03 kcal/min), active young men (1.15 ± 0.03 kcal/min), and active older men (1.09 ± 0.04 kcal/min) were all significantly higher than sedentary old men (0.97 ± 0.05 kcal/min). The researchers also found a significant linear correlation between RMR and FFM for all subjects (*r* = .57; *p* < .01). In an 8-week aerobic exercise intervention study, Poehlman and Danforth (1991) found cycling increased RMR by 10% (from 0.97 ± 0.03 to 1.07 ± 0.03 kcal/min, *p* < .01) in older adults (64.0 years). These researchers also found increases in the hormone norepinephrine (24%), which they found accounted for 49% of the increase in RMR. They did not find any significant changes in body composition as measured by underwater weighing during the 8 weeks, but it is likely that the other 51% of the increase in RMR is due to neuromuscular increases during those 8 weeks of training in the previously untrained subjects.

Furthermore, Goran and Poehlman (1992) conducted a study to determine the effects of endurance training (3 days/wk for 8 weeks) in 11 older individuals (ages 56-78 years). The researchers assessed TEE (measured by doubly labeled water), RMR, and body composition (underwater weighing). Body mass did not change (71.1 ± 8.5 versus 71.1 ± 8.4 kg, pre-exercise versus post-exercise), but FM (21.6 ± 6.6 versus 20.7 ± 6.6 kg) and body fat percentage (30.5 ± 8.9 versus 29.2 ± 8.8%) significantly decreased ($p < .05$). FFM increased as a result of the endurance training (49.5 ± 9.0 versus 50.4 ± 9.1 kg, $p < .05$). Even with a significant increase in RMR (1,596 ± 214 versus 1,763 ± 170 kcal/day, $p < .01$) and the increased EE from the exercise training sessions (averaging 150 kcal/day over the 10 days of doubly labeled water measurement), TEE did not significantly change (2,408 ± 478 versus 2,479 ± 497 kcal/day). Although the endurance exercise program was beneficial for cardiovascular fitness, body composition, and RMR, the increased exercise EE resulted in a compensatory decrease in non-exercise activity energy expenditure and thus no change in TEE. The researcher surmised that by the end of the program the intensity of the exercise, at 85% of VO_2max for 3 hours/week, was too vigorous for the older participants to keep up non-exercise activity.

Dieting and endurance training can cause loss in FFM, and RT in addition to endurance training can increase RMR and also prevent loss of FFM (Bryner et al., 1999). Dolezal and Potteiger (1998) compared the outcomes of endurance training, resistance training, and combined resistance and endurance training on RMR in young men. As expected, they found that endurance training significantly increases VO_2max (12.6%, $p < .05$) and significantly decreases body fat percentage (2.3%, $p < .05$), and RT significantly increases RMR (by 202 kJ/day, $p < .05$) and strength (23.9%, $p < .05$). However, they also found that the combination training provided benefits from both individual protocols (VO_2max: 6.7% increase; body fat: 3.5% decrease; RMR: 347 kJ/day increase; strength: 11.7% increase; $p < .05$). For postmenopausal women, Ryan, Pratley, Elashi, and Goldberg (1995) demonstrated that 16 weeks of LVRT both with and without a diet-based weight loss program increased RMR (by 3.8% versus 4.2%, respectively), FFM (1.1% versus 2.9%), and strength (43.5% versus 38.2%).

Furthermore, Pratley et al. (1994) conducted a 16-week RT protocol (leg press, chest press, leg curl, lat pull down, leg extension, military press, thigh adductor, upper back, triceps, lower back, bicep curls, upper abdominals, and lower abdominals) at 90% 3RM with older men (58.1 years). Although the participants met with a dietitian prior to the study and followed a diet regimen, the diet was designed to make the participants weight-stable throughout the exercise intervention. The diet composition (52% carbohydrate, 30% fat, and 18% protein) and total calories (9,699 ±356 versus 9,950 ± 272 kJ/day) was not significantly different before and after training. The RT intervention significantly increased RMR by 7.7% (6,499 ± 217 to 6,998 ± 226 kJ/day, $p < .01$), strength by 40.0% (571.0 ± 30.0 to 801.0 ± 43.0 kg, $p < .001$), and FFM by 2.6% (60.6 ± 2.2 to 62.2 ± 2.1 kg, $p < .001$).

Similiarly, Hunter, Wetzstein, Fields, Brown, and Bamman (2000) investigated the effects of a 26-week resistance training intervention (elbow extension, elbow flexion, lat pull down, seated row, chest press, leg extension, leg curl, leg press, back extensions, and bent-leg sit-ups) at 65-80% 1RM. The measured variables included TEE (assessed by doubly labeled water), RMR (canopy system), body composition (dual-energy X-ray absorptiometry), and strength (1RM) in 61-77 year olds (n = 15). The resistance program significantly increased upper body strength by 25.3% (59.0 ± 20.3 versus 73.9 ± 24.2 kg, $p < .01$), lower body strength by 41.7% (117.6 ± 36.5 versus 166.6 ± 47.5 kg, $p < .01$), and FFM by 4.0% (50.0 ± 10.1 versus 52.0 ± 10.7 kg, $p < .01$). Body fat percentage (28.8 ± 12.1% versus 25.4 ± 12.1%, $p < .01$) and FM (20.4 ± 9.8 versus 17.7 ± 9.3 kg, $p < .01$) were significantly lower by 11.8% and 13.2%, respectively, but body mass did not change (70.4 ± 8.7 versus 69.8 ± 8.3 kg, $p = .12$). RMR

(5,388 ± 520 versus 5753 ± 560 kJ/day, $p < .01$) and TEE (7,831 ± 2,223 versus 8,796 ± 1,629 kJ/day, $p < .01$) significantly increased by 6.8% and 12.3%, respectively. Adjusted for the estimated EE of the resistance exercise, the 9.5% TEE increase (7,834 ± 2,223 to 8,581 ± 1,612 kJ/day) remained significant ($p < .02$). This resistance training intervention increased RMR, FFM, strength, and TEE; however, it did not lower physical activity outside of the exercise program unlike the Goran and Poehlman (1992) endurance program.

Resistance training may be an effective, valuable tool for both increasing TEE and RMR and improving body composition in older adults. Even though FFM is not the only contributing factor to RMR, it is an extremely important and modifiable factor for older adults. Determining the effects of specific types of RT (e.g. LVRT and HVRT) on RMR will be helpful in determining beneficial RT programs for this population.

Summary

Increasing the health of seniors is vital for their quality of life and the nation’s physical and financial wellbeing. Exercise will be instrumental in effecting this change. Decreasing FM and improving FFM, RMR, and functional fitness are the central goals of exercise programs for older adults. Members of this population need to perform training programs that are effective in counteracting age-related, physical inactivity-related, and FFM-related decreases in muscle mass, muscle power, and RMR. As some of the differences between HVRT and LVRT exercise have been previously examined (muscular power, muscular strength and functional performance), the benefits of these two exercise modalities have not be researched in regards to RMR in older adults.

Chapter III

Methodology

This study was designed to compare the effects of a 12-week, HVRT protocol to a traditional LVRT training protocol on the RMR and other selected measures of functional performance in men and women over the age of 65. Outcomes were assessed by changes in the selected measures of RMR, body composition, muscular power, muscular strength, chair stand, and 8-ft up-and-go. The exercise participants were randomly assigned to either the HVRT group or LVRT group. The CTRL participants were not randomly assigned, but rather volunteered to be CTRL. RMR was measured by a computerized metabolic cart system with a canopy system, body composition by dual-energy X-ray absorptiometry, muscular power by the Biodex isokinetic dynamometer, muscular strength by estimated 1RM, and functional fitness by both the 30-seconds chair stand and 8-foot up-and-go test. All of these measures were evaluated before initiation and after completion of the 12-week exercise intervention. Additionally, the measurements of 1RM were performed at week 4 and week 8 for the progression of weight intensity for the experimental groups but not the CTRL group.

Participants and Recruitment

Older adults were recruited from a Northwest Arkansas adult wellness center. Informational fliers were placed around the center to recruit participants, and the researcher personally recruited various members. If individuals expressed interest and volunteered, their contact and some personal information (name and phone number and/or email address) were collected. Participants were screened for eligibility by the health history questionnaire. Individuals were included in the program based on the following criteria: (a) age 65 or older by the start of the intervention, (b) no diagnosis of debilitating, chronic diseases such as extreme arthritis or osteoporosis, (c) no diagnosis of unstable cardiovascular disease, and (d) received medical clearance if considered a high-risk individual such as those with known, stable cardiovascular disease or those with signs or symptoms of cardiovascular disease. None of the volunteers were required to get medical clearance as they were all free of unstable cardiovascular disease.

Informed Consent and Screening

Prior to any testing, all participants completed an informed consent and a health screening questionnaire previously approved by University of Arkansas Institutional Review Board (Appendixes A, B, and C). The health screening was used for participation exclusion or inclusion information.

Pre-intervention Testing

Due to the logistics of testing procedures, the tests were performed in two different locations. In the morning at the laboratory, RMR, DXA, and Biodex were conducted. For all participants, both the RMR test and DXA scan were performed prior to the Biodex test. For both the RMR and DXA, the participants remained in at least an 8-hour fasting state. Half of the participants had a testing order of DXA, RMR, Biodex and half RMR, DXA, Biodex. Prior to the Biodex testing, participants were allowed to break their fast with a light snack of granola bars and/or fruit and coffee or water. In the afternoon the estimated 1RMs (leg press, leg curl, leg extension, upper back, chest press, and shoulder press), 30-seconds chair stand, and the 8-foot up-and-go tests were all conducted at the wellness center at which the exercise intervention was performed. All participants performed this testing in the following order: Chair stand, up-and-go, estimated 1RMs.

Resting metabolic rate. Two ParvoMedics TrueMax 2400 computerized metabolic cart systems with canopy systems were utilized to measure RMR. Studies have found the ParvoMedics TrueMax 2400 computerized metabolic cart system (met cart) an accurate and reliable for the measurement of RMR (Bassett et al., 2001; Crouter, Antczak, Hudak, DellaValle, & Haas, 2006).

As recommended by the Compher et al. (2006) systematic review of indirect calorimetry and RMR measurement in healthy older adults, several requirements were met for measurement accuracy. Participants were required to fast for a minimum of 8 hours from all food, abstain from alcohol a minimum of 24 hours, abstain from nicotine and caffeine for a minimum of 8 hours, and abstain 24 hours from all forms of exercise. Due to safety and health issues with this population, the participants were allowed to continue regular medications. The procedures were explained and the equipment shown to the participants in order to allow them to get comfortable with the environment and process of measurement. Then the participants rested for 15 minutes in an upright sitting position before RMR measurement. During RMR measurement, the participants reclined on a padded table, propped up by one or two pillows under the head and a bolster under the knees, if requested. The environment temperature was maintained at room temperature (68°F to 77°F). For achieving steady-state measurement, they recommend discarding the initial 5 minutes and then achieving a 5 minute period with $\leq$ 10 % coefficient of variation in VO_2 and VCO_2. The time of day that each participant's RMR was measured at pre-testing was noted and post-testing schedule was constructed in such a manner as to have each participant measured at the same time as closely as possible.

Dual-energy X-ray absorptiometry. A total body DXA scan was used for this study as a measure of body composition, and standard laboratory DXA protocols were utilized. The researcher asked the participants to remove any form of metal (clothing, jewelry, etc.) from their bodies. Scrubs were provided for participants if they forget to wear clothing without buttons or clasps. With shoes and extraneous weight removed, a research assistant measured the participant’s height (both to nearest centimeter and nearest quarter inch) and weight (both to nearest tenth kilogram and nearest quarter pound) on a Detecto physician scale (Webb City, MO). Height and weight was entered into the computer during scan protocol set-up. The researcher again prepared the participants with information on the procedures to make the participants comfortable. They were then asked to lie supine on the table and to remain still throughout the whole measurement. The same researcher performed and analyzed all of the scans.

Biodex isokinetic dynamometer. The Biodex procedure was explained to the participants to them to get comfortable with the environment, process, and nature of the measurement. The bilateral isokinetic knee flexion and extension at 60°/sec, 120°/sec, 180°/sec and 240°/sec protocol was utilized. One set of 5 repetitions at each velocity with 15 seconds of rest in between each set was performed on the non-preferred or non-injured leg. The dynamometer was properly fitted and adjusted for each participant, with particular notice aligning the axis of rotation of the knee with the axis of rotation of the dynamometer. The manufacturer procedures of the Biodex were followed. The participants were given practice trials at each velocity at their discretion until familiar with the protocol.

Estimated one-repetition maximum. An estimated 1RM was used in this study to ensure participant comfort. For each of the exercises, the participants and researchers collaborated to determine what was likely to be the participant’s 1RM. The researcher then calculated 50% 1RM and instructed the participants to perform a warm-up set of 8-10 repetitions, followed by a rest of 60 seconds. Depending on how difficult the 50% 1RM warm-up trial seemed to the participants, 70-80% 1RM was performed for 8 repetitions, followed again by a 60-second rest. For the 1RM trials, the participant lifted the weight with correct form as many times as possible. The trial was accepted as maximal when both the researcher and participants felt the effort given was exhaustive and when only 2-10 repetitions were performed for increased accuracy (Wood et al., 2002). To encourage the participants to achieve an authentic maximal effort, the researchers cheered them through the estimated 1RM testing. When more than 10 repetitions were performed, the participant rested for 3-5 minutes and a heavier weight was used. Only 10 trials were needed each day of 1RM testing session to achieve maximum. Once a trial was performed with less than 10 repetitions, the weight and number of repetition performed was used to calculate estimated 1RM. The Wathen estimated 1RM formula was used due to the high accuracy and low relative error found with its application for use with older adults (Wood et al., 2002). Wathen's formula is the following equation:

$$1\ \mathrm{RM}_{est} = \text{weight lifted (lbs)} / [(48.8 + 53.8e^{-0.075\ \cdot\ \text{number of repetitions}}) / 100]$$

30-second chair stand. The chair stand is a component of the Senior Fitness Test and is intended to measure lower body strength and endurance (Rikli & Jones, 1999a). The participants were instructed to sit forward on the chair not using the back rest with feet flat on the ground and with arms held across their chest. The participants were then told to rise to a full stand and sit back down again as many times as possible during the timed 30-second interval. The number of chair stands was recorded as the score.

8-foot up-and-go test. The 8-foot up-and-go test is another component of the Senior Fitness Test and is intended to measure power, speed, agility, and dynamic balance (Rikli & Jones, 1999a). The participants were instructed to sit forward on the chair not using the back rest with feet flat on the ground. Then participants were then be told to rise, walk 8 feet to and then around a cone, and return to the chair in the shortest time possible. The participants were allowed to perform two trials, and the shortest time was recorded as the score.

Intermediate-intervention Testing

To maintain prescribed exercise intensity for the two experimental groups, the same estimated 1RM procedure from the pre-intervention testing was repeated after completing weeks 4 and 8 for the experimental groups.

Post-intervention Testing

The same procedures (RMR, DEXA, Biodex, estimated 1RM, chair stand, and 8-foot up-and-go) were repeated at week 12 for all three groups. In addition to these measures, the Mini Mental State Examination (MMSE) was used as a cognitive screening total for inclusion in data analysis. Rather than being performed with pre-testing, logistics required the MMSE be performed at post-testing, but the test was still used for the function of assessing cognitive awareness for inclusion in the study.

MMSE. The MMSE is an 11-question examination that tests orientation, registration, attention and calculation, recall, and language (Kurlowicz & Wallace, 1999). Research has indicated a significant link between exercise and cognition in which individuals with decreased cognition have altered ability to perform and adapt to exercise (Kramer, Erickson, & Colcombe, 2006). Therefore, out of the maximum score of 30, the participants must have scored a 24 or higher because a score of 23 or lower is indicative of cognitive impairment.

Exercise Intervention

The participants who volunteered to participate in the exercise component of the study and met all the eligibility requirements were randomly assigned to either the HVRT or LVRT group. Both experimental groups trained for approximately 30 minutes on Tuesdays and Thursdays for 12 weeks. A duration of 12 weeks was chosen to balance effectiveness and time considerations; long-term RT programs are beneficial for developing a greater understanding of fitness-related lifestyle changes, but even short-term RT programs have been able to show improvements in strength or power. Individual exercise adherence will be measured as the percentage of sessions attended out of the 25 possible sessions. Adherence of 80% or higher was required for inclusion in data analysis. All participants met this criteria.

For both groups, the exercise intervention was performed on Keiser pneumatic resistance-training machines (Keiser Corporation, Fresno, CA) and consisted of six exercises, chosen to give the participants a balanced, full-body work-out. The exercises included leg extension (quadriceps), leg curl (hamstrings), leg press (quadriceps, hamstrings, and gluteus muscles), upper back (seated row; latissimus dorsi, trapezius, rhomboids, deltoids, biceps brachii and triceps brachii), chest press (pectoralis major and minor, deltoids and triceps brachii), and shoulder press (pectoralis major, pectoralis minor, triceps, and deltoids). The researcher instructed the participants on the specifics for performing the exercises by mode of training (HVRT or LVRT) and supervised most the individual sessions (23 of 25), recording the exercises performed (Appendix D). At the beginning of each session, the participants were asked to do a low-intensity aerobic warm-up (on the track, cycle, or Nu-step) for approximately 10 minutes, were guided through the six exercises, and then asked to perform a light cool-down of stretching. The sessions were individualized to the participants with progressive overload until 3 sets of 10 at 80% 1RM. Generally, the participants performed 3 sets of on each machine, with the percentage of 1RM will be dependent on the week: week 1 60% initial 1RM ($1RM_i$), week 2 65% $1RM_i$, week 3 70% $1RM_i$, week 4 75% $1RM_i$, and then working at 70%, 75%, and then 80% of the most-recently accessed 1RM for the next eight weeks to tolerance. The participants were reminded of the procedures of executing the exercises randomly through each session and whenever the researcher observed deviations from the prescribed method. Some of the participants were highly cooperative and masterful of their respective protocol, while others did not always achieve the full requirements of the protocol on each repetition or set.

High-velocity resistance training group. The HVRT group was instructed to perform each repetition by executing the concentric phase as fast as possible (approximately less than 1 seconds), maintaining full extension/flexion for 1 second, and then performing the eccentric phase slowly for at least 3 seconds.

Low-velocity resistance training group. The LVRT group was instructed to perform each repetition in a slow, controlled manner by executing the concentric phase for 2 seconds, maintaining full extension/flexion for 1 second, and then performing the eccentric phase for 2 seconds.

Familiarization. Immediately prior to the initial 1RM during the pre-intervention testing, the participants were shown each of the machines that will be used in the study and testing. The researcher instructed the participants on the method by which they were to execute the exercises, based on which group they were assigned to and allowed the participants to perform the exercises at a light weight (50% assumed 1RM based off current strength and RT experience). During the same week of pre-intervention testing after all testing has been completed, the participant was again be allowed to perform the exercises at a light weight (60% initial estimated 1RM) for further familiarity. The exercise intervention began by the following week.

Statistical Analysis

Several statistical measures were used for analysis between groups. IBM SPSS Statistics 19.0 software was used to perform several analyses of variance (ANOVAs). First, a one-way ANOVA was used to determine any initial significant differences between the groups before the intervention. Then, a 2x3 repeated measures ANOVA test was used to determine interactions between time and group for each research hypothesis. If no significant differences between the two exercise groups were found in the first repeated measures ANOVA, then those variables were analyzed again grouping the two exercise groups together against the CTRL group in a 2x2 repeated measures ANOVA. Post hoc tests included Tukey (*q*) to determine significance ($\alpha \leq .05$). Additionally due to the small sample size used in this experiment, effect size (specifically Cohen's *d*) was used to measure the strength of the difference between groups. Effect size between two groups was calculated as the difference of the means divided by the pooled standard deviations of the two groups. A small effect size ($d = 0.20 - 0.49$) means there is little to no difference between the groups. A moderate effect size ($d = 0.50 – 0.79$) means that there is a moderately meaningful difference between the two groups. And a large effect size ($d = 0.80$ or higher) means that there is a large meaningful difference between the two groups. For further post hoc analysis, Pearson product correlations were performed for several measurements, and a one-way ANOVA and dependent samples t-tests were used to analyze the intermediate estimated 1RM data ($\alpha \leq .05$).

Chapter IV

Results

The purpose of this study was to compare the effects of a 12-week, high-velocity resistance training protocol to a traditional low-velocity resistance training protocol on the RMR and other selected measures of muscular and functional fitness in older adults. For each variable, the proper statistical comparisons are presented, followed by the sample effect size as a post hoc analysis due to the small sample size and subsequent, recurring lack of significance.

Demographics. A total of 19 older adults between the ages of 66 and 82 completed the training intervention. The demographic information is presented in Table 1. Of the 19 participants, 4 were CTRL (3 male and 1 female), 8 HVRT (4 male and 4 female), and 7 LVRT (3 male and 4 female). These participants all scored a 26 or higher on the MMSE, with an average score of 28.3 ± 1.3. The average height for all participants was 167.4 ± 8.2 cm. Initially, there were no differences between groups except for age, $F(2, 16) = 5.37$, $p = .016$ ($q_{HVRT,LVRT} = .028$; $q_{HVRT,CTRL} = .051$; $q_{LVRT,CTRL} = .992$). The HVRT group (average 75.6 years) was significantly older than the LVRT (69.6 years). The HVRT was not significantly older than the CTRL group (69.3 years), but there was a large effect between HVRT and CTRL ($d = 1.18$). Out of the 25 sessions for the two exercise groups, adherence rates ranged from 84% to 100%, with an average adherence rate of 93%. The pre-intervention and post-intervention measures are provided in Tables 2 and 3.

Hypothesis One. The first hypothesis was that after 12 weeks of training, the HVRT group would have significantly greater increases in RMR than the LVRT group and the CTRL group, and the LVRT group would have significantly greater increases in RMR than the CTRL group. The data only partially support this hypothesis. One subject in the HVRT group did not

Table 1

Demographic Information

	HVRT	LVRT	Control
Age (years)	75.6 ± 4.7	69.6 ± 3.9	69.3 ± 3.2
Weight (kg)	79.7 ± 16.7	83.9 ± 18.8	86.6 ± 22.8
Height (cm)	166.0 ± 9.4	169.0 ± 6.8	167.3 ± 9.3
MMSE score (out of 30)	28.4 ± 1.5	28.7 ± 1.0	27.5 ± 1.0
Adherence rate (%)	94.5 ± 5.6	90.9 ± 5.0	-

Note. Values are mean ± SD. HVRT = high-velocity resistance training. LVRT = low-velocity resistance training. CTRL = control. MMSE = Mini Mental State Examination.

participate in the RMR testing due to claustrophobia and therefore was not included in the analysis of RMR.

No significant interaction between time and group was found for RMR, F (2, 16) = 2.55, p = .111 ($q_{HVRT,LVRT}$ = .812; $q_{HVRT,CTRL}$ = .650; $q_{LVRT,CTRL}$ = .373). However, when the two exercise groups were compared together against the CTRL, a significant group by time interaction developed, F (1, 17) = 5.05, p = .039. All groups decreased RMR: LVRT by 182 kcal/day (11.4%), HVRT 234 kcal/day (15.6%), and CTRL 596 kcal/day (31.1%; see Table 2). In further analysis, there was a small effect size between LVRT and HVRT (d = 0.22) and a large effect size between CTRL and the other groups (d = 1.17 and d = 0.96, respectively).

Table 2

Body Composition and Metabolic Measures

	HVRT		LVRT		CTRL	
	Pre	Post	Pre	Post	Pre	Post
Weight (kg)	79.7 ± 16.7	79.1 ± 14.5	83.9 ± 18.8	83.9 ± 19.4	86.6 ± 22.8	83.6 ± 17.4
RMR (kcal/day)	1,500 ± 375	1,2323 ± 225	1,596 ± 143	1,414 ± 278	1,915 ± 436	1,319 ± 539
BMC (kg)	2.8 ± 0.6	2.8 ± 0.5	2.8 ± 0.4	2.8 ± 0.4	2.9 ± 0.9	2.9 ± 0.9
Body fat (%)	37.7 ± 6.7	36.5 ± 7.9	42.7 ± 6.5	40.8 ± 7.9	39.6 ± 8.3	39.6 ± 9.3
FM (kg)	29.1 ± 8.1	27.6 ± 7.6	35.0 ± 11.5	33.6 ± 12.6	32.5 ± 5.9	38.5 ± 16.4
FFM * (kg)	48.2 ± 11.4	48.5 ± 12.0	45.5 ± 9.0	46.9 ± 9.4	51.8 ± 17.4	49.1 ± 14.9

Note. Values are mean ± SD. HVRT = high-velocity resistance training. LVRT = low-velocity resistance training. CTRL = control. * denotes $p = .012$ for repeated measures ANOVA time X group interaction. BMC = bone mineral content. FFM = fat-free mass.

Table 3

Functional Fitness, Strength, and Power Measures

	HVRT		LVRT		CTRL	
	Pre	Post	Pre	Post	Pre	Post
Chair stand (# stands)	16.1 ± 4.4	19.1 ± 4.8	16.9 ± 5.2	20.9 ± 4.8	13.5 ± 3.7	16.0 ± 2.9
Up-and-go (sec)	5.8 ± 1.3	5.9 ± 1.6	5.0 ± 0.7	4.8 ± 0.8	5.2 ± 0.4	5.5 ± 0.4
Upper back (1RM kg)	45.2 ± 16.2	64.4 ± 23.5	42.4 ± 15.1	57.5 ± 16.6	40.5 ± 10.7	45.9 ± 14.1
Chest press (1RM kg)	29.4 ± 11.9	40.5 ± 15.9	25.1 ± 12.0	35.7 ± 12.0	32.1 ± 19.5	32.1 ± 19.7
Shoulder press (1RM kg)	23.2 ± 8.1	31.5 ± 10.4	21.9 ± 5.6	28.9 ± 8.3	20.4 ± 10.1	22.2 ± 13.4
Upper body (total kg)	97.7 ± 32.8	136.3 ± 47.2	86.3 ± 33.4	118.0 ± 40.3	69.8 ± 56.9	75.1 ± 61.9
Leg press * (1RM kg)	133.1 ± 33.8	194.4 ± 56.3	131.2 ± 33.4	184.8 ± 38.7	164.0 ± 52.0	171.2 ± 56.0
Leg extension (1RM kg)	32.40 ± 8.6	51.1 ± 15.5	34.6 ± 19.5	51.1 ± 23.5	38.8 ± 16.6	43.8 ± 13.4
Leg curl ** (1RM kg)	39.9 ± 11.2	51.5 ± 13.7	35.8 ± 9.2	50.9 ± 12.2	38.4 ± 13.6	39.6 ± 9.8
Lower body * (total kg)	205.4 ± 72.6	297.0 ± 83.4	201.6 ± 64.3	286.7 ± 70.0	241.1 ± 85.2	254.5 ± 78.0
Power 60°/sec (watts)	64.0 ± 15.0	71.0 ± 18.9	72.6 ± 20.1	75.7 ± 15.8	70.2 ± 34.1	70.0 ± 35.9
Power 120°/sec (watts)	92.2 ± 31.0	96.5 ± 30.5	99.5 ± 33.0	106.3 ± 24.9	92.2 ± 42.3	97.9 ± 51.7
Power 180°/sec (watts)	100.5 ± 34.5	112.3 ± 49.3	103.5 ± 33.7	112.5 ± 29.6	96.4 ± 50.3	99.3 ± 46.2
Power 240°/sec (watts)	103.6 ± 40.3	108.5 ± 53.7	98.3 ± 34.2	115.4 ± 35.8	83.0 ± 34.5	86.0 ± 35.1

Note. Values are mean ± SD. HVRT = high-velocity resistance training. LVRT = low-velocity resistance training. CTRL = control. * denotes $p \leq .05$ for repeated measures ANOVA time X group interaction. ** denotes $p \leq .01$ for repeated measures ANOVA time X group interaction.

Hypothesis Two. This hypothesis stated that after 12 weeks of training, the HVRT group and LVRT group would have equivalent increases in FFM, and both exercise groups would have significantly greater increases in FFM than the CTRL group. The data only partially support this hypothesis.

For FFM, a significant interaction between time and group existed, $F(2, 16) = 6.10$, $p = .012$. Post hoc tests were not significant ($q_{HVRT,LVRT} = 1.00$; $q_{HVRT,CTRL} = .838$; $q_{LVRT,CTRL} = .835$). While the CTRL group lost 5.3% of FFM (2.7 kg), HVRT increased 0.7% (0.3 kg), and LVRT increased 3.1% (1.4 kg). There was a large effect size between the CTRL and both exercise groups ($d = 1.17$ and $d = 1.50$, respectively) and a moderate effect size between HVRT and LVRT ($d = 0.62$).

Hypothesis Three. This hypothesis was that after 12 weeks of training, the HVRT group would have significantly greater increases in muscular power (as measured by average power of leg extension at 180°/sec) than the LVRT group and the CTRL group, and the LVRT group would have significantly greater increases in muscular power than the CTRL group. The data partially support this hypothesis.

Leg extension average power at 180°/sec was selected as the measure of muscular power. For obvious functional importance (chair standing, stair climbing, etc.) leg extension was chosen over leg flexion. For practical purposes and as all the tested velocities were highly correlated (Table 4), 180°/sec was chosen as it closely mimics the functional speed of older adults. No significant interaction between time and group was found for muscular power, $F(2, 16) = 0.341$, $p = .716$ ($q_{HVRT,LVRT} = .996$; $q_{HVRT,CTRL} = .933$; $q_{LVRT,CTRL} = .910$).

Table 4

Leg Extension Average Power Correlations

Velocity	60°/sec	120°/sec	180°/sec	240°/sec
60°/sec	-			
120°/sec	.969**	-		
180°/sec	.910**	.935**	-	
240°/sec	.819**	.877**	.959**	-

Note. Values are Pearson Product Correlations. ** denotes correlation is significant at the .01 level.

Although not significantly different, all groups increased in power: CTRL by 3.0% (2.9 watts), LVRT 8.7% (9.0 watts), and HVRT 11.7% (11.7 watts; Table 3). There was a moderate effect size between HVRT and CTRL (*d* = 0.53), a small effect size between LVRT and CTRL (*d* = 0.40), and no effect between HVRT and LVRT (*d* = 0.15).

Hypothesis Four. This hypothesis stated that after 12 weeks of training, the HVRT group and the LVRT group would have equivalent increases in muscular strength (as measured by the total of the three lower body estimated 1RMs and the total of the three upper body estimated 1RMs), and both exercise groups would have significantly greater increases in muscular strength than the CTRL group. The data support this hypothesis.

For total lower body strength (LBS), the three estimated 1RM values for the leg exercises (leg press, leg extension, and leg curl) were added together, and for total upper body strength (UBS), the three upper body exercises (chest press, shoulder press, and upper back) were added together. All three groups increased both UBS and LBS (Table 3).

Total lower body strength. One of the LVRT participants previously had a knee surgery and was extremely cautious in performing the leg extension 1RM, so she performed as many repetitions as possible at a specific weight. Her data is still included in the analysis.

For LBS, there was a significant interaction between time and group, F (2, 16) = 5.52, p = .016 ($q_{HVRT,LVRT}$ = .957; $q_{HVRT,CTRL}$ = .787; $q_{LVRT,CTRL}$ = .909). CTRL increased LBS by 13.4 kg (5.6%), LVRT by 85.2 kg (42.3%), and HVRT by 91.7 kg (44.6%). There were large effect sizes between the CTRL and both HVRT (d = 1.43) and LVRT (d = 1.61). There was no effect between HVRT and LVRT (d = 0.16).

Total upper body strength. One of the CTRL participants did not perform any of the upper body exercises and one of the LVRT participants did not perform the shoulder press, both due to shoulder injuries. Therefore, these participants were not included in the analysis for which they did not have data.

For UBS, there was no significant interaction between time and group, F = 3.63, p = .052 ($q_{HVRT,LVRT}$ = .780; $q_{HVRT,CTRL}$ = .231; $q_{LVRT,CTRL}$ = .520). CTRL increased UBS by 5.3 kg (7.6%), LVRT by 31.7 kg (36.8%), and HVRT by 38.6 kg (39.5%). In further analysis, there was a small effect size between HVRT and LVRT (d = 0.33) and a large effect size between CTRL and the other groups (d = 1.25 and d = 1.54, respectively). Additionally, when the two exercise groups were compared together against the CTRL, a significant interaction between time and group developed for UBS, F (1, 17) = 7.21, p = .016.

Time-course of strength changes. In addition to the pre- and post-intervention testing, estimated 1RM data was collected again at Weeks 4 and 8 for intensity progression for the two exercise groups. There were no significant differences between LVRT and HVRT for any of the exercises at any single time point (see Table 5). The four time-points of estimated 1RM data (Initial, Week 4, Week 8, and Week 12/Final) are plotted in Graphs 1 through 6. For a majority of the exercises, strength increased in linear-like fashion from initial testing to Week 8, and then plateaued from Week 8 to Week 12 with no significant differences for both HVRT and LVRT. For a few of the exercises (e.g. LVRT upper back and HVRT leg extension), the final estimated 1RM was actually lower than the Week 8 value, but the decreases were not significant (t = .625, p = .559 and t = .580, p = .583, respectively). For other exercises (e.g. LVRT shoulder press and HVRT chest press), some values increased slightly from Week 8 to Week 12. The increase between the two time points for LVRT shoulder press was not significant (t = -.755, p = .355), but the increase for HVRT chest press was significant from Week 8 to Week 12 (t = -3.825; p = .009).

Table 5

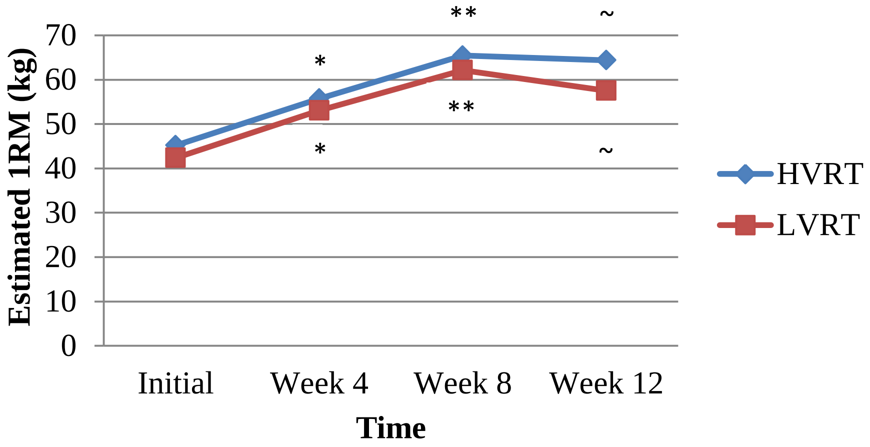
ANOVA Results Between Groups Estimated 1RM

		F	Significance
Upper Back			
	Initial	.120	.735
	Week 4	.085	.775
	Week 8	.074	.790
	Week 12	.413	.532
Chest Press			
	Initial	.455	.512
	Week 4	.578	.460
	Week 8	.092	.769
	Week 12	.407	.535
Shoulder Press			
	Initial	.081	.781
	Week 4	.126	.729
	Week 8	.211	.656
	Week 12	.242	.632
Leg Extension			
	Initial	.070	.795
	Week 4	.009	.924
	Week 8	.075	.789
	Week 12	.000	.996
Leg Curl			
	Initial	.564	.466
	Week 4	.108	.748
	Week 8	.023	.882
	Week 12	.011	.924
Leg Press			
	Initial	.011	.916
	Week 4	.051	.825
	Week 8	.032	.861
	Week 12	.143	.711

Note. One-way ANOVA between groups for each time point and exercise.

Graph 1

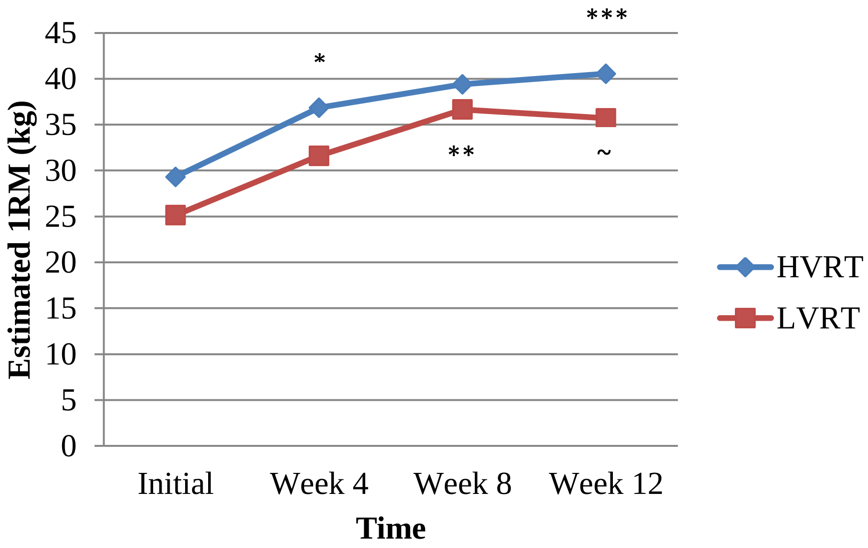
Upper Back Strength Changes



Note. HVRT = high-velocity. LVRT = low-velocity. Significance ≤ .05. * = within group between Week 0,4. ** = within Week 4,8. ~ = within Week 0,12. No difference between groups.

Graph 2

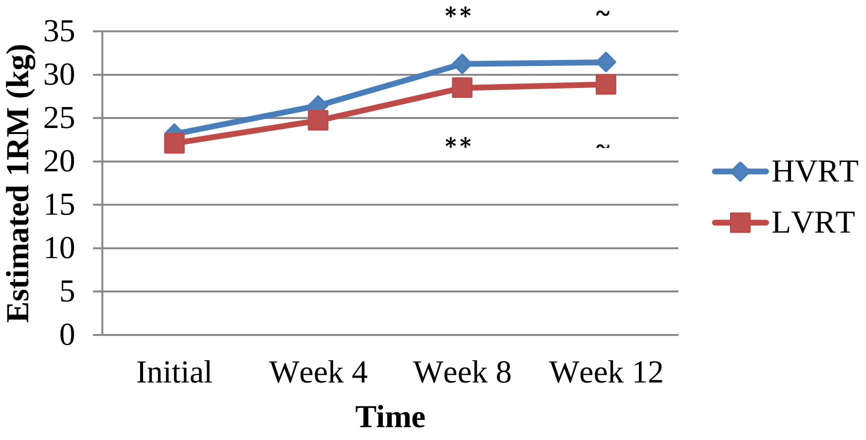
Chest Press Strength Changes



Note. HVRT = high-velocity. LVRT = low-velocity. Significance ≤ .05. * = within group between Week 0,4. ** = within Week 4,8. ~ = within Week 0,12. No difference between groups.

Graph 3

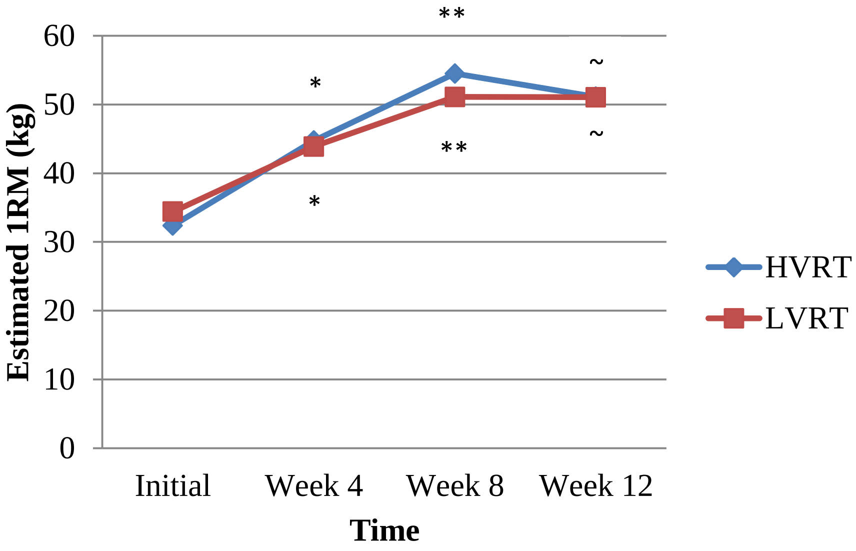
Shoulder Press Strength Changes



Note. HVRT = high-velocity. LVRT = low-velocity. Significance ≤ .05. * = within group between Week 0,4. ** = within Week 4,8. ~ = within Week 0,12. No difference between groups.

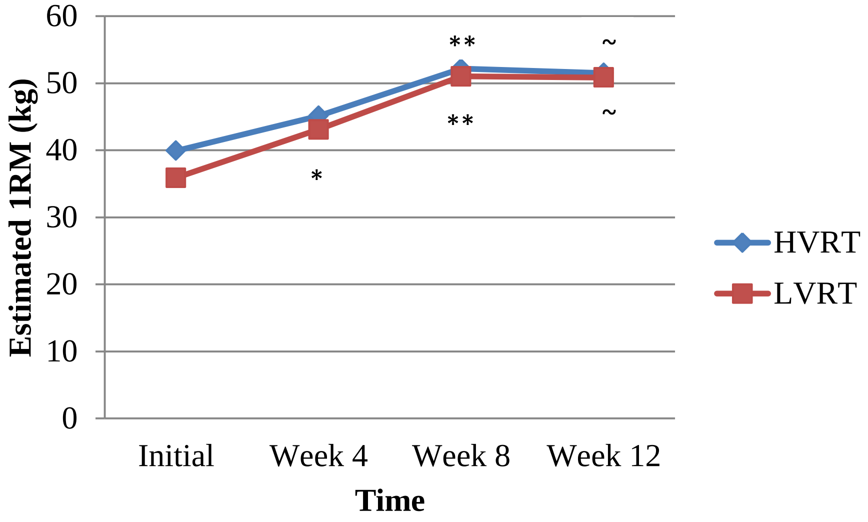
Graph 4

Leg Extension Strength Changes



Note. HVRT = high-velocity. LVRT = low-velocity. Significance ≤ .05. * = within group between Week 0,4. ** = within Week 4,8. ~ = within Week 0,12. No difference between groups.
Graph 5

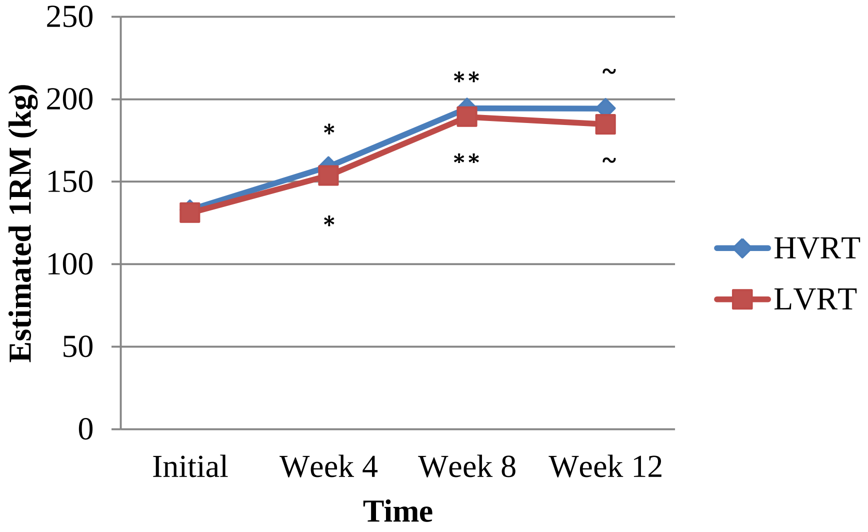
Leg Curl Strength Changes



Note. HVRT = high-velocity. LVRT = low-velocity. Significance ≤ .05. * = within group between Week 0,4. ** = within Week 4,8. ~ = within Week 0,12. No difference between groups.

Graph 6

Leg Press Strength Changes



Note. HVRT = high-velocity. LVRT = low-velocity. Significance ≤ .05. * = within group between Week 0,4. ** = within Week 4,8. ~ = within Week 0,12. No difference between groups.

Hypothesis Five. This hypothesis stated that after 12 weeks of training, the HVRT group would have significantly greater changes in functional fitness (as measured by score on the chair stand and time of the 8-foot up-and-go) than the LVRT group and the CTRL group, and the LVRT group would have significantly greater changes in functional fitness than the CTRL group. The data do not support this hypothesis.

Chair stand. No significant interaction between time and group was found for chair stand, F (2, 16) = 0.31, p = .739 ($q_{HVRT,LVRT}$ = .939; $q_{HVRT,CTRL}$ = .459; $q_{LVRT,CTRL}$ = .314). All groups increased the number of completed chair stands: CTRL by 2.5 (18.5%), HVRT by 3.0 (18.6%), and LVRT by 4.0 (23.7%). There were only small effect sizes between all groups: CTRL and LVRT (d = 0.49), CTRL and HVRT (d = 0.21), and LVRT and HVRT (d = 0.31).

8-ft up-and-go. No significant interaction was found for 8-ft up-and-go time, F (2, 16) = 1.37, p = .283 ($q_{HVRT,LVRT}$ = .243; $q_{HVRT,CTRL}$ = .753; $q_{LVRT,CTRL}$ = .761). LVRT improved by 0.3 seconds (5.2%), and both CTRL and HVRT were slower by 0.3 seconds (6.4%) and 0.2 (3.3%), respectively. There was a large effect size between LVRT and CTRL (d = 1.09), a moderate effect size between LVRT and HVRT (d = 0.64), and a small effect size between HVRT and CTRL (d = 0.23).

Additional analysis. Post hoc, the correlations among several variables were determined to emphasize the relationship among key measures. The main variable correlations are presented in Table 6, and the FFM, strength, and power correlations are presented in Table 7.

Main variable correlations. RMR was significantly correlated with FFM and LBS Percent body fat was inversely correlated with LBS, UBS, and FFM. Average power, UBS, LBS, and FFM were all highly correlated with each other. The two functional performance measures

Table 6

Main Variable Correlations

	RMR	Body Fat %	Fat-free Mass	Chair Stand	8-ft-up-and-go	Upper Body Strength	Lower Body Strength	180°/sec Avg. Power
RMR	-							
Body Fat %	-.064	-						
Fat-free Mass	.639**	-.516*	-					
Chair Stand	.027	-.159	-.231	-				
8-ft-up-and-go	.107	.011	.151	-.669**	-			
Upper Body Strength	-.005	-.634**	.581**	.075	.031	-		
Lower Body Strength	.557*	-.657**	.813**	.183	-.127	.731**	-	
180°/sec Avg. Power	.102	-.366	.647**	.048	-.410	.603**	.672**	-

Note. Values are Pearson product correlations (*p* value). ** denotes correlation is significant at the .01 level. * denotes correlation is significant at the .05 level.

(chair stand and up-and-go) were highly and inversely correlated with each other; however, the two measures were not significantly correlated with LBS or average power.

FFM, strength, and power correlations. All measures of strength—leg press 1RM, leg extension 1RM, leg curl 1RM, total LBS, chest press 1RM, shoulder press 1RM, upper back

Table 7

Fat-free Mass, Strength, and Power Correlations

	Fat-free Mass	Leg Press 1RM	Leg Exten 1RM	Leg Curl 1RM	Lower Body Total	Chest Press 1RM	Shlder Press 1RM	Upper Back 1RM	Upper Body Total	Avg. Power
Fat-free Mass	-									
Leg Press 1RM	$.840^{**}$	-								
Leg Exten 1RM	$.669^{**}$	$.799^{**}$	-							
Leg Curl 1RM	$.663^{**}$	$.848^{**}$	$.850^{**}$	-						
Lower Body Total	$.813^{**}$	$.979^{**}$	$.897^{**}$	$.919^{**}$	-					
Chest Press 1RM	$.855^{**}$	$.892^{**}$	$.806^{**}$	$.852^{**}$	$.907^{**}$	-				
Shlder Press 1RM	$.836^{**}$	$.947^{**}$	$.793^{**}$	$.867^{**}$	$.942^{**}$	$.953^{**}$	-			
Upper Back 1RM	$.747^{**}$	$.874^{**}$	$.816^{**}$	$.896^{**}$	$.906^{**}$	$.831^{**}$	$.817^{**}$	-		
Upper Body Total	$.581^{**}$	$.675^{**}$	$.669^{**}$	$.806^{**}$	$.731^{**}$	$.953^{**}$	$.949^{**}$	$.941^{**}$	-	
Avg. Power	$.647^{**}$	$.680^{**}$	$.560^{*}$	$.592^{**}$	$.672^{**}$	$.672^{**}$	$.714^{**}$	$.483^{*}$	$.603^{**}$	-

Note. Values are Pearson product correlations (*p* value). Leg exten = leg extension. Shlder = shoulder. Avg. power = average power at 180°/sec. ** denotes correlation is significant at the .01 level.

1RM, and total UBS—, FFM, and average power are all positively, significantly correlated. For FFM, the strongest correlation was with chest press and the weakest total UBS. For power, the strongest correlation was not with leg extension strength but with shoulder press strength.

Chapter V

Discussion, Summary, Conclusions, and Recommendations

Discussion

This study found that there was only a significant group by time interaction for FFM and total LBS when comparing HVRT, LVRT, and CTRL. However, when the two exercise groups were joined together for analysis, there was also a significant time-group interaction for RMR and total LBS. Furthermore due to the small sample size, effect size was important in determining clinically meaningful differences among the three groups for the other variables. For functional performance as measured by 8-ft up-and-go and 30-second chair stand, there was no clinically meaningful difference among the three groups for the chair stand, but LVRT had a meaningfully lower time than CTRL and HVRT. For power, HVRT had moderately meaningful increases in 180°/sec average power compared to CTRL, and LVRT had a small increase in average power compared to CTRL.

Hypothesis One. Contrary to the hypothesis, RMR decreased in all groups. These results are not consistent with previous RT and RMR research (Hunter et al., 2000; Pratley et al., 1994). Although the literature had only been concerned with LVRT, data indicate that RT increases RMR. Hunter and colleagues (2000) found a 6.8% increase (87 kcal/day) following a 26-week intervention, and Pratley et al. (1994) found a 7.7% increase (119 kcal/day) following 16 weeks (compared to the 182 and 234 kcal/day *decrease* for LVRT and HVRT in the current study).

However, a clinically meaningful difference between the exercise and CTRL participants existed. It is possible that the pre-intervention RMR testing was uncomfortable and novel to the participants and thus caused evaluated RMR measurements due to emotional stress and possibly increased levels of stress hormones. Then during the post-intervention RMR testing, the participants had the previous experience with the procedures and were more comfortable resulting in lower RMR. Moreover, the study duration was only 12 weeks, so it is unlikely that age-related changes in RMR caused such a dramatic decrease in RMR. It is also possible that seasonal differences could have contributed to RMR. The pre-intervention testing was performed in January while the post-intervention testing was in April. RMR can greatly vary season to season depending on an array of factors including environmental temperature, activity levels, and food-consumption.

Furthermore, the clinically meaningful difference between the exercise and CTRL participants shows that the two exercise groups decreased RMR less than the CTRL group. In practical terms, HVRT averaged 362 kcal/day higher than the CTRL group, and LVRT averaged 413 kcal/day higher than the CTRL group post-intervention. Overall, two explanations exist for the role of exercise in RMR change. First, the exercise could have prevented part of the age-related and time-related decrease in RMR. In contrast, if the assumption that the overall decrease in RMR was due to comfort rather than age-related changes, exercise could have even slightly increased RMR. Additionally, HVRT was an average of 6.0 and 6.2 years older than the CTRL and LVRT groups, respectively. Age has a large impact over RMR and exercise effects, so it is possible that the HVRT exercise could have been even more effective if the analysis could have controlled for age. Another variable not controlled for in the analysis is the weight and composition changes, which would influence RMR. These participants were not stable as the CTRL group lost 3.0 kg (with an average 2.7 kg decrease of FFM), HVRT 0.6 kg (with an average 0.3 kg increase in FFM), and LVRT only 0.1 kg (with an average 1.4 kg increase in FFM). Even though RMR decreased, RMR was still significantly correlated with FFM (post scores). Controlling for age and FFM may influence the changes and significance in RMR.

Hypothesis Two. Both of the exercise groups significantly increased FFM, but contrary to the hypothesis, the LVRT increased slightly more than HVRT. While the CTRL group lost FFM, the two exercise groups increased FFM in the 12-week intervention. It appears from the current investigation that HVRT is not better than LVRT, and possibly inferior to LVRT based on effect size, for increasing FFM. These results are somewhat consistent with the previous research of Henwood et al. (2008) which found a 24-week exercise intervention increased FFM in the LVRT group by 1.4 kg and 2.9% (compared to the 1.4 kg and 3.1% increase in the current LVRT group). However, their HVRT group similarly increased by 1.2 kg and 2.8% (compared to the 0.3 kg and 0.7% increase in the current HVRT group), and their CTRL group increased by 0.6 kg and 1.3% (compared to the 2.7 kg and 5.3% *decrease* in the current CTRL group). However, the age discrepancy between the HVRT and other two groups in the present study may have again influenced the increase in FFM for the HVRT participants.

Hypothesis Three. It was hypothesized that the HVRT or "power training" group should have increased power more than the LVRT group. HVRT did increase 3.0% (2.7 watts) more in average power at 180°/sec than the LVRT, but there was a small effect size between the two exercise groups. Additionally, there was a larger effect size between HVRT and CTRL than there was between LVRT and CTRL, so the HVRT increased average power more than the other two groups, just not significantly more than LVRT. In previous studies, the measurement of power varied greatly from peak power to average power, from leg press power to chest press power, and from a variety of assessments (Wingate, force plate, etc.; Bottaro et al., 2007; Earles et al., 2001; Fielding et al., 2002; Henwood et al., 2008; Miszko et al., 2003). These discrepancies make comparisons difficult, but generally, the current investigation induced small relative increases in power.

There are two possible explanations for the lack of significantly greater increase in power for HVRT. For one, the length of the intervention of 12 weeks may not have been long enough to produce significant differences, but since the trend was for the HVRT group to be higher in power than the LVRT group, a longer study, perhaps 24-week or 52-week, might have produced significantly higher power for the HVRT. Additionally and most likely, the intensity at 80% 1RM was too intense for the older HVRT participants and was not ideal for power improvements. A typical power curve reveals that the highest power occurs at approximately 70% 1RM with a curvilinear decrease in power above 70% 1RM (Bean et al., 2004). Perhaps, 70% 1RM is the ideal intensity for HVRT for power production. Although the researcher supervised most of the sessions (23 out of 25), there was some deviation from the HV protocol at the higher weights, throughout the sets. Some, if not most, of the individuals were highly compliant and masterful of the HV technique, while others struggled to maintain the HV throughout all 3 sets. The three oldest participants, one aged 78 and two aged 82, were all in the HVRT group and two of which were the most difficult to encourage to maintain the HV protocol due to the intensity of the weight and the velocity.

Hypothesis Four. In agreement with this hypothesis, LVRT and HVRT similarly increased muscular strength both of the upper body and lower body, and both exercise groups increased strength more than the CTRL. Both exercise protocols at 80% 1RM produced strength increases. These results are consistent with previous research. Bottaro and colleagues (2007) found that a 10-week intervention at 60% 1RM increased leg press and chest press strength in both exercise groups. Leg press increased in HVRT by 47.3 kg and 27.1% and in LVRT by 47.2 kg and 26.7%, and chest press increased in HVRT by 12.7 kg and 28.2% and in LVRT by 12.5 kg and 24.9%.

Interestingly, the strength increases in the present study were similar between exercise groups despite slightly larger increases in FFM in LVRT compared to HVRT and despite slightly larger increases in power in HVRT compared to LVRT. Power, strength, and FFM are all highly correlated but distinctly different measures of functional capacity and muscular fitness. For example, the finding that average power of leg extension at 180°/sec was more strongly correlated with shoulder press 1RM than leg extension 1RM was interesting, but power and strength tests do not assess the same component of muscular fitness. Furthermore, the speed at which activities utilizing a shoulder press (faster at a lighter weight; reaching into a cabinet) is more similar to power than activities utilizing a leg extension (slower at a heavier weight; stepping out of a car).

Although not included in the original research hypotheses, the time course changes for estimated 1RM values in the current study provide additional insight into strength increases. Fielding et al. (2002) reported the 16-week time course strength increases (in 4-week intervals) for leg press and leg extension only. Similarly, there was no significant time group interaction between the HVRT and LVRT groups. These researchers compared each 4-week interval to the baseline rather than the previous time interval, so significant increases through the time course cannot be directly compared to current study. Overall the graphs from the 16-week study look slightly different from this 12-week study as there appears to be a larger initial increase from initial to Week 4 for the Fielding study. This could be partly due to the inclusionary criteria: the Fielding study did not include subjects previously participating in regular exercise more than one day per week. Otherwise, the Fielding study leg press and leg extension strength measures appear to increase almost linearly from Week 4 to Week 16. It appears that the knee extension graph could indicate a plateau from Week 8 to Week 12, but the significance between Weeks 8 and 12 is unknown without being able to run additional statistics on the Fielding data. The plateau effect from Week 8 to Week 12 that was found in the current study bares important inferences to exercise interventions. Further research should be performed to determine how long such a plateau typically lasts (another 2, 4, or more weeks) and what intensity increases are needed to prevent the plateau. Furthermore, determining whether the frequency of the exercise intervention (2 versus 3 or 4 day/week) also influences the time course of strength increases would be a beneficial investigation. All plateaus in muscular fitness cannot be avoided or eliminated as the body readily adapts the stresses placed on its systems through exercise, but a better understanding of the response patterns of strength increases could greatly benefit long-term fitness programs.

Hypothesis Five. Contrary to the hypothesis, there were no significant differences between groups for the chair stands, and LVRT was slightly faster at the 8-ft up-and-go. As mentioned in the additional analysis, the two functional performance measures were highly and significantly correlated with each other but not with either LBS or average power. There is a slight disagreement in the literature concerning HVRT and LVRT effects on functional fitness, largely depending on the initial level of fitness, length of intervention, intensity of exercise, and the specific exercises utilized. Leszczak (2010) found that a 12-week HVRT involving body and ankle weights did not improve up-and-go time but did increase the number of chair stands in 30 seconds from baseline by 2.7 (27%). The chair stand increase was not significant compared to CTRL. Bottaro et al. (2007) found that the 10-week intervention at 60% 1RM improved up-and-go time by 0.9 seconds (15.3%) for HVRT (compared to 0.2 second and 3.3% increase) and only 0.1 seconds (0.8%) for LVRT (compared to 0.3 and 5.2% in the current study). The Bottaro protocol also increased number of chair stands by 7.7 (43.0%) for HVRT compared to 3 (18.6%) in the current study and 1.3 (6.0%) for LVRT compared to 4 (23.7%).

It is interesting that despite meaningfully higher increases in strength and power in both the exercise groups compared to the CTRL, there were not meaningful increases in these two functional performance measures. According to norms for the Senior Fitness Test, the average range for chair stands for men ages 65-69 is 12 to 18 and for women ages 65-69 is 11 to 16 (Rikli & Jones, 1999b). Before the exercise intervention time period, all of the men (all three groups, average age 73) averaged 15 chair stands, and all of the women (all three groups, average age 72) averaged 17 stands. For 8-ft up-and-go time, the average range for men ages 65-69 is 5.7 to 4.3 seconds and for women ages 65-69 is 6.4 to 4.8 seconds (Rikli & Jones, 1999b). Before the exercise intervention time period, all of the men (all three groups, average age 73) averaged 5.4 seconds, and all of the women (all three groups, average age 72) averaged 5.4 seconds on the up-and-go. Therefore, the average scores of the participants compared to only the youngest possible age group norms (65-69) showed that they were already highly functional individuals and therefore caused a ceiling effect for these two measures of functional fitness. Therefore, the likelihood of finding significant improvements in these measurements would be highly unlikely. Also, all of the CTRL participants participated in walking activities on their own, so their increases in chair stands and up-and-go times may have been influenced by the functional action of walking even without the improvements in power and strength.

Summary

The purpose of this study was to compare the effects of a HVRT and a more traditional, LVRT protocol on RMR and selected measures of muscular and functional fitness in older adults. A total of 19 participants completed the study. Compared to the CTRL of self-selected walking, both LVRT and HVRT significantly improved RMR, FFM, total UBS, and total LBS. Additionally compared to CTRL, LVRT had a moderate effect size for the 8-ft up-and-go, and HVRT had a moderate effect size for average power. There were no differences among any of the groups for chair stand. Overall, the results indicate that these two types of training over a 12-week period at 80% 1RM produce similar improvements in RMR, total UBS, total LBS, and average power. There was also a moderate effect size in the favor of LVRT for FFM and up-and-go. However, there was also a large effect size for age between the HVRT and the other two groups.

Conclusions

According to the present study, both LVRT and HVRT protocols at 80% 1RM have been found to be safe and effective for older adults, and at least one of the interventions was able to increase UBS, LBS, FFM, RMR, and up-and-go time compared to CTRL. Average adherence to the intervention was high (92.8%), and this was likely do to the interaction and relationships developed with the researcher and among participants. It is common for individuals to lose motivation for exercise when exercising alone. Resistance exercise in the one-on-one training or group-setting instructor-supervised format is ideal for older adults as the participants benefit both physically and socially. The social element in this study among participants and between participants and the researcher should not be overlooked. These individuals were highly committed to this exercise intervention with several individuals never missing a session. This study adds to the literature that physical activity and exercise are beneficial for older adults.

Recommendations

As decreased FFM, strength, power, energy expenditure, and functional fitness are important issues for older adults, determining the beneficial RT programs for these variables is crucial. In future investigations with HVRT, it is recommendation that a lower intensity at 70% 1RM be utilized for ideal power increases. As no to little changes were produced for the two functional fitness measures, determining the ideal intensity, duration, and length of a RT protocol for improvements in the chair stand and 8-ft up-and-go would greatly benefit the older population. It is further recommended to determine the effects of a more long-term intervention for HVRT and LVRT on RMR in older adults. Additionally, the effects of age differences on training responses within the broad “older adult” population should be examined. Overall, the improvements made by either RT program were favorable, and older adults are encouraged to begin or increase involvement in RT as able.

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Appendix A: Informed Consent

Informed Consent
Effects of Resistance Training on Resting Metabolic Rate in Older Adults

Principal Researcher: Laura Morgan
Faculty Advisor: Dr. Inza Fort
Faculty Advisor: Dr. R. Michelle Gray

INVITATION TO PARTICIPATE

You are invited to participate in a research study about resistance training with older adults. You are being asked to participate in this study because you fit the age criteria, can personally benefit from the study, and will contribute to the research effort.

WHAT YOU SHOULD KNOW ABOUT THE RESEARCH STUDY

Who is the Principal Researcher?

Laura Morgan
University of Arkansas
Rogers Adult Wellness Center Graduate Assistant

Who is the Faculty Advisor?

Dr. I. Fort
    University of Arkansas
Dr. R. Gray
    University of Arkansas

What is the purpose of this research study?

The purpose of this study is to examine the effects of a 12-week resistance training intervention on resting metabolic rate in older adults.

Who will participate in this study?

30 City of Rogers Adult Wellness Center (RAWC) members will participate in this study. Participants must be 65 years or older.

What am I being asked to do?

Your participation will require the following:

- 2 pre-intervention testing dates (one at RAWC and one at the University of Arkansas)

- 12 weeks of six resistance training exercises on Mondays and Wednesdays for 30-45 minutes (except for control participants)
- 3 additional dates mid-intervention testing at RAWC (except for control participants)
- 2 post-intervention testing dates (one at RAWC and one at the University of Arkansas)

What are the possible risks or discomforts?

Physical activity and exercise ***innately*** impose some risks for individuals in the form of

- Heart problems, such as sudden cardiac death
- Dehydration and/or heat exhaustion (but improbable with this form of exercise)
- Musculoskeletal problems, such as strained muscles or joints
- Muscle soreness

However, it is generally accepted by health professionals that the risks are minimal and that the benefits greatly outweigh the risks. Precautions (from health screenings to researcher supervision of exercise sessions) will be engaged to ensure that participants have minimal risk in testing procedures and exercise performance.

What are the possible benefits of this study?

The exercise participants will have the benefit of free, individualized, supervised, biweekly resistance training sessions for 12 weeks. You will potentially receive any or all of the benefits associated with resistance training exercise, including but not limited to

- Increased muscular strength and power
- Increased functional fitness
- Increased self-efficacy
- Increased ability to perform activities of daily living
- Increased independence

Additionally, both the exercise participants and the control participants will have the benefit of the free fitness testing, including RMR, DXA, Biodex, muscular strength, and functional fitness. All participants will be given the opportunity at the end of the intervention after all post-intervention testing is complete to receive instructions on continuing resistance training exercise (exercise participants) or starting a resistance training exercise program (control participants) based on your interest and fitness testing results.

How long will the study last?

The whole study will last 14 weeks (with one week of pre-intervention testing, 12-week intervention, and one week of post-intervention testing). The pre- and post-testing will be about a 5 hour commitment over two days. The exercise sessions will be 30-45 minutes twice weekly.

Will I receive compensation for my time if I choose to participate in this study?

Monetary compensation will be given only to participants who drive themselves to testing dates in compensation for gas.

Will I have to pay for anything?

Participants will not have to pay for any of the testing or training sessions.

What are the options if I do not want to be in the study?

If you do not want to be in this study, you may refuse to participate. Also, you may refuse to participate at any time during the study. Your relationship with the RAWC or University of Arkansas will not be affected in any way if you refuse to participate.

How will my confidentiality be protected?

All information will be kept confidential to the extent allowed by applicable State and Federal law. Personal data will only be accessible to the researchers, and data will also be coded to protect to identity of individuals.

Will I know the results of the study?

At the conclusion of the study you will have the right to request feedback about the results. You may contact the Principal Researcher, Laura Morgan (contact information listed previously and listed again below).

What do I do if I have questions about the research study?

You have the right to contact the Principal Researcher or Faculty Advisors as listed below for any concerns that you may have.

Principal Researcher

Laura Morgan
University of Arkansas
Rogers Adult Wellness Center Graduate Assistant

Faculty Advisors
Dr. I. Fort
University of Arkansas
Dr. R. Gray
University of Arkansas

You may also contact the University of Arkansas Research Compliance office listed below if you have questions about your rights as a participant, or to discuss any concerns about, or problems with the research.

University of Arkansas Research Compliance
Ro Windwalker, CIP
Institutional Review Board Coordinator
University of Arkansas

I have read the above statement and have been able to ask questions and express concerns, which have been satisfactorily responded to by the investigator. I understand the purpose of the study as well as the potential benefits and risks that are involved. I understand that participation is voluntary. I understand that significant new findings developed during this research will be shared with the participant. I understand that no rights have been waived by signing the consent form. I have been given a copy of the consent form.

Participant - Printed Name Signature

Date

Witness - Printed Name Signature

Date

Appendix B: Health Screening

Please answer the following questions. Today's Date: ____________

(1) Age greater than 65 years old

Date of Birth _____________ What is your current age? ____________

(2) Participation in strengthening activities in the past year

Do you currently participate in any form of physical activity? Yes No

Activities:

Frequency (days per week)__ Duration (min per day)____ Length of Participation ______

Do you currently participate in any form of *strengthening* activity? Yes No

Activities:

Frequency__________ Duration__________ Length of Participation __________________

(3) No diagnosis of unstable or unmanaged cardiovascular disease, hypertension, or diabetes;

Have you ever had any of the following conditions? Check yes or no. If yes, explain.

Heart Disease	☐ Yes ☐ No
Heart Attack	☐ Yes ☐ No
Angina (Chest Pain)	☐ Yes ☐ No
Peripheral Artery Disease	☐ Yes ☐ No
Stroke	☐ Yes ☐ No
High Cholesterol (>220)	☐ Yes ☐ No
High Blood Pressure (>140/90)	☐ Yes ☐ No
Diabetes	☐ Yes ☐ No
Rheumatic Fever	☐ Yes ☐ No
Aneurysm	☐ Yes ☐ No

(4) Lack of neuromuscular or musculoskeletal disease or injury that prohibits participation in resistance exercise

Have you ever had any of the following conditions? Check yes or no. If yes, explain.

Arthritis, rheumatism, or gout	☐ Yes ☐ No
Any joint, bone, or muscle pain	☐ Yes ☐ No
Any joint, bone, or muscle injury	☐ Yes ☐ No
Any physical disability	☐ Yes ☐ No

(5) No history of hospitalization for any cause within the past year

Have you ever had any of the following conditions? Check yes or no. If yes, explain.

Severe Illness (in the last year)	☐ Yes ☐ No
Operations (in the last year)	☐ Yes ☐ No
Broken bone/fracture (in the last year)	☐ Yes ☐ No

(6) No history of a fall within the preceding one year

Have you fallen in the past 12 months?	☐ Yes ☐ No	**If yes, explain.**

(7) Additional information

Have you experienced any of these symptoms? Check yes or no. If yes, explain.

Pain and/or discomfort in the chest, neck, jaw, or arms	☐ Yes ☐ No	
Shortness of breath at rest or with mild exertion	☐ Yes ☐ No	
Dizziness	☐ Yes ☐ No	
Ankle edema (swelling)	☐ Yes ☐ No	
Rapid or irregular beating heart	☐ Yes ☐ No	
Leg pain, cramping, or tightness during exercise	☐ Yes ☐ No	
Heart murmur	☐ Yes ☐ No	
Fatigue or shortness of breath during the day	☐ Yes ☐ No	
Do you smoke?	☐ Yes ☐ No	☐ Quit
Have you gained or lost weight in the past year?	☐ Yes ☐ No	

(8) Please attach a list of all medication (prescription or over-the-counter) you are currently taking or use the form below.

Medication	***Reason Prescribed***	***When do you take this medication?*** *(all that apply)*
_____________	_________________	☐ Morning ☐ Mid-Day ☐ Evening ☐ Bedtime
_____________	_________________	☐ Morning ☐ Mid-Day ☐ Evening ☐ Bedtime
_____________	_________________	☐ Morning ☐ Mid-Day ☐ Evening ☐ Bedtime
_____________	_________________	☐ Morning ☐ Mid-Day ☐ Evening ☐ Bedtime
_____________	_________________	☐ Morning ☐ Mid-Day ☐ Evening ☐ Bedtime
_____________	_________________	☐ Morning ☐ Mid-Day ☐ Evening ☐ Bedtime

Appendix C: IRB Approval Letter

September 17, 2012

MEMORANDUM

TO:	Laura Morgan Inza Fort Michelle Gray
FROM:	Ro Windwalker IRB Coordinator
RE:	New Protocol Approval
IRB Protocol #:	12-09-080
Protocol Title:	*Effects of High-Velocity versus Traditional Resistance Training on Resting Metabolic Rate in Older Adults*
Review Type:	☐ EXEMPT ☐ EXPEDITED ☒ FULL IRB
Approved Project Period:	Start Date: 09/14/2012 Expiration Date: 09/13/2013

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (http://vpred.uark.edu/210.php). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

This protocol has been approved for 80 participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

Appendix D: Participant Exercise Chart

Morgan - Thesis			**Participant:**			
Exercise▶ Adjustments▶ DATE▼	**Upper Back** Seat:________ Chest Pad:___	**Leg Extens.** Seat:_______ Leg Pad:____ Start Pos____	**Chest Press** Seat:_______ Arm:________	**Leg Curl** Seat:_______ Leg Pad:____ Start Pos:____	**Leg Press** Seat:______	**ShoulderPress** Seat:_______
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____
T Th	Res:______ Set:_______ Rep:______	Res:______ Set:_______ Rep:_______	Res:______ Set:_______ Rep:______	Res:______ Set:______ Rep:______	Res:_____ Set:______ Rep:_____	Res:_____ Set:______ Rep:_____

Appendix E: Data Collection Template

Code: LMT __

Date: _____________

Demographic Information	Consent Completed		
	Health Screening Completed		
	Age (years)		
	Sex		
	Height		
	Weight		
Group (IV)	HVRT, TRT, or Con		
RMR	Cart Used (Old or New)		
	15 min rest		
	Measurement time		
	Events Noted		
	RMR (kcal)		
DXA	Body Fat		
	Muscle Mass		
	Bone Density		
BIODEX	Avg. Power 240 L Extension (watts)		
	Avg. Power 240 R Extension (watts)		
	Avg. Power 240 L Flexion (watts)		
	Avg. Power 240 R Extension (watts)		
	TQ/BW % 60 L Extension (%)		
	TQ/BW % 60 R Extension (%)		
	TQ/BW % 60 L Flexion (%)		
	TQ/BW % 60 R Flexion (%)		
Functional Fitness	30-second Chair Stand (# reps)		
	8-foot Up-and-go (seconds)		