VARIABILITY IN REPETITIONS AT SUBMAXIMAL RELATIVE INTENSITIES IN YOUNGER AND OLDER MEN AND WOMEN

BY

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ABSTRACT

PURPOSE: To assess the individual variability in the capacity to lift submaximal loads in younger and older men and women in resistance training exercises.

METHODS: We recruited 16 younger (8 female, 22.8±1.8 yrs) and 32 older adults (16 female, 74.3±5.4 yrs). One repetition maximum (1RM) was measured on two days for all participants using three different exercises: leg press (LP), leg extension (LE), bicep curl (BC). On days three and four, participants performed repetitions to failure at 60% or 80% 1RM, the order of which was randomized.

RESULTS: For LP, LE, and BC, at 60% 1RM, younger men completed 26.3 (95% CI=12.9-39.6), 13.9 (10.7-17.1) and 12.9 (10.0-15.8) repetitions and younger women completed 28.8 (22.0-35.5), 11.4 (9.7-13.1), and 13.0 (9.8-16.2). At 60% 1RM, older men completed 19.3 (14.7-23.8), 11.8 (10.2-13.3), and 14.3 (11.8-16.8) and older women completed 23.3 (14.8-31.7), 11.1 (9.0-13.3), and 16.1 (12.4-21.4) repetitions. For LP, LE, and BC, at 80% 1RM, younger men completed 14.9 (8.7-21.0), 7.3 (5.8-8.7), 6.1 (5.0-7.3) and younger women completed 17.0 (12.2-21.8), 8.8 (7.3-10.2), and 6.5 (4.2-8.8). At 80% 1RM older men completed 9.1 (7.2-11.0), 8.6 (7.2-9.9), 6.1 (4.5-7.6) and older women completed 12.8 (8.7-16.8), 7.9 (6.1-9.6), 8.9 (6.7-11.2). Greater muscular strength was observed in younger participants on all tasks (p<0.01).

CONCLUSIONS: We observed considerable inter-individual variability in the number of repetitions completed in younger and older men and women at 60% and 80% 1RM. Practitioners should give consideration to individual variability when attempting to maximize the benefits of resistance exercise.

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REVIEW OF THE LITERATURE

SIGNIFICANCE OF AGING AND DISABILITY

As a result of advances in medicine and science, people all over the world are living longer and healthier lives. In 2010, over 40 million Americans were older adults, that is age 65 or older, a 15% increase compared to 2000 [1]. The number of older adults will increase significantly in the next 20 years, as the “baby boomers” enter into older adulthood. By the year 2030, an estimated 72 million Americans will be ≥65 years of age [1].

Older adults have an increased likelihood of developing significant health issues, particularly chronic diseases and disability. In 2010, 37% of the older adult population reported some type of disability. Disability increases markedly with age. In people 85 or older, 62% of women and 46% of men report some mobility limitation [2]. Mobility is a strong predictor of physical disability and it plays a critical role in the disablement process [3]. For example, people with mobility limitations are often unable to independently perform some key activities of daily living (ADL’s). The inability to perform ADLs can result in serious health declines, increasing the likelihood of institutionalization or death [4]. In addition, limitations in mobility associated with aging put a serious burden on the health care system. In 2004, $135 billion was spent on long term care for older adults [5]. As the number of older adults in the United States continues to increase, countermeasures designed to attenuate the decline of physical function and the onset of disability in this expanding population must be identified and implemented in this population.
MOBILITY DISABILITY

Mobility Disability Defined

Mobility is defined as the ability to move independently from one place to another [3]. Mobility is critical for an individual to be able to independently carry out activities of daily living (ADL’s)[4]. Katz identified six primary activities of daily living and they are: bathing, dressing, toileting, transferring, continence, and feeding [6, 7]. The Katz Index of Independence in the Activities of Daily Living uses these six activities to assess functional status, as a patient’s ability to perform activities of daily living [7]. This index ranks adequacy of task performance for each of these six basic functions using a dichotomous (yes/no) scale [6]. More complex activities of daily living, deemed essential for an individual to be able to function independently are known as instrumental activities of daily living (IADL’s)[8]. Instrumental activities of daily living include tasks such as shopping, cleaning, and cooking [3]. Limitations in individual independence result in a dramatic decrease in quality of life for the individual and increased stress for their caregivers and family members [9]. Older adults, in particular those with chronic disease, are at a much greater risk for developing physical impairments which can lead to mobility limitations and negatively impact their ability to live without assistance [10].

Mobility disability occurs at the point when mobility impairments result in the restriction of an individual to move about in their natural environment and carry out activities deemed essential for daily living [3]. The extent to which a mobility limitation affects an individual is dependent upon the individual as well as the environment in which they live [11].
Disablement Models

An understanding of the process leading to disability is crucial to efforts aimed at preventing or postponing disability in older adults [2]. Unlike younger adults, where disability can often be attributed to a single source, in older adults, the presence of disability is often due to the interaction of multiple factors; especially chronic diseases and comorbidities [10].

Disablement models such as the one proposed in 1965 by sociologist Said Nagi, allow us to better understand how these interacting factors ultimately result in disability [12]. The Nagi model of disablement characterizes disability as a gap between a person’s physical capabilities and the demands created by their social and physical environment [12]. Nagi’s disablement pathway carefully distinguishes disability from three other distinct, yet inter-related and precipitating concepts: active pathology, impairment, and functional limitation [13]. The traditional Nagi model of disablement was expanded upon by Verbrugge and Jette to include the influence of both intra and extra individual factors on the progression of disablement [14]. Inclusion of intra and extra individual factors into the disablement model helps to explain how both individual and environmental characteristics play a role in the disablement process [11].

Other models such as the more recent International Classification of Functioning, Disability and Health proposed by the World Health Organization have attempted to introduce a new and universal language of disablement using the biopsychosocial view of health [15]. Currently however, there exists no agreed upon gold-standard to be used in assessing mobility disability. Approaches aiming to measure mobility/mobility disability
focus on tasks believed to indicate an ability to perform necessary activities of daily living such as walking a quarter of a mile, or climbing a flight of stairs.

**PHYSICAL ACTIVITY**

*Physical Activity and Aging*

Physical activity is a behavior widely accepted to reduce all-cause mortality rates and improve upon a number of different health outcomes [16]. Benefits of engaging in a program of physical activity include significant improvements in cardio-respiratory, musculoskeletal, and mental health [17]. More recent investigations have focused on physical activity in the elderly. Health experts agree that physical activity can have a significant impact on the health and physical function of the elderly [18]. Unfortunately, older Americans are the least physically active age group and generate by far the highest health care expenditures [19]. Today, we see older adults being increasingly encouraged to begin some sort of physical activity program to help attenuate the normal trajectory of physical decline associated with age and improve functioning in the elderly while helping to reduce health care costs [18].

Epidemiologic studies have shown consistent associations between high levels of physical activity and high physical function in the elderly [20]. Numerous other studies have shown beneficial effects of physical activity on physical function and other suspected precursors of disability in the elderly [21-23]. The Lifestyle Interventions and Independence for Elders (LIFE) Pilot Study (LIFE-P) has shown the benefits of a physical activity program compared to a successful aging education program on two suspected markers of mobility disability. In this study, the physical activity group showed an improved score on the Short Physical Performance Battery (SPPB), a measure of
lower-extremity function, as well as improved performance on a 400 meter walk test compared to a successful aging control group [24]. Unfortunately, it is difficult to prove that physical activity interventions, such as LIFE-P, actually reduce disability because disability is such a complex and individually defined concept.

Over the past two decades researchers have focused on developing safe and effective guidelines for physical activity in the elderly [25]. Today, older adults are increasingly encouraged to take a multi-factorial approach to physical activity by incorporating manageable aerobic, strength, and flexibility programs into their daily lives [26].

*Recommendations for Physical Activity in the Elderly*

Using work done by exercise professionals, in 1975, the American College of Sports Medicine (ACSM) established physical activity guidelines recommended for healthy individuals. Since the establishment of these initial guidelines, a growing body of research has focused on physical activity and health. This has generated a greater understanding of the ways in which various types of physical activity affect the body and consequently has resulted in numerous revisions and updates of the 1975 physical activity guidelines. The most recent guidelines for physical activity released by the ACSM in 2011 recommend that healthy adults engage in cardiorespiratory exercise for at least 30 minutes a day, 5 or more days a week for a combined total of no less than 150 minutes of cardiorespiratory exercise a week [27]. Should individuals choose to engage in more vigorous-intensity cardiorespiratory exercise training, they are recommended to do so for at least 20 minutes a day on 3 or more days a week, thus accumulating at least 75 minutes of vigorous cardiorespiratory exercise a week. For individuals wishing to combine moderate and vigorous intensity exercise they are recommended to achieve total energy
expenditure greater than 500 MET minutes per week. MET stands for metabolic equivalent of task, also known as the metabolic equivalent, and MET units serve as a useful and convenient way to describe the intensity of a variety of physical activities [27]. One MET is the energy equivalent spent by an individual who is seated and at rest for one minute.

In addition to cardiorespiratory exercise, older adults are encouraged to use resistance training as a means of achieving the recommended 500 MET minutes of energy expenditure per week. The ACSM recommends that older adults perform resistance exercises for each of the major muscle groups, supplemented with neuromotor exercise involving balance, agility, and coordination at least 2-3 days a week. For maintaining joint range of movement, completing a series of flexibility exercises for each the major muscle-tendon groups (a total of 60 s per exercise) on 2 or more days a week is recommended [26].

It is important to realize that not all individuals are physically capable of meeting the recommended physical activity guidelines. Therefore, the ACSM notes that any exercise program must be modified to an individual’s habits, physical function, health status, exercise response, and stated goals [26] This is particularly important when considering older individuals with mobility limitations. Regardless of impairment status, it is essential that older adults avoid inactivity. The ACSM guidelines explicitly state that “some physical activity is better than none,” even if one fails to meet the recommended amount of 150 minutes or more of physical activity per week [28].

In older adults, resistance training increases muscular strength, improves gait speed, and improves stair climb time [25, 29]. Although cardiorespiratory exercise has been the
traditional mode of exercise prescribed in older adults, strength training is an integral part of any fitness program, especially in older adults where loss of muscle mass and weakness are prominent deficits [30].

**RESISTANCE TRAINING**

Muscle Mass and Aging

One of the greatest long-term threats to our ability to remain healthy and function independently is the steady decline of lean muscle mass seen with advanced aging, a condition known as sarcopenia [30]. Age related sarcopenia typically begins between 40-50 years of age, and is primarily the result of muscle atrophy or muscle wasting [31]. Associated with sarcopenia is a decline in muscle strength, defined as the maximal capacity of the muscle to generate force. The Baltimore longitudinal study of aging compared measures of muscular strength in 654 subjects, 346 men and 308 women between 20-93 years of age [31]. Lindle and colleagues [31] used the data obtained from the Baltimore study to show that both men and women experience age-related declines in isometric, concentric, and eccentric knee extensor peak torque with aging. Studies have shown that lower extremity muscle power is a strong predictor of functional limitations and disability in older men and women [32-34]. Declines in muscle strength and power are associated with an increased risk for falls, hip and other bone fractures, and numerous adverse physiological changes such as a reduced glucose tolerance and a decrease in bone mineral density [35, 36]. In addition to changes in muscle mass, studies on the histochemical changes in muscle tissue associated with aging have shown a decreased proportion of Type II muscle fibers and selective atrophy of Type II fibers with
increasing age [36, 37]. Decreases in Type II muscle fiber area have been shown to correlate highly with a decline in strength, commonly seen in old age [38].

Older adults who develop sarcopenia are at a greater risk for osteoporosis, a condition of reduced bone mineral density. The decrease in muscle mass seen with sarcopenia results in less mechanical stress on the bones and consequently a reduction in bone mineral density [39]. In addition to osteoporosis, age related muscle loss also decreases immune system functioning and leads to a slower recovery process from surgery or injury. These decrements are thought to be a product of reduced muscle mass which results in a decreased metabolic reservoir. This metabolic reservoir is responsible for producing proteins and metabolites essential for survival and recovery from injury [40].

A number of different mechanisms have been proposed to explain sarcopenia including sub-optimal hormone levels, inadequate dietary protein intake as well as other nutritional imbalances, oxidative stress, inflammation, and physical inactivity [29, 41]. Of the many factors thought to contribute to this decline in muscle mass, physical inactivity is one of the factors that may be modified. Unfortunately, physical activity levels appear to decline with age [41, 42]. By educating and encouraging older adults to incorporate exercise training into their daily lives, we can diminish the effect that physical inactivity has on the decline in function commonly observed in older adults [41].

*Importance of Resistance Training in Older Adults*

Reducing physical inactivity with resistance training, has been shown to attenuate muscle loss in older adults as well as promote an increase in muscle mass [29]. High-intensity resistance training has also been shown to improve the aerobic capacity of targeted muscle groups [30]. Consequently, progressive resistance training has been
found to be an effective countermeasure for sarcopenia [43]. Experimental trials have shown that progressive resistance training (PRT) improves muscular strength in the elderly [29, 44-46]. In 2004 Latham and colleagues [47] did a systematic review of literature looking at the effect of many randomized controlled trials using PRT interventions intended to reduce physical disability in older adults. Latham and colleagues identified 62 randomized controlled trials (RCT’s) with 3,674 participants that used PRT as a primary intervention in adults 60 years of age or older. It was found that PRT produced a moderate to large effect on strength (SMD=0.68). 14 trials composed of 798 participants were pooled to assess the effect of PRT on suspected precursors of disability, particularly gait speed. The researchers note that although these trials were of poor quality, a modest effect was found on gait speed (WMD= 0.07 m/sec) [47]. Fiatarone and colleagues [29] showed that that improvements in muscular strength resulting from PRT interventions are associated with improvements in aspects of functional capacity such as stair climb power and chair rise time [29, 30]. Other PRT programs in the elderly have been shown to improve balance, decrease falls, and reduce pain from osteoarthritis [43].

Research has also shown that resistance training helps to reduce the risk of developing chronic diseases such as Coronary Heart Disease and Type II Diabetes [18, 48-50]. Furthermore, benefits from resistance training include a reduction in fat mass and an increase in lean muscle [25, 29, 51] both of which are particularly beneficial for this older population. As a result of the explosion of resistance training studies in older adults showing favorable results, the ACSM guidelines have increased the emphasis on resistance training for older adults.
Resistance Training Prescription in Older Adults

The ACSM recommends that healthy older adults engage in resistance training exercises for 20-45 minutes with a frequency of 2-4 times per week [25-27, 48, 52, 53]. The recommendations suggest that older adults target major muscle groups by doing 10-15 repetitions per exercise with loads of approximately 65-75% of their one repetition maximum. It is recommended that older adults use primarily multi-joint exercises as these will work a greater amount of muscle. Initially, individuals should begin with one set per exercise and increase the number of sets separated by 2-3 minutes of rest as they progress. For safety and skill related reasons, older adults are most frequently advised to use exercise machines instead of free weights. This is especially important for those beginning an exercise program. As individuals progress, the switch to free weights can be made when deemed appropriate by an exercise professional [54]. For some older adults with specific limitations or goals, resistance training programs can be manipulated with these constraints in mind.

When developing a resistance training program, there are 5 key variables to consider: resistance training exercise choice, order of exercises, number of sets, rest periods, and exercise load [55, 56]. The overall intensity of a resistance training program can be adjusted through the manipulation of these variables. Of these variables, exercise load has emerged as the most studied [55]. For the purpose of exercise prescription, exercise load is typically expressed as a percentage of one-repetition maximum (1RM). The 1RM is defined as the maximum amount of weight that an individual can successfully lift through the full range of motion for a given exercise using good lifting form. Research has shown that older adults have significant improvements in muscular strength training with loads
between 65-75% of 1RM, with some studies showing improvements using loads as heavy as 85% of 1RM [45, 57, 58]. Although it has been shown that health benefits from resistance training in older adults are available using lighter weights, current consensus is that older adults should use weights between 65-75% of their individual 1RM for optimal benefits in muscular strength while seeking to minimize musculoskeletal injury [58, 59].

Muscular Fitness

Muscular strength, power, and endurance are fitness components that are important for health and physical function. Muscular strength can be defined as the ability of the muscle to exert force [27]. Power, a fitness component related to strength, is the ability to exert force over time (power = work ÷ time) [60]. Finally, muscular endurance is the muscle’s ability to continue to perform for successive exertions or many repetitions [27].

Muscular strength and power, two related components of muscular fitness are important for self-maintenance and instrumental activities of daily living [8, 61]. Fortunately, skeletal muscle is highly adaptable [62] and therefore, deficiencies can be amended with adequate training. When healthy skeletal muscle is subjected to a greater than normal stimulus, such as resistance training, it improves its function by adapting in a manner that makes it easier for that skeletal muscle to meet external demands [62].

Fitness tests to assess muscular strength and endurance as part of a fitness screening evaluation can provide exercise practitioners with valuable information in regards to a patient’s fitness level. Tests of muscular fitness can also be used to track gains or losses over time, so that adaptations can be made to a resistance training program [27].
Muscular strength can be assessed in a variety of ways. Tests of muscular strength measure the amount of resistance (typically in kilograms or pounds) that an individual can maximally lift. Strength testing can be either be static (no muscular movement) or dynamic (movement of external load so that the muscle changes length) [63]. Static measures of muscular strength measure the peak force of a maximum voluntary contraction with devices such as cable tensiometers and handgrip dynamometers. A limitation to measuring static muscular strength is measurements are specific to a particular muscle group and joint angle [27]. The most traditional means to assess muscular strength is the one repetition maximum or 1RM, the greatest resistance that can be moved through the full range of motion for a specific task [64]. Testing to determine the maximum amount of weight that an individual can lift for a pre-determined number of repetitions (e.g. 3–RM) has also been proposed as a means of measuring muscular strength [65].

Muscular endurance testing is most frequently measured by determining the total number of repetitions that an individual can complete at a given resistance [27, 66-68]. Field tests of muscular endurance such as determining the number of curl-ups or pushups that an individual can complete in a minute have also been used to evaluate the endurance of specific muscle groups [69].

*Relationship between Repetitions and Selected Percentages of 1RM*

The most commonly used measure to assess dynamic muscular strength is the 1RM [70]. As a result exercise prescription is frequently based on a percentage of an individual’s 1RM. Information obtained from 1RM testing can be used to prescribe both training load and number of repetitions to be performed for each exercise. The percent of
1RM being prescribed will depend upon individual goals. For individuals seeking to improve muscular strength, a higher percent of 1RM will be prescribed so that each set will consist of a low number of repetitions, typically 1-6 using between 70-90% of 1RM [71, 72]. On the other hand, muscular endurance programs will use a lower percent of 1RM (30-65%), such that the individual will be able to perform more repetitions, usually more than 12 [73-75].

Organizations such as the National Strength and Conditioning Association (NSCA) have developed charts that predict the number of repetitions for a range of submaximal percentages of 1RM [64]. Such charts are frequently used for the design of resistance training programs. However, Earl and Baechle identified a number of different factors that might affect the utility of the chart [64]. These include:
1. The effect of training status on the %1RM-Repetition relationship remains an area of debate. Some studies have shown that those who are trained are capable of performing more repetitions than those who are untrained for a given percent of 1RM [68, 76, 77]. Hoeger and colleagues [68] showed a significant difference in the number of repetitions performed in 7 different exercises at 40% of 1RM between trained and untrained individuals. As the percentage of 1RM increased, the difference in number of repetitions between trained and untrained individuals decreased. At 60% 1RM, differences were found in the knee extension, bench press, sit-up, leg curl and

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Adapted From a Table Published by the National Strength and Conditioning Association
leg press and in only the bench press, sit-up, and leg press at 80% 1RM. However, other studies however showed that training status makes no difference [66, 71, 78]. Shimano and colleagues [66] found no significant differences when using three free-weight exercises (back squat, bench press, and arm curl) at 60, 80, and 90% of 1RM (except for in the bench press at 90% 1RM).

2. The number of sets being performed may influence the %1RM-Repititon relationship. Although no studies could be found that looked specifically at this outcome it seems that as the participant fatigues with subsequent sets, there will be a decrease in the number of repetitions they will be able to perform.

3. Choice of exercise appears to influence the number of repetitions an individual can perform. Shimano and colleagues [66] showed that when using a given submaximal percentage (60%) individuals were able to perform a mean of 35.0±13.4 repetitions on the back squat while on the arm curl participants performed only 17.2±3.7 repetitions [66, 71, 79, 80]. Therefore, it is important that attention is paid to the exercise before prescribing a certain number of repetitions for a given percentage.

4. The mode of resistance training appears to affect the %1RM-Repititon relationship. Studies have found that more repetitions can be performed using machine-based exercises than with free weight exercises [56, 66-68]. Because free weight exercises require greater motor coordination and balance than machine-based tasks, it seems likely individuals will perform fewer repetitions at a given percent of 1RM using free-weight exercises. A number of studies have found that for a given percent of 1RM, more repetitions are performed for multi-joint core exercises than single-joint assisted exercises [66, 81]. Shimano and colleagues [66] found that for a given
percentage of 1RM the number of repetitions performed in two multi-joint tasks (back squat and bench press) was significantly greater than the number of repetitions performed using a single joint task (arm curl).

5. The sequence of the exercise in the training program may also affect the number of repetitions that can be performed at a given percentage of 1RM. Regardless of the nature or mode of the exercise, it is likely that if an exercise is done at the end of the training program, the total number of repetitions for that exercise will decrease due to fatigue [81-83]. Simao and colleagues [81] demonstrated that when using a sequence of exercises, the mean number of repetitions per set was always less when an exercise was performed later in an exercise sequence. For this reason, the recommendation has been made to place large muscle group exercises at the beginning as opposed to the end of the training session [55, 83-85]. The rationale for such a recommendation is based upon the total force production (repetitions x resistance). By placing large muscle mass exercises at the beginning of a session followed by smaller muscle mass exercises, total force production for the session is maximized [84].

Two major observations can be made from previous studies that have investigated the %1RM-repetition relationship. First, as the percent of 1RM increases, the number of repetitions decreases [66-68]. Second, more repetitions can be performed using multi-joint/large muscle group exercises at a given percent of 1RM compared to single-joint/smaller muscle group exercises [66-68, 80]. This phenomenon has been attributed to a mechanism known as asynchronous recruitment, in other words at submaximal intensities, motor units take turns firing which helps to delay the onset of fatigue [66]. Therefore, at a fixed percentage of 1RM, in large muscle group, multi-
joint exercises such as leg press, more repetitions can be performed compared to an exercise such as bicep curl, a smaller muscle group, single joint exercise. The majority of studies examining the %1RM-Repetition relationship have assessed younger adults [66-68, 71, 80, 81]. Studies have sought to quantify functional task efficiency [86, 87], and maximal strength in older adults [88, 89]. However, after a thorough search of the literature, no studies were identified that directly examined the relationship between repetitions and load in single- and multi-joint muscle groups in older adults. However, two studies were identified that have examined prediction of the 1RM and the reliability of the 1RM in older adults [90, 91].

In 1999, Knutzen and colleagues [91] examined the validity of equations generated to predict 1RM using the number of repetitions individuals can perform to failure with a submaximal weight. The study was comprised of 51 subjects, all over 60 years of age. The study used 11 machine based tasks including tricep press, bench press, and supine leg press. On day one, subjects were asked to perform repetitions using a weight they could lift 7-10 times for each of the 11 machines. Using the number of repetitions (between 7-10) and the weight used, 1RM was predicted using 6 different prediction equations. Five to eight days later subjects were asked to return to perform 1RM tests on each of the tasks. Researchers found a moderate to strong relationship between predicted and actual 1RM with higher coefficients in the upper extremities (0.77-0.90) compared to the lower extremities (0.61-0.81). For comparison, Mayhew and colleagues [70] used 14 different prediction equations to predict 1RM bench press in young females. Of the equations, only 3 of them produced inter-class correlations less than .90, two of which were .87 and .89. [70]. A
comparison of the inter-class correlation coefficients between predicted and actual 1RM measures from these two studies illustrates that it is possible that a difference exists in the number of repetitions younger and older adults can perform at selected percentages of 1RM.

Phillips and colleagues assessed the reliability of maximal strength tests (1RM) in older adults and sought to determine the impact that different periods of familiarization had on 1RM measures. They recruited 47 independently living men and women with a mean age of 75 ± 4.7 years. The main outcome measure in this study was systematic and random error in 1RM measures for the bench press and leg press. In conclusion, they found that systematic error was virtually eliminated after 2-3 familiarization sessions and 2-3 1RM measures [90].

Given the increased emphasis for resistance training in older adults, an analysis of the relationship between intensity and number of repetitions in this population appears beneficial. Due to the variability that has been identified in the capacity to complete submaximal repetitions, it has been suggested that alternative methods of exercise prescription for resistance exercise be prescribed considered [66, 68]. It appears that techniques such as RM-Based resistance exercise prescription, based on a maximal resistance with which a pre-determined number of repetitions can be completed, would eliminate many of the problems seen with %1RM based exercise prescription.
PURPOSE OF THE STUDY

The purpose of this investigation was to assess the individual variability in the capacity to lift submaximal loads in younger and older men and women in both multi and single-joint tasks. We will achieve this by first determining the 1RM, and then determining the maximum number of repetitions that can be performed by both young and older adults at 60% and 80% 1RM in 3 different tasks: a multi-joint large muscle task (leg press), a single-joint large muscle task (leg extension), and a single-joint small muscle task (bicep curl).

HYPOTHESES

We hypothesize that:

1. For a given submaximal percent of 1RM, older adults will complete fewer repetitions than younger adults.

2. For a given submaximal percent of 1RM, more repetitions will be performed in large muscle group tasks (leg press, leg extension) than small muscle group task (bicep curl) [66-68].

3. For a given submaximal percent of 1RM, more repetitions will be performed in the multi-joint task (leg press) than the single-joint tasks (leg extension, bicep curl). [67, 68].

4. More repetitions will be performed on the same task for a lower intensity (60%) than for a higher intensity (80%).
METHODS

PARTICIPANTS

Participants for the study were 16 younger and 32 older adults, with an even split of men and women. The younger adults were recruited from the Wake Forest University Campus. The older adults for the study were recruited from The Healthy Exercise and Lifestyles Program run by the Department of Health and Exercise Science and from various continuing care retirement communities near the campus. Younger adults for the study were between 21-29 years of age and older adults were between 65-89 years of age. All of these participants met the following inclusion criteria: do not plan on moving out of the community for the duration of the study, willing and able to participate in all aspects of the trial, and were able to provide written consent of waiver approved by the institutional review board. Participants were excluded from the study if they met any of the following criteria: any musculoskeletal, visual, auditory, orthopedic, or neuromuscular deficit that might interfere with proper lifting technique or that might reasonably be expected to be exacerbated as a result of the study protocol, evidence of unstable angina, congestive heart failure or exercise induced complex ventricular arrhythmias. Older adults recruited outside of the Healthy Exercise and Lifestyle Program were asked to obtain written physician approval prior to participating in the study and those that were unable to do so were also excluded. In addition participants were excluded if they had a resting blood pressure greater than 160/100 mmHg, they were unable to speak or read English, or if for any reason the participant was deemed unsuitable for participation.
Measures

One repetition maximums for each of the three tasks (leg press, bicep curl, and leg extension) was determined and verified to ensure reliability, during the first two assessment sessions. During days 3 and 4 of our assessments the participant was asked to perform repetitions to failure, using either 60% or 80% of their previously determined 1RM. The number of repetitions participants were able to perform was the primary outcome of this study. Measures for each of the three tasks were done as follows:
1. Leg Press- We used the Cybex plate loaded squat press machine for this task. The participant was instructed to sit in the machine with their buttocks and back firmly against the pads, placing their feet on the platform so that their knees were bent as close to a 90 degree angle as possible (Figure 1). They were then instructed to push the platform out by straightening their legs as much as possible, without locking their knees (Figure 2). The safety stop on the leg press was not removed for safety reasons. Each time the participant was able to fully extend their legs was counted as one repetition.

Figure 1. Leg Press Start/End

Figure 2. Leg Press Midpoint
2. Bicep Curl- We used Cap Barbell’s 4 pound, 1 in diameter, standard E-Z curl bar for this task. The participant was instructed to stand up straight, keeping their backs against a wall, with the bar resting on their thighs (Figure 3). They were then instructed to concentrically contract their biceps curling the bar into their chest (Figure 4). Each time the participant was able to curl the bar through the entire range of motion, as judged by the study investigator, one repetition was counted.

Figure 3. Bicep Curl Start/End

Figure 4. Bicep Curl Midpoint
3. Leg Extension- We used the Cybex plate loaded leg extension machine for this task. The participant was instructed to sit in the machine, keeping their butt and back against the pads at all times (Figure 5). The machine was then adjusted so that the rollers were positioned at the participant’s ankles and their knees were freely hanging off the edge of the seat. They were then asked to straighten their legs as far as possible, without hyper-extending at the knee joint (Figure 6). While the participant did this, the investigator fixed an elastic cord held between two wooden poles such that when the participant was at full extension, the plate pole would graze the cord. This was done to ensure that the participant completed the entire range of motion for each repetition. Every time the participant was able to extend his or her legs such that the elastic band was touched was counted as a complete repetition.

![Figure 6. Leg Extension Start/End](image1)

![Figure 5. Leg Extension Midpoint](image2)
For each task, the investigator ensured that each repetition was done with proper form, through the full range of motion in order for it to count. For submaximal repetitions to failure, participants were encouraged to perform repetitions consecutively and no more than 3 seconds was allowed between repetitions. The velocity at which the movement was done was controlled using a metronome allowing 2 seconds for both the concentric and eccentric portions of the task. After each task the participant was asked to rate their perceived exertion (RPE) using the Borg 10-point scale.

**ASSESSMENTS**

Participants for the study completed four assessment sessions. The first two assessment sessions were used to determine the participant’s one-repetition maximum (1RM) for each of the three tasks used in the study (leg extension, bicep curl, and leg press). On the third and fourth day, participants were asked to perform repetitions to failure using 60% and 80% of their 1RM. The first testing session took approximately two hours. The remaining three sessions lasted approximately an hour and a half. Assessments were completed in Reynolds gymnasium.

**Day 1:**

All participants were met by a study investigator at Reynolds Gymnasium on Wake Forest University Reynolda Campus. Older adults recruited outside of the Healthy Exercise and Lifestyles Program were asked to bring a signed copy of the physician approval form, which was required prior to beginning any other testing procedures. Participants were initially taken to “The Six” where the study investigator issued participants the Informed Consent document. Participants were asked to carefully read over the document and to ask any questions they may have while doing so. In addition, the study investigator verbally briefed the participant on the study protocol and
procedures to ensure complete understanding. After obtaining written consent, participants were taken to the J.B. Snow Biomechanics Laboratory where the study investigator obtained height and body mass measurements. Participants were then taken back up to “The Six” where participants were asked to provide investigators with demographic and medical history information as well as complete the ACSM/AHA exercise pre-participation questionnaire. After ensuring that participants were safe to participate in the study, participant’s blood pressure was measured and recorded. Next, participants were taken through a familiarization session during which testing procedures were explained and the correct technique for each of the three tasks was demonstrated by the investigator and practiced by participants to make sure the participant was comfortable with the resistance training equipment. The instruction script to the participant and definitions of one complete repetition for each of the three tasks, leg press, bicep curl, and leg extension were as follows [92]:

Seated leg press:

**Step 1:** Starting position: Sit in the machine, with your back flat against the machine's backrest. Place your feet on the resistance plate, and adjust your seat and foot position so that the bend in your knees is at approximately 90 degrees with your heels flat. Knees are parallel and your toes are lined up with your knees. Lightly grasp the handles to either side of you to help stabilize your upper body. Do not allow movement in your low back throughout the task.

**Step 2:** Slowly exhale while pushing the resistance plate away from your body. Keep your heels flat against the resistance plate and avoid any movement in the upper body.
**Step 3:** Continue to straighten your legs until the knees are straight but not locked. The heels should still be pressed firmly into the plate. Do not round the low back, lock-out your knees or allow your bottom to lift off the seat pad.

**Step 4:** Pause briefly then slowly return to your starting position in a slow, controlled manner. Do not allow your upper thighs to compress your ribcage.

**Note:** For safety, control the extension phase by keeping your heels in contact with the plate and avoid locking out your knees. During the return phase, control the movement and avoid compressing your upper thighs against your ribcage.

**E-Z Bar Bicep Curl**

**Step 1:** Stand with feet about hip-width apart, abdominals engaged as you hold the weight in front of the thighs. Make sure to keep back against the wall at all times.

**Step 2:** Contract the biceps and bend the arms, curling the weight up towards the shoulders.

**Step 3:** Keep the elbows stationary and only bring the weight as high as you can without moving the elbows.

**Step 4:** Slowly lower the weight, keeping a slight bend in the elbows at the bottom (e.g., don't lock the joints and try to keep tension on the muscle

**Note:** While this task targets the biceps effectively, proper technique is important to prevent unnecessary stress placed in low back by swinging your torso backwards during the movement. Follow the instructions provided to avoid potential injury.
Machine Leg Extension:

**Step 1:** Adjust the machine to your body's dimensions. The rollers should be comfortably positioned at your ankles and the back should be positioned so that you are sitting upright with your knees hanging freely off the end of the seat.

**Step 2:** Sit on the machine holding the handles. Your legs will be bent with your ankles behind the rollers. Make sure your spine is in contact with the back pad.

**Step 3:** Breathe in through your nose. Exhale and straighten your knees ensuring that the plate holder touches the elastic band positioned by the study investigator to ensure full range of motion. Engage your quadriceps muscles equally by pointing your toes straight up to the ceiling. Inhale and resist the weight down to the starting position. Exhale and extend.

**Note:** Be sure not to lock your knees when you straighten them and properly coordinate your breathing with exertion. Doing so will help to avoid potential injury.

Following the explanation for each of the three tasks the participants were asked to demonstrate one complete repetition to ensure proper understanding of each of the tasks. The familiarization session and all strength assessments, both maximal and submaximal, were conducted by the same individual. All assessments were conducted at times when at least one other Health and Exercise Science master’s student or professor was near in case of emergency.
Day 1&2:

One Repetition Maximum Testing

One repetition maximum testing was executed using procedures identified as the gold standard for assessing 1RM as described by Kraemer and Fry [93]. Participants were instructed to do a warm-up set using a light weight (roughly 50% estimated 1RM) of 8-10 repetitions. Subjects were then asked to perform a second warm-up set of 3-5 repetitions using a moderate weight (estimated 75% 1RM). A final warm-up set of 2-3 repetitions using a heavier weight was then completed. On Day 1 of 1RM testing, warm-up loads were established by the study investigator, a trained exercise physiologist, taking into account participant height, weight, age, and familiarity with resistance training. Participants were asked to report their rating of perceived exertion (RPE) following each of the three warm-up sets so the investigator could gage participant effort and make alterations to the loads since these initial loads were best estimates. Participants had 90 seconds of rest between warm-up sets.

After completion of the warm-up session, participants were tested for 1RM strength by increasing the load until the subject was unable to fully execute one complete repetition. Each 1RM attempt was separated by 3-5 minutes of rest. 1RM testing was conducted for each of the three tasks on the same day with a 20 minute break between tasks. The task order separated the leg press and the leg extension with the bicep curl. The order of the leg press and leg extension that flanked the bicep curl task was randomized. Following each task session the investigator lead the participant through a series of stretches to cool-down to minimize the chance of an adverse event.
The participant was asked to return for another series of 1RM testing no sooner than 48 hours later to determine the reliability of initial 1RM assessments (Day 2). In the event that the participant became too fatigued to continue the assessment protocol, testing was stopped, and the participant was rescheduled to return and complete the testing on another day, at least 48 hours after the session.

After completion of the maximal strength assessments the study investigator re-measured the participants’ blood pressure and the participant was not permitted to leave until the blood pressure returned to +/- 20 mmHg resting measure (baseline).

**Day 3&4:**

*Submaximal Testing*

The submaximal sessions involved performing each of the 3 tasks, spacing the upper body task between the lower body tasks as was done in the 1RM tests. Half of the participants were asked to do 60% 1RM for all 3 tasks on the first day of submaximal testing and then do 80% 1RM on the second day, the other half did 80% and then 60%.

Resting blood pressure of participants was measured prior to beginning every session to ensure the participant was safe to complete the assessment. Following blood pressure measurements, participants were asked to perform a 5 minute unloaded warm-up on a Monark Ergomedic 8-18 E exercise bicycle followed by a light warm-up set of 5 repetitions using 50% of their 1RM for each task. Ninety seconds after the completion of the warm-up, participants were asked to perform repetitions to failure using either 60% or 80% of their 1RM for each of the three tasks. As was done with the 1RM assessments, 20 minutes of rest was given in-between tasks in a session and there was at least 48 hours between testing sessions. Following each assessment session, the study investigator lead
the participant through a series of stretches to cool-down and to minimize the chance of an adverse event. In the event that the participant became too fatigued to continue the assessment protocol, testing was stopped, and the participant was rescheduled to return and complete the testing on another day, at least 48 hours after the session.

Verbal encouragement was standardized and provided during all testing sessions in order to ensure equal and adequate motivation and effort [94, 95]. The following script was used for all participants:

Submaximal Testing Script

Begin first task: “There you go, keep up the good work.”

After beginning first task: “Fantastic work, let’s give you 20 minutes to rest before we start the next task.”

Begin second task: “Great job _________ (Participant name), you did a really good job with the _________(last task). Let’s see how many repetitions you can do on the bicep curl.

Middle of second task: “Looking strong, way to go!”

End second task: “Wow, well done, just one more task to go! Let’s give you another 20 minutes to let those muscles recover.”

Begin last task: “Alright last one, let’s see what you can do!”

After beginning last task: “Keep it up, you got it!”

End last task: “Good job, thank you very much for volunteering to help me with this today!”
Sample of participant assessment schedule:

An example of the 4 testing sessions for a subject randomized to the leg press, bicep curl, and leg extension order would be:

Day 1: Consent, Collect anthropometric data, Collect demographic and medical history data, Familiarization Session, 1RM Testing (leg press, bicep curl, and leg extension)

Day 2: Repeat 1RM Testing (leg press, bicep curl, and leg extension)

Day 3: 80% Leg Press, 80% Bicep Curl, 80% Leg Extension

Day 4: 60% Leg Press, 60% Bicep Curl, 60% Leg Extension

Following the submaximal strength assessments the investigator re-measured the participants blood pressure and the participant was not permitted to leave until their blood pressure returned to baseline (+/- 20 mmHg resting measure).

Statistical Analyses

Statistical analyses of demographic data were performed using SPSS, Version 19. Statistical significance for the study was set at $p < 0.05$ level. Statistical analyses of 1RM and repetition data were performed by PhD Michael Miller.

Descriptive Statistics

Descriptive statistics of baseline data included means and standard deviations of age, height, body mass, and blood pressure response.

1RM Data

Mixed effects analyses of variance using restricted maximum likelihood estimation were used to analyze 1RM task outcome data (LP, LE and BC) within sex. Each model contained a main effect for day (day 1 or day 2), age group (young adults or
old adults), and a day by sex interaction. The covariance structure for the repeated measures allowed for separate estimates of the between and within person variability (variance components) for each age group. Contrasts were used to test for equality of means between days and young versus old for day 2. Models assuming common variance components (e.g. the same between person variance component for each age) subsequently were fitted and likelihood ratio tests were used to test for equality of variances. We note that due to the small sample sizes within sex (N=8 for young adults; N=16 for older adults), these tests have limited power to detect small differences.

*Repetition Data*

Analysis of the number of repetitions performed at 60% and 80% of 1RM for each task was performed separately for each task and within sex/age groups. Paired t-tests were performed to assess equality of the mean number of repetitions at 60% versus 80% of 1RM. Pitman’s test for equality of variances in dependent samples [96] was used to test for equality of variances at 60% versus 80% of 1RM within sex/age group; whereas, an F-test for equality of variances was used to test for variance equality between young and old adults at 60% and 80% of 1RM, within sex.

A mixed models two-way analysis of variance (ANOVA) was used to compare the mean number of repetitions completed by task and age by sex. In the case that no significant interaction of age and task was identified, the interaction term was dropped from the model, and a test of main effects was run to identify any potential effect of either age or task on the number of repetitions completed. In the case that a significant (p<0.05) task by age interaction was observed, multiple pairwise comparisons were used
to compare the mean number of repetitions between groups defined by the cross-classification of age and task.
RESULTS

Demographics

A total of 48 individuals completed the study, 16 younger and 32 older adults, with an even distribution of males to females. Descriptive statistics of demographic data are presented in Table 1.

Age

Younger adults completing the study were between 19-26 years of age (22.8±1.8 yrs). Fourteen of the younger participants were white, one was black, and one was Asian. All of the younger adults had either completed an undergraduate degree in college, or were in the process of completing one, and 7 of them were working on a post-graduate degree. Average height of the younger adults was 175.0±10.5 cm with a range of 152-194 cm. Average body mass of the younger adults was 71.6±13.6 kg, ranging between 46.5-93 kg. Eleven of the 16 younger adults reported having resistance training experience. Ten of the young adults reported participating in resistance training activity once a week or more, with sessions lasting between 20-60 minutes. Half of the younger adults had previously performed one-repetition maximum testing.

Older adults completing the study were between 66-87 years of age (74.3±5.4 yrs). All of the older participants were white. All but 4 of the older adults had completed an undergraduate degree, and 13 of them had completed some form of post-graduate education. Older adults had an average height of 168.6±8.3 cm with a range of 152-191 cm. Mean body mass for this population was 78.9±13.5 kg, ranging from 50-101 kg. Twenty-seven of the 32 older adults reported having some resistance training experience.
Twenty-five of the older adults reported participating in resistance training with sessions between 15-30 minutes in length. Only 4 of the older adults had ever done 1RM testing.

Independent samples t-tests were performed to check for baseline differences between younger and older adults. Significant differences between groups were found for 1RM experience, with a greater percentage of younger adults having participated in 1RM testing (p=0.015). Younger adults were also taller (p=0.042). No differences were found for body mass (p=0.087) or training experience (p=0.475).

Sex

Male subjects were significantly (p<0.001) taller and had more body mass (p<0.001) than female subjects. No difference was reported in training experience (p=1.00) or 1RM experience (p=0.515) between men and women.

Safety and Acceptability of Protocol

Of the 50 participants who began the study, two were not able to complete all four assessment sessions for personal reasons that were unrelated to the study protocol. Assessment sessions varied in length, with one-repetition maximum sessions (day 1 & day 2) lasting between 105-150 minutes and sessions of submaximal repetitions to failure (day 3 & 4) lasting between 60-90 minutes. Participant feedback was positive, and many of the older adults reported that the sessions were enjoyable and expressed a desire to continue with resistance training at the Healthy Exercise and Lifestyle Program. There were no reports of discomfort or injury induced by the study protocol. No adverse events occurred during any of the 192 assessment sessions.
Blood Pressure

Subject’s blood pressure measurements for visit 3 are shown in Table 3. No difference in blood pressure was observed between younger and older adults. In older adults, a significant decrease in diastolic blood pressure was observed after completing the assessment session (p=0.006). No difference between systolic or diastolic blood pressure (pre vs. post) was observed in younger adults. No difference was observed in blood pressure between men and women during Visit 3. In males, no difference was observed between systolic or diastolic blood pressure pre- vs. post-testing (p=0.908 and 0.058 respectively). In females, no difference was observed in systolic blood pressure pre- vs. post testing (p=0.645), however a significant decrease in diastolic blood pressure was observed after completing the assessment (p=0.038).

1RM TESTING

Reliability of 1RM Testing

A reliability analysis of 1RM testing in both younger and older adults is presented in Tables 4 and 5. Intraclass correlation coefficients for 1RM testing were 0.970, 0.970, and 0.930 in younger women and 0.990, 0.940, and 0.980 in younger men on the leg press, leg, extension, and bicep curl respectively. Reliability tests in older adults were similar, with values of 0.990, 0.910, and 0.900 in older women and 0.980, 0.980, and 0.960 in older men.

Comparing Day 1 to Day 2

An analysis of variance (ANOVA) between day one and day two of 1RM testing is presented in Tables 4 and 5. In all four groups, there was a significant increase (p<0.05) in 1RM measures on the second day of testing for each exercise, except in younger men on day 2 on the bicep curl (p=0.053).
Muscular Strength and Age

A comparison of 1RM’s of younger and older women and younger and older men is presented in Tables 4 and 5. For each of the three exercises, younger women lifted significantly more weight on day 2 of 1RM testing than older women (p<0.01). Table 5 shows younger men were able to lift a significantly greater amount of weight on day 2 of 1RM testing than older men (p<0.001).

Inspection of Tables 4 and 5 show that the between person variance appears to be larger for the leg press compared to either the leg extension or bicep curl in both younger and older men and women. The within person variance also appears to be greater for the leg press compared to the other two tasks in younger and older women and older men.

Analysis of Repetition Data

Variability in Number of Repetitions to Failure

Side-by-side frequency histograms are presented in Figures 7-12, demonstrating the variability in the number of repetitions participants were able to perform at the two task intensities in each of the three tasks. In addition, Tables 6 and 7 show the mean number of repetitions and 95% CI for younger and older men and women on each task. At both 60% and 80% 1RM, there was a large range in the number of repetitions that participants were able to perform.

At 60% 1RM on the leg press the number of repetitions ranged from 10 to 70 with a mode of 19 repetitions. In the bicep curl at 60% 1RM, the mode was 14 repetitions. In the bicep curl, there was a wide range in number of repetitions; one individual was only able to perform 6, while another was able to do 100. Leg Extension at 60% 1RM yielded
a range much smaller than the other two tasks (6-23 repetitions). In the leg extension, the mode was 11 repetitions.

Using 80% 1RM in the leg press the mode was 10 repetitions with a range of 2-38 repetitions. In the bicep curl at 80% 1RM the mode was 7 repetitions with a range of 1-18 repetitions. Finally, in the leg extension at 80% 1RM, the mode was 9 repetitions with a range from 3-16.

Repetitions at 60% vs. 80% 1RM

A paired T-Test of equal means (Tables 6 and 7) was used to compare the number of repetitions completed at 60% vs. 80% 1RM in younger and older men and women. Younger and older men and women completed significantly more repetitions at 60% 1RM than at 80% 1RM on each of the three tasks (p<0.05).

A test of equal variances (Tables 6 and 7) was used to compare the variance observed at 60% vs. 80% 1RM for each of the three tasks in younger and older men and women. In younger women, no significant difference in variance was observed at 60% vs. 80% 1RM in any of the three tasks. In older women, greater variance was observed at 60% 1RM than 80% 1RM on the leg press and the bicep curl (p<0.001). In younger men, a significant difference in variance was found between 60% and 80% 1RM in each of the three tasks (p<0.05). Finally, in older men, the only significant difference in variance was observed on the leg press (p<0.05)

Age and Variability in Number of Repetitions

Tests of equal variance between young and older adults were done in both men and women (Tables 6 and 7) to check for differences in variability between age groups. At 60% 1RM on the bicep curl, greater variability was observed in older women than
younger women (p<0.001). However, once the outlier was removed (an older woman who completed 100 repetitions at 60% 1RM), no significant difference in variability between the groups was observed (p=0.120). When comparing the variability at 60% and 80% 1RM in younger and older women on the leg press and leg extension no significant differences were found (Table 6).

A comparison of the variability in the number of repetitions completed by younger and older men at 60% and 80% 1RM (Table 7) showed no differences on the leg extension or the bicep curl. However, on the leg press, more variability was observed in the number of repetitions completed by younger adults at both 60% (p=0.016) and 80% 1RM (p=0.007).

Task and the Number of Repetitions

A mixed models analysis of variance (ANOVA), Table 8, was used to determine the effect of task on the number of repetitions that younger and older men and women were able to complete at 60 and 80% 1RM. At 60% 1RM, task had a significant effect on the number of repetitions completed by both men (p=0.003) and women (p=0.001). At 60% 1RM, a greater number of repetitions were completed by men and women on the leg press compared to the bicep curl (p=0.0060 and p=0.0001) or leg extension (p=0.0010 and 0.0048). At 60% 1RM, women completed a greater number of repetitions on the bicep curl than the leg extension (p=0.0108), but no difference was observed in the number of repetitions completed by men on bicep curl and leg extension (p=0.2620).

At 80% 1RM in women, task was also found to significantly impact the number of repetitions that women were able to complete (p=0.0017). Women completed a greater number of repetitions at 80% 1RM on the leg press than the bicep curl (p=0.0006) or the
leg extension (p=0.0010). At 80% 1RM in men a significant interaction of age and task on the number of repetitions that participants could complete was identified. T-tests comparing the number of repetitions by task at 80% 1RM (Table 7) demonstrated that younger men were able to complete a greater number of repetitions on the leg press than either the bicep curl (p=0.0002) or the leg extension (p=0.0005). In older men at 80% 1RM, significantly more repetitions were completed on the leg extension (p=0.0124) and leg press (p=0.0374) compared to the bicep curl.

Age and the Number of Repetitions

At 60% 1RM, no effect of age on the number of repetitions that men and women were able to complete was observed. Similarly, at 80% 1RM in women, age had no effect on the number of repetitions completed. At 80% 1RM a mixed models ANOVA (Table 8) demonstrated a significant interaction between task and age on the number of repetitions that men were able to complete. Although no difference for age was observed at 80% 1RM on the leg extension or bicep curl, younger men completed a greater number of repetitions on the leg press compared to older men (p=0.0258).
Table 2. Demographic Data

<table>
<thead>
<tr>
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<th>Younger Adults, n=16</th>
<th>Older Adults, n=32</th>
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<tr>
<td></td>
<td>Mean±SD</td>
<td>Range</td>
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</tr>
<tr>
<td>Height (cm)</td>
<td>175.0±10.5</td>
<td>152-194</td>
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<td>Body Mass (kg)</td>
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Table 3. Blood Pressure Measurements Visit 3

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<th>Blood Pressure</th>
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<th>Older Adults</th>
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<td>121.44±12.4</td>
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<tr>
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<td>119.94±13.3</td>
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<tr>
<td>Diastolic Post</td>
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*Indicates p<0.05 vs. corresponding value for pre-assessment BP
Table 4. Analysis of Women's 1RM Data

<table>
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<tr>
<th>Task</th>
<th>Young Adults (N=8)</th>
<th>Older Adults (N=16)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
<td>Day 2</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td></td>
<td>95% C.I.</td>
<td>95% C.I.</td>
</tr>
<tr>
<td>Leg Press (kg)</td>
<td>244.7 (83.86)</td>
<td>262.2(1) (76.62)</td>
</tr>
<tr>
<td></td>
<td>(183.2 to 306.1)</td>
<td>(206.1 to 318.4)(2)</td>
</tr>
<tr>
<td>Leg Extension (kg)</td>
<td>57.0 (14.16)</td>
<td>59.5(1) (15.32)</td>
</tr>
<tr>
<td></td>
<td>(46.6 to 67.4)</td>
<td>(48.3 to 70.8)(2)</td>
</tr>
<tr>
<td>Bicep Curl (kg)</td>
<td>19.1 (4.53)</td>
<td>20.5(1) (4.33)</td>
</tr>
<tr>
<td></td>
<td>(15.9 to 22.4)</td>
<td>(17.4 to 23.7)(2)</td>
</tr>
</tbody>
</table>

(1) indicates significant difference compared to Day 1 1RM measure (p<0.05)
(2) indicates significant difference compared to corresponding Day 2 1RM measure for older women (p<0.01)
Table 5. Analysis of Men’s 1RM Data

<table>
<thead>
<tr>
<th>Task</th>
<th>Young Adults (N=8)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1 Mean (SD)</td>
<td>Day 2 Mean (SD)</td>
<td>Between Person Variance</td>
<td>Within Person Variance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>95% C.I.</td>
<td>95% C.I.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Press (kg)</td>
<td>347.3 (80.39)</td>
<td>358.1(1) (85.71) (2)</td>
<td>6872 (ICC=0.99)</td>
<td>32.15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(288.3 to 406.2)</td>
<td>(295.2 to 420.9)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Extension (kg)</td>
<td>101.5 (27.24)</td>
<td>110.0(1) (24.22) (2)</td>
<td>625.3 (ICC=0.94)</td>
<td>38.76</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(81.5 to 121.5)</td>
<td>(92.2 to 127.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicep Curl (kg)</td>
<td>40.4 (6.06)</td>
<td>41.2 (5.28) (2)</td>
<td>31.60 (ICC=0.98)</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(35.9 to 44.8)</td>
<td>(37.4 to 45.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task</th>
<th>Older Adults (N=16)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1 Mean (SD)</td>
<td>Day 2 Mean (SD)</td>
<td>Between Person Variance</td>
<td>Within Person Variance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>95% C.I.</td>
<td>95% C.I.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Press (kg)</td>
<td>167.5 (69.59)</td>
<td>176.8(1) (70.75) (2)</td>
<td>4858 (ICC= 0.98)</td>
<td>79.37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(131.5 to 203.6)</td>
<td>(140.1 to 213.4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Extension (kg)</td>
<td>61.2 (14.77)</td>
<td>63.5(1) (13.28) (2)</td>
<td>193.7 (ICC= 0.98)</td>
<td>3.43</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(53.6 to 68.9)</td>
<td>(56.6 to 70.4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicep Curl (kg)</td>
<td>25.1 (5.14)</td>
<td>26.1(1) (5.15) (2)</td>
<td>25.46 (ICC= 0.96)</td>
<td>1.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(22.4 to 27.7)</td>
<td>(23.4 to 28.7)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) indicates significant difference compared to Day 1 measure (p<0.05)
(2) indicates significant difference compared to corresponding Day 2 1RM measure for older men (p<0.01)
Figure 7. Variability in Leg Extension at 60% 1RM

Figure 8. Variability in Bicep Curl at 60% 1RM

Figure 9. Variability in Leg Press at 60% 1RM
Figure 10. Leg Extension Variability at 80% 1RM

Figure 11. Bicep Curl Variability at 80% 1RM

Figure 12. Leg Press Variability at 80% 1RM
Table 6. Analysis of Women’s 60% and 80% 1RM Data

<table>
<thead>
<tr>
<th>Task</th>
<th>Young Adults (N=8)</th>
<th>Older Adults (N=16)</th>
<th>p-value For Paired T-Test of Equal Means</th>
<th>p-value For Test of Equal Variances(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60% 1RM Mean (SD)</td>
<td>80% 1RM Mean (SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>95% C.I.</td>
<td>95% C.I.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Press (kg)</td>
<td>28.8 (9.21)</td>
<td>17.0 (6.57)</td>
<td>&lt;0.001</td>
<td>0.165</td>
</tr>
<tr>
<td></td>
<td>(22.0 to 35.5)</td>
<td>(12.2 to 21.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Extension (kg)</td>
<td>11.4 (2.33)</td>
<td>8.8 (1.98)</td>
<td>&lt;0.001</td>
<td>0.508</td>
</tr>
<tr>
<td></td>
<td>(9.7 to 13.1)</td>
<td>(7.3 to 10.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicep Curl (kg)</td>
<td>13.0 (4.34)(2)</td>
<td>6.5 (3.16)</td>
<td>&lt;0.001</td>
<td>0.313</td>
</tr>
<tr>
<td></td>
<td>(9.8 to 16.2)</td>
<td>(4.2 to 8.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Press (kg)</td>
<td>23.3 (16.37)</td>
<td>12.8 (7.83)</td>
<td>0.002</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>(14.8 to 31.7)</td>
<td>(8.7 to 16.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Extension (kg)</td>
<td>11.1 (4.15)</td>
<td>7.9 (3.40)</td>
<td>&lt;0.001</td>
<td>0.296</td>
</tr>
<tr>
<td></td>
<td>(9.0 to 13.3)</td>
<td>(6.1 to 9.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicep Curl (kg)</td>
<td>21.3 (22.32)</td>
<td>8.9 (4.33)</td>
<td>0.023</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>(9.7 to 32.9)</td>
<td>(6.7 to 11.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicep Curl (Remove outlier with 100 reps)</td>
<td>16.1 (7.87)</td>
<td>8.9 (4.33)</td>
<td>&lt;0.001</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>(12.4 to 21.4)</td>
<td>(6.7 to 11.2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Pittman’s test for equality of variances in dependent samples
(2) Indicates significant difference compared to corresponding variance in older women (p<0.001)
Table 7. Analysis of Men’s 60% and 80% 1RM Data

<table>
<thead>
<tr>
<th>Task</th>
<th>Young Adults (N=8)</th>
<th>Older Adults (N=16)</th>
<th>p-value For Paired T-Test of Equal Means</th>
<th>p-value For Test of Equal Variances(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1RM=60 Mean (SD) 95% C.I.</td>
<td>1RM=80 Mean (SD) 95% C.I.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg Press (kg)</td>
<td>26.3 (18.20)(2) (12.9 to 39.6)</td>
<td>14.9(3)(8.37)(2) (8.7 to 21.0)</td>
<td>0.018</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Leg Extension (kg)</td>
<td>13.9 (4.36) (10.7 to 17.1)</td>
<td>7.3 (1.98) (5.8 to 8.7)</td>
<td>0.001</td>
<td>0.037</td>
</tr>
<tr>
<td>Bicep Curl (kg)(1)</td>
<td>12.9 (3.98) (10.0 to 15.8)</td>
<td>6.1 (1.55) (5.0 to 7.3)</td>
<td>0.001</td>
<td>0.024</td>
</tr>
<tr>
<td>Leg Press (kg)</td>
<td>19.3 (8.69) (14.7 to 23.8)</td>
<td>9.1(3)(3.68) (7.2 to 11.0)</td>
<td>&lt;0.001</td>
<td>0.003</td>
</tr>
<tr>
<td>Leg Extension (kg)</td>
<td>11.8 (3.07) (10.2 to 13.3)</td>
<td>8.6(4) (2.66) (7.2 to 9.9)</td>
<td>&lt;0.001</td>
<td>0.531</td>
</tr>
<tr>
<td>Bicep Curl (kg)(1)</td>
<td>14.3 (4.78) (11.8 to 16.8)</td>
<td>6.1 (2.98) (4.5 to 7.6)</td>
<td>&lt;0.001</td>
<td>0.084</td>
</tr>
</tbody>
</table>

(1)Pittman’s test for equality of variances in dependent samples
(2)indicates significant difference compared to corresponding variance in older men (p<0.05)
(3)indicates significant difference compared to corresponding value in younger men on bicep curl (p=0.0002) and leg extension (p=0.0005)
(4)indicates significant difference compared to corresponding value in older men on bicep curl (p=0.0124)
(5)indicates significant difference compared to corresponding value in older men on bicep curl (p=0.0374)
(6)indicates significant difference compared to corresponding value in older men (p=0.0258)
Table 8. Mixed Models ANOVA for Repetitions
(unstructured covariance because of large heterogeneity of variance across tasks)

<table>
<thead>
<tr>
<th>Test of task by age interaction</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>P=0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P=0.30*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Effect for Task*</td>
<td>P=0.001*(2)</td>
<td>P=0.0017(2)</td>
</tr>
<tr>
<td>Main Effect for Age*</td>
<td>P=0.83*</td>
<td>P=0.7303</td>
</tr>
<tr>
<td>Compare LP to BC</td>
<td>P=0.0001*(3)</td>
<td>P=0.0006(3)</td>
</tr>
<tr>
<td>Compare LP to LE</td>
<td>P=0.0048(3)</td>
<td>P=0.0010(3)</td>
</tr>
<tr>
<td>Compare BC to LE</td>
<td>P=0.0108*(3)</td>
<td>P=0.97</td>
</tr>
</tbody>
</table>

* remove bicep curl outlier
(1) Indicates significant task by age interaction
(2) Test of simple main effects for task demonstrate significant effect of task
(3) Indicates significant difference in number of repetitions completed between tasks
**DISCUSSION**

The number of older adults in America is rapidly increasing. By the year 2050, 90 million Americans are expected to be 65 years of age or older [1]. Unfortunately, frequently seen with old age is a decline in muscle mass, affecting our ability to remain healthy and function independently [30]. The decline in muscle mass with age, commonly known as sarcopenia, is partly a product of muscle atrophy [31]. In order to attenuate age-associated muscle wasting, older adults are encouraged to participate in regular physical activity [18]. Resistance training activity in particular, has been shown to promote increases in muscular strength and improvements in physical function in older adults [29, 47].

Resistance training prescription is frequently based on a percentage of an individual’s 1RM. Past research has focused on determining the number of repetitions younger adults can perform at selected percentages of 1RM, however, a thorough search of the literature identified no such studies in older adults. Therefore, the primary purpose of this study was to investigate the variability in the capacity to lift submaximal loads in older adults and compare that to the variability observed in younger adults.

**PARTICIPANTS**

Fourteen of the 16 younger adult participants were white. The majority of our younger adults were currently working on graduate degrees at Wake Forest. All of our older adult participants were white and had completed an undergraduate degree. Also, approximately 85% of the older adults in our study reported resistance training experience. Previous research has produced mixed findings related to the impact of training status on the number of repetitions participants could perform [66, 68, 76, 77].
Different tasks and intensities used by various studies serve as a possible explanation for this lack of consensus. The habitual training program followed by participants is yet another factor that could possibly modify the impact of training status. A limitation of our analysis was unequal recruitment of trained and untrained participants (only 10 of our 48 participants were untrained). Therefore, we do not have sufficient sample size to determine the effect of training status in our study.

**RELIABILITY OF 1RM TESTING**

In order for our study to successfully examine variability in the number of repetitions participants could complete at selected percentages of 1RM, it is critical that our 1RM measures were reliable. The interclass correlation coefficients for 1RM testing in Tables 4 and 5 show extremely high reliability of our 1RM measures. Phillips et al. [90] examined the reliability of 1RM testing in younger adults and the impact of differing periods of familiarization on the reliability of 1RM measures. It was shown that by providing participants with 3 familiarization sessions and 2-3 1RM testing sessions, systematic error was virtually eliminated in men (0.7%, p<0.05, CI- 2.7-4.3%) and women (3.6%, CI-0.8-6.6). Our results suggest that a single familiarization session followed by two days of 1RM testing was ample to produce reliable testing of maximal strength in both younger and older men and women.

**VARIABILITY IN NUMBER OF REPETITIONS TO FAILURE**

We observed a large range in the number of repetitions that both younger and older men and women were able to perform for a given task at a given percentage of 1RM. Variability in the number of repetitions participants were able to complete could be due to a number of individual differences such as effort provided by the participant,
familiarity with resistance training, sex, age, muscle fiber type, or capillary density [66, 68, 80, 97].

While it seems obvious that participants who don’t give a full effort during submaximal testing will not perform as many repetitions as those who do, familiarity with resistance training has also been shown to influence the %1RM-Repetition relationship. Hoeger and colleagues showed that untrained participants could perform a greater number of repetitions at a selected percentage of 1RM while Pick and Becque found the opposite [68, 77]. Unfortunately, due to the homogenous nature of our sample, we were not able to examine the effect of resistance training experience on the number of repetitions that our participants were able to complete.

Sex is another factor that has been investigated as a potential moderator of the %1RM-Relationship. In particular, Hoeger and colleagues found sex to have a significant influence on the number of repetitions males and females could perform in seven different tasks at selected percentages of 1RM. Such differences are potentially explained by differences in muscle fiber type distribution between males and females [98, 99]. For example, a female with more slow-twitch Type I muscle fibers would possess greater capillary density to provide the working muscles with more oxygen, theoretically, allowing them to sustain a sub-maximal contraction for a longer period of time, thereby, performing a greater number of repetitions [97, 100-102]. Lastly, it has been shown that differences in capillary density can have an impact on the number of submaximal repetitions an individual can perform [97, 102]. Regardless of the reason for these differences, there was significant variability in the number of repetitions participants
were able to perform for a task at a given intensity, and an even larger variability across
tasks at a given percent of 1RM.

**COMPARING REPETITIONS TO FAILURE**

*Task Intensity*

For each of the three tasks, a greater number of repetitions was performed at 60% 1RM than at 80% (p<0.05). This is consistent with several other studies reporting that an individual will perform a greater number of repetitions at lower intensities than at higher ones [66-68]. By increasing load, there is an increased demand on muscle to lift the load and consequently the muscle will more quickly deplete its creatine phosphate and adenosine triphosphate (ATP) energy stores [103]. This will result in the muscle fatiguing more quickly, and a subsequent decrease in the number of repetitions with the heavier load.

*Age, Sex, and Task at 60% & 80 % of 1RM*

We observed no effect of age on the number of repetitions at 60% 1RM. This finding suggests that there is little to no difference in the relationship between muscular strength and muscular endurance between younger and older adults at a low to moderate intensity (60% 1RM). Previous research investigating the effects of aging on muscle morphology has demonstrated that while both Type I and Type II fibers decrease at an equal rate in number with age, Type II fibers, responsible for muscular strength, are likely to undergo selective atrophy while Type I fibers responsible for muscular endurance, typically do not [104-107]. It is possible that the reason no difference was found for age on the number of repetitions at 60% 1RM is at least, in part, due to the integrity of Type I fibers with age.
It is also possible that motivation and effort had an effect on the number of repetitions participants were able to perform at 60% and 80% 1RM. While half of the younger adults had previous 1RM testing experience, only 4 of the 32 older adults were familiar with 1RM testing. It is possible that the older adults did not feel as comfortable with providing maximal effort for the 1RM sessions as younger adults and consequently, the individuals who did not provide full effort for the 1RM sessions were lifting with less than their true 60% and 80% 1RM for the submaximal repetitions to failure. As a consequence, these individuals may have completed more repetitions.

At 60% 1RM, task was found to have a significant effect on the number of repetitions completed by men (p=0.003) and women (p=0.001). The strong relationship found at 60% 1RM between task and number of repetitions completed is likely the result of two factors; nature of the task (single vs. multi-joint) and differences in muscle mass required to perform different tasks [66-68, 80]. Previous studies have produced similar findings in that participants were able to perform a greater number of repetitions for multi-joint tasks utilizing larger amounts of muscle tissue, such as the leg press, than for single-joint tasks requiring smaller amounts of muscle tissue [66-68, 80]. It has been proposed that the reason for such findings could potentially be attributed to asynchronous recruitment [66, 108], the alternating contraction of motor units that enables a muscle to sustain a submaximal contraction for a longer period of time. Therefore, in submaximal intensity multi-joint tasks utilizing large amounts of muscle tissue such as the leg press, while some of the muscle is firing, the remainder can recover. At the same intensity in single-joint smaller muscle tissue tasks such as the bicep curl however, a smaller portion
of the muscle is able to relax with each contraction, and therefore in these single-joint smaller muscle mass tasks individual will perform fewer repetitions.

At 80% 1RM no difference between the number of repetitions completed by younger and older men and women was observed, except for 80% 1RM on the leg press (p=0.0258). No difference was found at 80% 1RM between the number of repetitions completed on the leg press in younger and older women, or the number of repetitions younger and older men and women were able to complete on the bicep curl or leg extension. The difference between younger and older men on the leg press at 80% could be attributed to selective atrophy of Type II muscle fibers commonly seen with age [106, 107]. A number of studies have shown a direct correlation between Type II muscle fiber atrophy and declines in muscular strength in older adults [38, 107, 109]. Because an increase in load demands activation of Type II muscle fibers [110], it is not surprising that at 80% 1RM in the leg press younger men were able to perform more repetitions. This explanation however does not fit with our findings that there was no difference between the number of repetitions younger and older men were able to perform on the leg extension or bicep curl. It is possible that this is due to differences in muscles being recruited by the different tasks. In a study done in 2000 by Yamada and colleagues comparing surface EMG activity between younger and older adults, it was shown that the older adults appeared to have adapted a motor strategy to help cope with age-related neuromuscular deteriorations. This, enabled them to fatigue at a slower rate than younger adults with contractions of the same relative intensity [111]. Potentially, the primary muscles being utilized by the single-joint tasks of the bicep curl and the leg extension (bicep and quadriceps), were able to delay fatigue by utilizing this motor strategy and
subsequently, there was no difference observed in the number of repetitions older and younger adults were able to perform on these two tasks. Conversely, in the leg press, a multi-joint task utilizing a greater number of muscles, it is possible that older adults were not able to employ this adaptive motor strategy.

As analysis of the effect of task on the number of repetitions at 80% 1RM, demonstrated that women were able to complete a greater number of repetitions on the leg press than the bicep curl (p=0.0001) or leg extension (p=0.0048) but no difference was found between leg extension and bicep curl. Similarly, in younger men at 80% 1RM, a greater number of repetitions was completed on the leg press than the bicep curl (p=0.0002) or the leg extension (p=0.0005). In older men however no difference was found between the number of repetitions completed on the leg press and leg extension (p=0.7007). Findings at 80% 1RM are consistent with findings at 60% 1RM in that at both loads, task was found to have a significant effect on the number of repetitions. As with 60% 1RM, this is likely due to the advantage gained by multi-joint large muscle mass tasks which are better able to utilize asynchronous recruitment of muscle fibers than single-joint smaller muscle tissue tasks. Unlike at 60% 1RM however, at 80% 1RM, older men were not able to perform a significantly greater number of repetitions on the leg press than the leg extension. The inability of older adults to perform a greater number of repetitions on the leg press than the leg extension at 80% 1RM is potentially explained by the increase in percent of 1RM. With an increase in percent of 1RM, fewer motor units are able to relax per repetition, dampening the effect of asynchronous recruitment.
**Practical Applications**

Results from this study indicate there is no clear-cut number of repetitions associated with a given percent of 1RM. For example, at 80% 1RM participants in our study we observed that participants were able to perform between 1-38 repetitions. The table published by the NSCA states that at 80% 1RM the number of repetitions allowed is 8 [64]. Should a personal trainer or other exercise professional prescribe clients 8 repetitions at 80% 1RM to work on muscular strength in accordance with the chart, there would be some drastic discrepancies in difficulty with performing the task. While some individuals would find the prescribed number of repetitions far too easy, others would find it impossible. Therefore, if task prescription is to be based on a percent of 1RM, attention must be paid to account for individual variability. Consideration should also be given to the task being prescribed, as it appears that the nature of the task (single vs. multi-joint) and the amount of muscle mass involved will impact the number of repetitions people will be able to perform at a given percentage of 1RM.

**Safety**

None of our participants reported complications resulting from the study protocol and no adverse events occurred during any of the assessment sessions. Two participants dropped out of the study after visit one, one younger adult and one older adult, neither one of which did so for reasons related to the study. The younger participant dropped out due to a prior medical condition, and the older participant dropped out due to transportation issues. Both of the participants who left the study were replaced in order to maintain a balance in the number of male and female participants.
A number of the older adults reported anxiety before beginning the study, primarily due to fear of aggravating chronic lower back pain or knee replacements. After familiarization, test anxiety diminished and a number of the participants reported they felt as if the tasks were helping them. By the third and fourth visit, many of the participants were eager to begin the assessment sessions, and reported enjoying the sessions. Given that the testing protocol resulted in no complications or adverse events in any of the 48 participants completing the study, it appears as though both 1RM and repetition based maximal resistance testing is a safe and effective way to evaluate muscular strength and endurance in older adults.

**LIMITATIONS**

The results from this study should be interpreted in the context of their limitations. First, our sample was of modest size (48 participants) and the vast majority of our sample consisted of well-educated whites, most of which reported prior participation in a resistance training program. The homogeneous nature of our sample limits the generalizability of our results. Therefore, future investigations should seek to include minorities and less active individuals in order to increase the generalizability of findings. Second, although the gold-standard for determining 1RM established by Kraemer and Fry [93] was used, the initial warm-up load for participants was determined subjectively. Loads for subsequent warm-up sets were established with ratings of perceived exertion using the Borg 10-point scale. It is possible that an improper initial warm-up load might have decreased accuracy of 1RM measures on day one. To control for this, on the second day of 1RM testing warm-up loads were established objectively, using percentages of 1RM measures from day one. An additional potential limitation of our 1RM testing was
that we only provided participants with one familiarization session and two 1RM testing
sessions while a study on reliability of 1RM measures in older adults by Phillips and
colleagues [90] produced findings that recommended 3 familiarization sessions and 2-3
1RM testing sessions. Another limitation was our inability to control for knee and hip
angle on the plate-loaded leg press machine; thus, impacting the range of motion (ROM)
required to complete a repetition across participants of different heights. Post hoc
measures of the shortest participant who was 152 cm tall, showed knee and hip angles to
be 129 and 81 degrees respectively when seated in the leg press machine. In contrast, the
tallest participant was 194cm tall and when in the leg press machine knee and hip angles
of 88 degrees and 56 degrees were measured. Differences in ROM required to complete
one repetition likely impacted both 1RM measures as well as the number of repetitions
participants were able to perform, although no correlation was found between height and
number of repetitions participants could perform on the leg press at either 60% or 80%
1RM (p=0.984 and p=0.969 respectively). Finally, we cannot discount motivation, or the
lack thereof, as a factor affecting performance. Even though participants were
encouraged in a standardized manner, it was clear that some participants were willing to
push themselves more than others. Older adults in particular seemed more reluctant than
younger adults to fully exert themselves, especially at 80% 1RM. This could be at least
partially responsible for our finding that younger adults performed a greater number of
repetitions on the leg press at 80% 1RM than older adults. However, as long as
motivation stays consistent throughout 1RM and repetition testing, even if exertion is not
maximal, the number of repetitions performed would not be affected.
**CONCLUSION**

As the number of older Americans increases, measures must be taken to prevent sarcopenia, age-associated muscle wasting commonly seen in older adults. Previous research on resistance training in the elderly has demonstrated resistance training to be a safe and effective counter-measure for attenuating muscle loss, as well as a way for older adults to increase muscular strength and functional capacity. Before prescribing resistance training to older adults however, it is paramount we understand the relationship between muscular strength and endurance in this population. Findings from this study demonstrate a significant amount of variability in the capacity to lift submaximal loads in older adults. Therefore, when prescribing resistance training to older adults, it is important to account for variability. The impact of age and sex and on the number of repetitions an individual can complete remain subjects of debate. Resistance training exercise prescription based on completing a given number of repetitions at the maximum weight at which they can be completed, or RM-Based exercise prescription could potentially be used as an alternative to alleviate problems with %1RM-based exercise prescription, a product of the variability in the number of repetitions possible at a given intensity [66, 77, 112].
REFERENCES


APPENDIX
APPENDIX A

IRB Protocol
January 11, 2012
Relationship Between Number Of Repetitions And Selected Percentages Of The One Repetition Maximum In Younger And Older Adults
Anthony Marsh, PhD, Department of Health and Exercise Science
Gregory Grosicki, BS, Department of Health and Exercise Science

Introduction
Progressive resistance training is considered an important component of the health related physical fitness model (1). Incorporation of a resistance training program into an exercise program can have many benefits including the reduction of the risk of chronic diseases such as coronary heart disease, type two diabetes, and osteoporosis. In addition, resistance training has been shown to result in a decrease in fat mass and increases in lean muscle mass, while, enhancing balance, and preserving functional capacity (1, 2, 3).

Proper design of a resistance training program involves the manipulation of five key variables: choice of exercise, order of exercise, number of sets, rest periods, and exercise load (2, 3, 4, 6). The intensity of a training program can be adjusted through the management of these variables. Exercise load has emerged as the most studied of these variables (6). Prescription of resistance training exercises is typically done based on repetition maximum (RM) or on a percentage of 1RM. The 1RM is defined as the maximum amount of weight that an individual can successfully lift for a given exercise using correct form. To determine a 1RM for a particular exercise, an individual will perform a series of warm-up repetitions using a sub-maximal load. The load will be systematically increased until the individual is unable to complete a single repetition using correct form. The information from the 1RM testing is then used to determine the loads used in resistance training programs. In practice there is considerable utility in prescribing a load at a given percentage of the 1RM, e.g., 75% 1RM, that, in theory, leads to a precise number of repetitions, e.g., 10, particularly in the research setting when controlling dose is critically important.

Shown is a chart providing guidance from the National Strength Conditioning Association that illustrates the predicted number of repetitions possible for a range of submaximal percentages of 1RM (19). Such charts are often used in the design of resistance training programs. However, a major limitation of these charts is lack of appreciation for individual variability, as well as variability by exercise. Additionally, a number of limitations may affect the charts utility (18).

1. It appears that those that are trained are capable of performing more repetitions than those who are untrained for a given percent of 1RM.
2. It is important to remember that the number of repetitions used to establish the relationship is only for a single set of repetitions and not multiple sets. With subsequent sets, fatigue will influence the number of repetitions one can perform.
3. Most of the research done to examine the relationship between % of 1RM and number of repetitions was done using the bench press, back squat, and power clean. For many reasons when switching exercises the number of repetitions for a given submaximal percent will change and therefore, it is imperative that caution is taken when using the relationship for program prescription.

4. The mode of resistance training appears to affect the relationship. It has been shown that more repetitions can be performed using machine-based exercises than with free weight exercises.

5. More repetitions can be performed at any given percent of 1RM for multi-joint core exercises than single-joint assisted exercises.

6. The order of the exercise may also affect the number of repetitions that can be performed at any given % of 1RM. Regardless of the nature or mode of the exercise, if an exercise is done at the end of the workout, the total possible number of repetitions possible will decrease.

Two major observations can be made from previous studies that have investigated the relationship between the maximal number of repetitions that can be achieved at a given percent of 1RM. First, as the percent of 1RM increases, the number of repetitions decreases. Second, multi-joint/large muscle group exercises allow for the completion of more repetitions at a given percent of 1RM compared to single-joint/smaller muscle group exercises (7, 9, 10). Therefore, at a fixed percentage of 1RM, in large muscle group, multi-joint exercises such as leg press, more repetitions can be performed compared to an exercise such as leg extension, a smaller muscle group, single joint exercise. The majority of studies in this area have assessed younger adults (3, 7, 9, 10, 11, 12). Very few have examined the relationship between repetitions and load in single- and multi-joint muscle groups in older adults (13).

The purpose of this investigation will be to better understand the individual variability in the capacity to lift submaximal loads in older adults in both single- and multi-joint exercises. We will achieve this by 1) determining the 1RM, and then 2) determining the maximum number of repetitions that can be performed by both young (baseline comparison) and older adults at 60 and 80% 1RM in 3 different exercises: a multi-joint large muscle exercise (leg press), a single-joint large muscle exercise (leg extension), and finally a single-joint small muscle exercise (bicep curl).

**Methods**

**Personnel**

Principle Investigators: Dr. Tony Marsh 336-758-4643 marshap@wfu.edu Gregory Grosicki – HES MS Student 703-303-7812 grosgj11@wfu.edu

**Participants**

Participants for the study will be 16 younger and 32 older adults. The younger adults will be recruited from the Wake Forest Campus. The older adults for the study will be recruited from The Healthy Exercise and Lifestyles Program run by the Department of HES. Should additional older adults be needed they will be recruited from local continuing care communities such as Arbor Acres and Homestead Hills. Recruitment will be done using flyers and information sessions. Participants recruited outside of the Healthy Exercise and Lifestyle Program will be asked to obtain physician approval prior to their first visit. These participants will be given a copy of the physician approval form and asked to schedule an appointment with their primary care provider to obtain physician approval. After the participant has obtained physician approval they will be contacted by the study investigators to schedule their first visit to which they will be required to bring the signed physician approval form. All Participants will meet the following inclusion/exclusion criteria.
Inclusion Criteria
Age: Younger adults (age 21-29) and older adults (age 65-89)
Stability of Residence: Does not plan on moving out of the community for the duration of the study
Agreeableness: Willing and able to participate in all aspects of the trial
Consents: Participants must be able to provide written consent of waiver approved by the institutional review board

Exclusion Criteria
Physical: any musculoskeletal, visual, auditory, orthopedic, or neuromuscular deficit that might interfere with proper exercise technique or that might reasonably be expected to be exacerbated as a result of the study protocol.
Severe Symptomatic Heart Disease: evidence of unstable angina, symptomatic congestive heart failure, or exercise-induced complex ventricular arrhythmias
Blood Pressure: Resting blood pressure >160/100 mmHg
English literacy: Unable to speak or read English
Judgment by staff: Participant is deemed unsuitable for participation by staff for any reason

Assessments
Day 1:
All participants will begin by completing the ACSM/AHA exercise pre-participation questionnaire. Should participants be of moderate risk it we will obtain physician clearance prior to beginning any activity. Next a familiarization session during which all the testing procedures will be explained, informed consent will be obtained, and the correct exercise technique for each of the three exercises demonstrated and practiced to make sure the participant is comfortable with the resistance training equipment. During this session demographic and anthropometric data (age, sex, height, body mass) will be assessed and blood pressure will be taken and recorded. The familiarization session and all strength assessments, both maximal and submaximal, will be conducted by master’s student Gregory Grosicki, who is trained in health and exercise science. All assessments will be conducted in Reynolds Gymnasium at times when other master’s students and professors are present and near in case of emergency. Next the participants will undergo 1RM testing (14).

Day 1&2:
One Repetition Maximum Testing
One repetition maximum testing will be executed using procedures identified as the gold standard for assessing 1RM as described by Kraemer and Fry (14). Participants will be asked to begin by doing a warm-up set using a light weight (roughly 50% estimated 1RM) of 8-10 repetitions. Subjects will then do a second warm-up set of 3-5 repetitions using a moderate weight (estimated 75% 1RM). A final warm-up set of 2-3 repetitions using a heavy weight will be completed. As participants do each of these three warm-up sets they will be asked to report their perceived exertion (RPE) in order for researchers to gage participant effort and make alterations to the loads since initially the loads are best estimates. After completion of the warm-up session, participants will be tested for 1RM strength by increasing the load until the subject is unable to fully execute one repetition. Each 1RM attempt will be separated by 3-5 minutes of rest. 1RM testing will be conducted for each of the three exercises on the same day with a 20 minute break between exercises. The exercise order will separate the two lower body exercises with the upper body exercise. The order of the leg press and leg extension that flank the upper body exercise will be randomized. Following each exercise session study investigators will take participants through a cool-down series of stretches to minimize muscle soreness. In the unlikely event that the
participant becomes too fatigued to continue the assessment protocol, testing will be stopped, and the participant will be rescheduled to return and complete the testing on another day, at least 48 hours after the session. The participant will return for another 1RM test no sooner than 48 hours later so we can examine the reliability of the 1RM assessments. Instructions to the participant and definitions of one complete repetition for each of the three exercises, leg press, bicep curl, and leg extension are as follows (17):

**Seated leg press:**
**Step 1:** Starting position: Sit in the machine, with your back flat against the machine's backrest. Place your feet on the resistance plate, and adjust your seat and foot position so that the bend in your knees is at approximately 90 degrees with your heels flat. Knees are parallel and your toes are lined up with your knees. Lightly grasp the handles to either side of you to help stabilize your upper body. Do not allow movement in your low back throughout the task.
**Step 2:** Slowly exhale while pushing the resistance plate away from your body. Keep your heels flat against the resistance plate and avoid any movement in the upper body.
**Step 3:** Continue to straighten your legs until the knees are straight but not locked. The heels should still be pressed firmly into the plate. Do not round the low back, lock-out your knees or allow your buttocks to lift off the seat pad.
**Step 4:** Pause briefly then slowly return to your starting position in a slow, controlled manner. Do not allow your upper thighs to compress your ribcage.

**Note:** For safety, control the extension phase by keeping your heels in contact with the plate and avoid locking out your knees. During the return phase, control the movement and avoid compressing your upper thighs against your ribcage.

**E-Z Bar Bicep Curl**
**Step 1:** Stand with feet about hip-width apart, abdominals engaged as you hold the weight in front of the thighs. Make sure to keep back against the wall at all times.
**Step 2:** Squeeze the biceps and bend the arms, curling the weight up towards the shoulders.
**Step 3:** Keep the elbows stationary and only bring the weight as high as you can without moving the elbows.
**Step 4:** Slowly lower the weight, keeping a slight bend in the elbows at the bottom (e.g., don't lock the joints and try to keep tension on the muscle)

**Note:** While this task targets the biceps effectively, proper technique is important to prevent unnecessary stress placed in low back by swinging your torso backwards during the movement. Follow the instructions provided to avoid potential injury.

**Machine Leg Extension:**
**Step 1:** Adjust the machine to your body's dimensions. The rollers should be comfortably positioned at your ankles and the back should be positioned so that you are sitting upright with your knees hanging freely off the end of the seat.
**Step 2:** Sit on the machine holding the handles. Your legs will be bent with your ankles behind the rollers. Make sure your spine is in contact with the back pad.
**Step 3:** Inhale through your nose. Exhale and straighten your knees ensuring that the plate holder touches the elastic band positioned by the study investigator to ensure full range of motion. Engage your quadriceps muscles equally by pointing your toes straight up to the ceiling. Inhale and resist the weight down to the starting position. Exhale and extend.

**Note:** Be sure not to lock your knees when you straighten them and properly coordinate your breathing with exertion. Doing so will help to avoid potential injury. Following the maximal strength assessments the investigator will re-take the participants blood pressure and the participant will not be permitted to leave until the blood pressure returns to baseline (+/- 20 mmHG resting measure).
Day 3&4:

Submaximal Testing
The submaximal sessions will involve performing each of the 3 exercises, spacing the upper body exercise between the lower body exercises as was done in the 1RM tests. Half of the participants will do 60% 1RM for all 3 exercises on the first day of submaximal testing and then do 80% 1RM on the second day, the other half will do 80% and then 60%.

Before beginning every session, investigators will take the resting blood pressure of participants to ensure the participant is safe for exercise. Following blood pressure measurements, participants will perform a 5 minute warm-up on an exercise bicycle as well as a warm-up set of 50% of 1RM for 5 repetitions before an exercise. As with the 1RM, 20 minutes of rest will be given in-between exercises in a session and at least 48 hours of rest between each testing session will be used. Following each exercise session study investigators will take participants through a cool-down series of stretches to minimize muscle soreness. In the unlikely event that the participant becomes too fatigued to continue the assessment protocol, testing will be stopped, and the participant will be rescheduled to return and complete the testing on another day, at least 48 hours after the session.

The investigator will ensure that each repetition is done with proper form in order for it to be counted. Should a repetition be performed for more than half of the range of motion, but not the entire range, it will be counted as half (0.5) of a repetition. Participants will be encouraged to perform the repetitions consecutively and no more than 3 seconds will be allowed between repetitions. The same definition will be used to define a complete repetition for both the 1RM test and the repetition testing. The velocity at which the movement is done will be controlled such that the concentric and eccentric phases take 2 sec each. Following the exercise participants will be asked to rate their perceived exertion (RPE) using the Borg 10-category scale. Verbal encouragement will be standardized and provided during all testing sessions in order to ensure equal and adequate motivation and effort (15, 16). It is critical that verbal encouragement be uniform for each participant and that the encouragement make the participant feel confident and elicit maximal effort (16). Therefore we will use the following script for all participants:

Submaximal Testing Script
Begin first task: “There you go, keep up the good work.”
After beginning first task: “Fantastic work, let’s give you 20 minutes to rest before we start the next task.”

Begin second task: “Great job ________ (Participant name), you did a really good job with the ________(last task). Let’s see how many repetitions you can do on the bicep curl.
Middle of second task: “Looking strong, way to go!”
End second task: “Wow, well done, just one more task to go! Let’s give you another 20 minutes to let those muscles recover.”

Begin last task: “Alright last one, let’s see what you can do!”

After beginning last task: “Keep it up, you got it!”
End last task: “Good job, thank you very much for volunteering to help me with this today!”

Sample of participant assessment schedule
An example of the 4 testing sessions for a subject randomized to the leg press, bicep curl, and leg extension order would look as follows:
Day 1: Familiarization Session, Collection of anthropometric and demographic data, 1RM Test
Day 2: Repeat 1RM Test
Day 3: 80% Leg Press, 80% Bicep Curl, 80% Leg Extension
Day 4: 60% Leg Press, 60% Bicep Curl, 60% Leg Extension
Following the submaximal strength assessments the investigator will re-take the participants blood pressure and the participant will not be permitted to leave until the blood pressure returns to baseline (+/- 20 mmHG resting measure).

**Statistical Analysis**
We will analyze the differences between different exercises and the number of repetitions that individuals were able to perform on them at a selected submaximal load. In addition, this study will investigate the differences in the number of repetitions that older adults are able to perform for a given exercise at a given load compared to younger adults. To make these comparisons a two-way analysis of variance will be used. Should significant differences present themselves, a Tukey post-hoc test will be used to determine the pair-wise differences, as was done by Shimano et al in 1995 (7). Pearson product moment correlations will then be used to determine selected pair-wise relationships with significance set at p≤0.05.

**Human Subjects Protection**

**Informed Consent**
Written informed consent will be obtained from each subject. The staff will be trained and knowledgeable of the exercises being performed. Furthermore, consent will be obtained in a quiet, no pressure area.

**Confidentiality and Privacy**
Confidentiality will be maintained by collecting only information necessary for the purpose of this study. When collecting data from subjects, subjects will be assigned an identification number to protect subject privacy. Any subject information that might make it possible to identify the subject will be excluded. Access to data from the subject will be kept in a manner that only the study personnel can see. Any data that is kept on a computer will be password protected and no reference shall be made in data analysis to a particular patient or a characteristic of a certain participant. Records including signed consent forms and research data will be securely kept for a minimum of 3 years after completion of the study.

**Safety procedures**
Participants will be appropriately familiarized with all machines before doing any exercises. Blood pressure will be taken and recorded before beginning any physical activity. All participants will warm-up before beginning the exercises and staff will be knowledgeable individuals that will help participants with proper lifting form while minimizing behavior that might put the participant at risk.

**Risks**
There is minimal risk associated with the exercises being done in this study. This being said, precautions will be taken to minimize whatever risk there is. Instead of using free-weights, machines will be used. Participants will all under-go a familiarization session with the three exercises (leg press, bicep curl, and leg extension) during which the staff will thoroughly explain to the participants (11)

1. What muscle groups are being used
2. Demonstrate the lift with accompanying verbal explanation
3. Allow the participant to do the lift with little to no weight, ensuring appropriate grip/body positioning
4. Remind the participant of proper breathing technique
5. Obtain RPE using the Borg-10 category scale to determine approximate RPE of participant
6. Entertain any questions the participant might have regarding the exercise before beginning
   It should be known by all participants that mild muscle soreness following the exercise is typical and to minimize soreness all participants will adequately warm-up before doing any exercises.

**Reporting of unanticipated problems, adverse effects, or deviations**
Any unanticipated problems, adverse effects, or deviations from the above protocol will be reported to the Wake Forest University IRB.

Emergency Roles and Procedures

Two person procedure:

Person one:

- Move to scene and assess PT (HR, BP, breathing, symptoms, etc.)
- Begin CPR if necessary
- IF AED is NEEDED: Contact EMA via phone*
- Meet EMS in front of building or instruct another participant to meet EMS
- Record/document times and procedures of events
- Monitor PT until EMS arrives

Person two:

- Move to scene and bring AED
- Connect patient to AED and activate if needed
- Follow AED instructions
- Assess and record vital signs (HR, BP, breathing, symptoms, etc.)
- Monitor PT until EMS arrives
  *A cell phone will be available

Three person procedure:

Person one:

- Move to scene
- Assess PT
- Begin CPR if necessary
- Record/document times and procedures of events
- Monitor PT until EMS arrives

Person two:

- Bring AED to scene
- Connect PT to AED and activate if needed
- Follow AED instructions
- Assess and record vital signs (HR, BP, breathing, symptoms, etc.)
- Monitor PT until EMS arrives

Person three:

- Move to scene
- Contact EMS via phone if necessary
- Meet EMS in front of building or instruct another participant to meet EMS

No drugs will be administered by study staff during an adverse event.
All emergency procedures will be practiced and reviewed on a monthly basis to ensure staff understand their responsibilities.
Patient’s emergency contact will be contacted as soon as possible to inform contact of situation
Any adverse events or emergency events will be reported to the IRB using available adverse events form.
**APPENDIX B**

Wake Forest University Dept. of Health and Exercise Science  
Winston-Salem, NC

Informed Consent

**Relationship between Number of Repetitions and Selected Percentages of the One Repetition Maximum in Younger and Older Adults**

Anthony Marsh, Ph.D., Principal Investigator, Wake Forest University  
Gregory Grosicki, B.S., Co-investigator, Wake Forest University

**Introduction**

You are invited to be in a research study. Research studies are designed to gain scientific knowledge that may help other people in the future. You are being asked to participate in this research study because you are between the ages of 21-29 or 65-89, are physically capable of performing the testing protocol, and have shown a willingness to participate in testing and research. Your participation is voluntary. Please take your time to make your decision and ask the study staff to explain any words or information that you do not understand. You may also discuss the study with your friends and family.

**Why Is This Study Being Done?**

The purpose of the Strength Assessment Study is to analyze the capacity of muscular strength with the objective of improving the quality of strength training programs for all ages.

**How Many People Will Take Part In The Study?**

About 48 people, 16 younger adults and 32 older adults, will take part in the study.

**What Is Involved In The Study?**

The study involves four separate visits, each one separated by at least forty-eight hours. Each visit is explained below. If you decide to participate, we would ask that you please refrain from engaging in any structured physical activity twenty-four hours before each visit.

**Visit Day 1: Three Parts**

There will be three parts to the first visit that will take place in Reynolds Gymnasium on Wake Forest University Reynolda campus. Older adults recruited outside of the Healthy Exercise and Lifestyles Program from continuing care communities such as Arbor Acres and Homestead Hills will be asked to obtain written physician permission prior to their first visit.

**Part One:**

For the first visit you will meet in Reynolds Gymnasium. Before beginning any part of the study you will be asked to review and sign the informed consent document. You will then
meet with study investigators who will begin by giving you a brief preliminary screening, which will involve obtaining blood pressure, height, weight, medical history, information about medications you are currently taking, demographic data, and a pre-participation questionnaire to ensure you are not at risk by participating in the study. After this you will be asked a few questions to ensure that you do not have any orthopedic or musculoskeletal issues that may make you ineligible to participate in the study.

**Part Two:**
Following the preliminary screening you will undergo a familiarization session with the strength assessment equipment to be used in the study. This familiarization session will consist of a thorough explanation of testing procedures, explanation of proper technique for all of the muscular strength assessment exercises, and a demonstration by the investigator and trial run by the participant during any part of which questions by the participant will be entertained by investigators.

**Part Three:**
During the final part of the first day you will undergo a one repetition maximum (1RM) test for leg press, bicep curl, and leg extension. Before attempting a maximal lift you will follow the suggested warm-up procedures that are currently the standard for assessing strength. This will involve starting with a light weight, roughly 50% of max, and doing between 8-10 repetitions. Next more weight will be added to approximate 75% of the maximum weight you can lift, and a set of 3-5 repetitions will be done. Adding more weight, a final warm-up set of 2-3 repetitions will be done before attempting a maximal effort lift. Maximal effort attempts will proceed, with small amounts of weight being added each time until you can no longer do one repetition of the weight. About 3-5 minutes of rest will be provided between each maximal repetition attempt. Investigators will question participants about their perceived exertion following every lift, including warm-ups (using the Borg-10 scale). There will be 20 minutes of rest given between maximal effort exercises. This will be done for all three exercises.

**Visit Day 2:**
The second visit will be at least forty-eight hours after the first visit. During the second visit you will do the same thing that you did in part three of the first visit. The purpose of this visit is to ensure accuracy of 1RM tests done during visit one.

**Visit Day 3:**
During the third day you will meet with investigators in Reynolds Gymnasium again. On the third day, you will do submaximal repetition tests of either 60% or 80% of your one repetition max. The order that you do these percentages of your maximum will be randomized (like flipping a coin to determine which one is done first). You will begin by warming-up on an exercise bicycle for 5 minutes. Next you will proceed to the three muscular strength assessment exercises. Before beginning every exercise you will do a light warm-up set of 5 repetitions at 50% of 1RM. Following the warm-up you will be asked to complete as many repetitions of the submaximal weight percent as you can while keeping a constant rhythm of 2 seconds up and 2 seconds down. After each exercise you will be asked to rate your perceived exertion on a scale from 0-10, 0 being nothing at all and 10 being very, very hard. Again, you will be given 20 minutes of rest between each exercise.

**Visit Day 4:**
The fourth visit, coming at least 48 hours after the third, will be identical to day 3 except that for this day you will use a different submaximal 1RM percent. For example, if on day 3 you used 60% of your 1RM, on day 4 you will perform submaximal repetitions with 80% of your 1RM.

**How Long Will I Be In The Study And How Long Is Each Visit?**
If you agree to be in this study it will take 1-2 weeks to complete. The first visit will be the longest, and will likely take about 2 hours. The remaining visits should take about 1.5 hours. You can stop participating at any time. If you decide to stop participating in the study we would like you to talk to the investigators or study staff first to learn about any possible health or safety issues.

**What Are The Risks Of The Study?**
Being in this study involves some risk to you. For this reason, study staff will be prepared and emergency response procedures have been established should any complications arise from testing. You should discuss the risk of being in this study with the study staff.

Physical Activity and Testing Program: Although minimal, there is inherent risk in participating in the muscular strength assessments involved in this study. It should be known that study investigators will be sure to take all precautions necessary to prevent risk. You will be permitted to avoid any assessment that makes you feel uncomfortable or uncertain that you can complete. You will be familiarized with the muscular strength assessments by a study investigator who will supervise all the strength assessment sessions to ensure proper form and technique. Muscle soreness is typical with strength training sessions. In order to minimize muscle soreness, a warm-up will be used before beginning exercise and a cool-down with stretching will follow.

**Are There Benefits To Taking Part In The Study?**
If you agree to participate in the study, there may be a direct benefit to you as you will gain insight into the submaximal endurance capacity of your muscles. We also hope that the information learned in this study will benefit others in the future.

**What Are The Costs?**
There are no costs to you for taking part in this study. Any costs for your regular medical care, which are not related to this study, will be your own responsibility.

**Will You Be Paid For Participating?**
You will be reimbursed $80 in gas cards, over the duration of the study ($20 per visit).

**Who Is Sponsorizing This Study?**
This study is being sponsored by the Department of Health & Exercise Science.

**What Are My Rights As A Research Study Participant?**
Taking part in this study is voluntary. You may choose not to take part or you may leave the study at any time. Refusing to participate or leaving the study will not result in any penalty or loss of benefits to which you are entitled. If you decide to stop participating in the study we encourage you to talk to the investigators or study staff first to learn about any potential health or safety consequences. The investigators also have the right to stop
your participation in the study at any time. This could be because you are unwilling or unable to undergo testing procedures at follow-up visits. You will be given any new information we become aware of that would affect your willingness to continue to participate in the study.

CONFIDENTIALITY
The data collected will be kept in a secure location. Only authorized people will have access to the research records and passwords for office computers and networks will be protected. When research data are no longer scientifically useful, they will be destroyed.

WHOM DO I CALL IF I HAVE QUESTIONS OR PROBLEMS?
You are encouraged to ask questions at any time during the study. Any questions regarding the study should be directed to the principal investigator, Dr. Tony Marsh, Ph.D., at 758-4643. If you have any questions about your rights as a research participant, please contact the Office of Research and Sponsored Programs at (336) 758-5888.

You will be given a signed copy of this consent form.

Signatures
By signing below, you indicate that you are willing to participate in this research project.

__________________________________________________________  Time
Subject Name (Printed)

__________________________________________________________
Subject Signature

__________________________________________________________
Person Obtaining Consent
I would like to learn more about your background.

1. What is your birth date?  __/__/_____

2. What is your gender?  
   □ Male  □ Female

3. Which of these best describes your racial background?
   □ Native Hawaiian or Other Pacific Islander
   □ Black or African American
   □ American Indian or Alaska Native
   □ White
   □ Asian
   □ Other

4. Do you live alone?  
   □ Yes
   □ No
   □ Don’t know

5. Who lives with you?  
   □ Spouse
   □ Other relative
   □ Child
   □ Paid employee
   □ Friend
   □ Other
   Specify: __________

6. Including yourself, how many live in your household?  __________

7. Which of the following best describes your current marital status?
   □ Married
   □ Widowed
   □ Separated
   □ Never Married
   □ Divorced
   □ Other
   Specify: __________

8. What was the last grade you completed in school?  
   (please write the year in the space provided)
   □ No formal education
   □ Elementary School
   □ High School/Equivalent  __________________________
   □ College
   □ Post Graduate  ________
   □ Other

9. What is your household income range?
   □ Less than $50,000
   □ $50,000 - 74,999
   □ $75,000 - 99,999
   □ $100,000 - 150,000
   □ More than $150,000

Anthropometric Data:
   Height: __________  Weight: __________
APPENDIX D
Medical History

The questions that follow will ask for some information about your health history. Please answer them as completely as possible.

1. Has a doctor ever told you that you have diabetes?  
   □ Yes  
   □ No  
   □ Don’t know

If you do have diabetes, do you use insulin to control your diabetes?  
   □ Yes  
   □ No  
   □ Don’t know

2. Has a doctor ever told you that you have high blood pressure (hypertension)?  
   □ Yes  
   □ No  
   □ Don’t know

If you do have high blood pressure, do you take medication for your blood pressure?  
   □ Yes  
   □ No  
   □ Don’t know

3. Has a doctor ever told you that you have had a heart attack?  
   □ Yes  
   □ No  
   □ Don’t know

If a doctor has told you that you have had a heart attack, did your heart attack occur within the past 6 months?  
   □ Yes  
   □ No  
   □ Don’t know

4. Has a doctor ever told you that you may have any of the following?  
   a. angina (chest pain, discomfort, pressure or heaviness due to a blocked or clogged blood vessel in your heart)?  
      □ Yes  
      □ No  
      □ Don’t know

   b. heart failure or congestive heart failure?  
      □ Yes  
      □ No  
      □ Don’t know

   c. heart rhythm problem or irregular heartbeat?  
      □ Yes  
      □ No  
      □ Don’t know

   d. heart conduction problem or heart block?  
      □ Yes  
      □ No  
      □ Don’t know

   e. heart valve problem?  
      □ Yes  
      □ No
<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Has a doctor ever told you that you had had a stroke or transient ischemic attack (TIA) or mini-stroke?</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>If a doctor told you that you have had a stroke or a mini-stroke, did the stroke or mini-stroke occur within the last 6 months</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>6. Has a doctor ever told you that you have a blood circulation problem in any of the following areas?</td>
<td></td>
</tr>
<tr>
<td>a. in your head or neck?</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>b. in your legs or feet (peripheral vascular disease (PVD) or peripheral arterial disease (PAD))?</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>c. in any other part of your body?</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>7. Has a doctor ever told you that you have emphysema, chronic bronchitis, chronic obstructive pulmonary disease (COPD), or lung disease?</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>8. Do you have a hearing impairment that cannot be corrected and results in inability to use the telephone or to have a normal conversation?</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>9. Do you have a vision impairment that cannot be corrected and results in inability drive?</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>10. Has a doctor ever told you that you have Parkinson's disease?</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>11. Has a doctor ever told you that you have cancer?</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>If a doctor told you that you have cancer, were you treated for this within the last 6 months?</td>
<td>Yes, No, Don't know</td>
</tr>
</tbody>
</table>
12. Has a doctor ever told you that you have a systemic rheumatic condition such as rheumatoid arthritis, psoriatic arthritis, Reiter’s disease, systemic lupus erythematosus?

- Yes
- No
- Don’t know

If yes, please state the type: 

13. If a doctor has told you that you have arthritis, where do you have arthritis?

<table>
<thead>
<tr>
<th>Body Part</th>
<th>Yes</th>
<th>No</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. neck</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. hands</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. feet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. back</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. shoulders</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. hips</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. knees</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

14. Has a doctor told you that you have had a fracture in upper or lower extremity within the last 6 months?

- Yes
- No
- Don’t know

15. Have you ever had an upper or lower extremity amputation?

- Yes
- No
- Don’t know

16. Has a doctor ever told you that you have kidney disease?

- Yes
- No
- Don’t know

17. Has a doctor ever told you that you have liver disease?

- Yes
- No
- Don’t know
18. Have you been treated in the last 2 years by a doctor or other health care professional for either:
   a. major depression?
      □ Yes  □ No  □ Don’t know
   b. other psychiatric problem?
      □ Yes  □ No  □ Don’t know

19. Which of the following best describes how often you drink wine, beer, whiskey, or liquor? (please mark only one)
   □ Never drank  
   □ Used to drink, but don’t drink now
   □ One or two times a year or very occasionally
   □ Less than once a week or only at parties
   □ Once or twice a week
   □ Three or four times a week
   □ Nearly every day
   □ Every day
   □ I do not wish to answer

If you drink three or four times a week, nearly every day, or every day, how many drinks do you have each day, on average? (please mark only one)
   □ One or two drinks per day, on average
   □ More than two drinks per day, on average

20. Which of the following best describes your cigarette smoking history?
   □ At the present time (now), I smoke regularly
   □ I do not smoke at the present time (now), but I smoked cigarettes in the past
   □ I have never smoked cigarettes regularly

21. Have you been hospitalized within the past 12 months?
   □ Yes  □ No  □ Don’t know

   If you have been hospitalized in the past 12 months, please provide details below:

<table>
<thead>
<tr>
<th>Date</th>
<th>Reason</th>
<th>Length of hospitalization</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

22. Please provide a list of your current medications both prescription and non-prescription

<table>
<thead>
<tr>
<th>Name</th>
<th>Dose</th>
<th>Frequency</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

   Emergency contact name: ____________  Emergency contact phone #: ____________
APPENDIX E

AHA/ACSM Health/Fitness Facility Pre-participation Screen

Assess your health needs by marking all true statements.

History
You have had:
___ A heart attack
___ Heart surgery
___ Cardiac catheterization
___ Coronary angioplasty (PTCA)
___ Pacemaker/implantable cardiac defibrillator/rhythm disturbance
___ Heart valve disease
___ Heart Failure
___ Heart transplantation
___ Congenital heart disease

If you marked any of these statements in this section, we require a physician’s release, attached, in order to continue with the joining process.

Symptoms
___ You experience chest discomfort with exertion.
___ You experience unreasonable breathlessness.
___ You experience dizziness, fainting, blackouts.
___ You take heart medications.

Other health issues
___ You have diabetes
___ You have or asthma other lung disease.
___ You have burning or cramping in your lower legs when walking short distances.
___ You have musculoskeletal problems that limit your physical activity
___ You have concerns about the safety of exercise.
___ You take prescription medication(s)
___ You are pregnant

Cardiovascular risk factors
___ You are a man older than 45 years.
___ You are a woman older than 55 years, you have had a hysterectomy, or you are postmenopausal.
___ You smoke, or quite within the previous 6 mo.
___ Your blood pressure is greater than 140/90.
___ You don’t know your blood pressure.
___ You take blood pressure medication.
___ Your blood cholesterol level is >200 mg/dL.
___ You don’t know your cholesterol level.
___ You have a close blood relative who had a heart attack before age 55 (father or brother) or age 65 (mother or sister).
___ You are physically inactive (i.e., you get less than 30 min. of physical activity on at least 3 days per week).
___ You are more than 20 pounds overweight

If you marked two or more of the statements in this section you are required to obtain a physician’s release, attached, in order to join the facility.

___ None of the above is true.

You should be able to exercise safely without consulting your physician or other healthcare provider in a self-guided program or almost any facility that meets your exercise program needs.
APPENDIX F
1RM Testing Form

Acrostic: _ _ _ _ _   Visit: _ _    Date: _ _/ _ _/ _ _

I.D #: _ _ _ _           Staff: _ _ _

STRENGTH TESTING – LEG Press

<table>
<thead>
<tr>
<th>Seat Position:</th>
<th>Lever Length:</th>
<th>Start:</th>
<th>Stop:</th>
</tr>
</thead>
</table>

Start with a light weight warm-up of _ _ _ _ _ lbs Number of reps (8-10) _ _ _ _

What is the participant's RPE? _ _
Did you have any knee pain? Yes (end the test) ☐ No (continue) ☐

90SEC REST

Move on to a moderate weight warm-up of _ _ _ _ _ lbs Number of reps (3-5) _ _ _ _

What is the participant's RPE? _ _
Did you have any knee pain? Yes (end the test) ☐ No (continue) ☐

90 SEC REST

Move on to a heavy weight warm-up of _ _ _ _ _ lbs Number of reps (2-3) _ _ _ _

What is the participant's RPE? _ _
Did you have any knee pain? Yes (end the test) ☐ No (continue) ☐

<table>
<thead>
<tr>
<th>Trial</th>
<th>Weight Lifted (lbs)</th>
<th>RPE</th>
<th>RPE Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
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<td>3</td>
<td></td>
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<td>3</td>
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<td>4</td>
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<td>4</td>
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<td>5</td>
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<td>6</td>
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<td>7</td>
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<td>6</td>
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<td>8</td>
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<td>7</td>
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<td>9</td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>1RM</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>1RM (N)</td>
<td></td>
<td></td>
<td>Other ☐</td>
</tr>
</tbody>
</table>

1RM not achieved due to: Pain ☐ Safety ☐ Refusal ☐

Other ☐ → Specify: ____________________________

84
### STRENGTH TESTING – Bicep Curl

<table>
<thead>
<tr>
<th>Seat Position:</th>
<th>Lever Length:</th>
<th>Start:</th>
<th>Stop:</th>
</tr>
</thead>
</table>

Start with a light weight warm-up of [ ] lbs Number of reps (8-10) [ ]

What is the participant’s RPE? [ ]

Did you have any knee pain? Yes (end the test) [ ] No (continue) [ ]

---

**90SEC REST**

Move on to a moderate weight warm-up of [ ] lbs Number of reps (3-5) [ ]

What is the participant’s RPE? [ ]

Did you have any knee pain? Yes (end the test) [ ] No (continue) [ ]

---

**90 SEC REST**

Move on to a heavy weight warm-up of [ ] lbs Number of reps (2-3) [ ]

What is the participant’s RPE? [ ]

Did you have any knee pain? Yes (end the test) [ ] No (continue) [ ]

<table>
<thead>
<tr>
<th>Trial</th>
<th>Weight Lifted (lbs)</th>
<th>RPE</th>
<th>RPE Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
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<tr>
<td>2</td>
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<td>9</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td>10</td>
</tr>
</tbody>
</table>

1RM not achieved due to: Pain [ ] Safety [ ] Refusal [ ]

1RM (N) [ ]

Other [ ] Specify: [ ]
STRENGTH TESTING - LEG EXTENSION

Seat Position:  
Lever Length:  
Start:  
Stop:  

Start with a light weight warm-up of  
lbs Number of reps (8-10)  

What is the participant's RPE?  
Did you have any knee pain?  Yes (end the test)  No (continue)  

Move on to a moderate weight warm-up of  
lbs Number of reps (3-5)  

What is the participant's RPE?  
Did you have any knee pain?  Yes (end the test)  No (continue)  

Move on to a heavy weight warm-up of  
lbs Number of reps (2-3)  

What is the participant's RPE?  
Did you have any knee pain?  Yes (end the test)  No (continue)  

<table>
<thead>
<tr>
<th>Trial</th>
<th>Weight Lifted (lbs)</th>
<th>RPE</th>
<th>RPE Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>VERY LIGHT</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>FAIRLY LIGHT</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>MODERATE</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4</td>
<td>SOMEWHAT HARD</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
<td>HARD</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>7</td>
<td>VERY HARD</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>10</td>
<td>VERY VERY HARD (MAXIMAL)</td>
</tr>
<tr>
<td>1RM</td>
<td>1RM not achieved due to:</td>
<td>Pain</td>
<td>Safety</td>
</tr>
<tr>
<td>1RM (N)</td>
<td>Other</td>
<td>Specify:</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX G

Submaximal Repetitions Assessment

Acrostic: __ __ __ __ __  Visit: __  Date: __/__/__

I.D #: __ __ __  Staff: __ __ __

Resting BP measurement: __ __ __/__ __

5 minute warm-up on cycle: seat position: ________

---

SUBMAXIMAL STRENGTH TESTING – LEG EXTENSION

1RM: ______ lbs  5 repetitions @ 50% 1RM: _________ lbs  RPE: _________

90 seconds rest

_____% of 1RM = _______ lbs

Number of repetitions performed to failure: _________  RPE: ______

---

SUBMAXIMAL STRENGTH TESTING – BICEP CURL

1RM: ______ lbs  5 repetitions @ 50% 1RM: _________ lbs  RPE: _________

90 seconds rest

_____% of 1RM = _______ lbs

Number of repetitions performed to failure: _________  RPE: ______

---

SUBMAXIMAL STRENGTH TESTING – LEG PRESS

1RM: ______ lbs  5 repetitions @ 50% 1RM: _________ lbs  RPE: _________

90 seconds rest

_____% of 1RM = _______ lbs

Number of repetitions performed to failure: _________  RPE: ______
APPENDIX H
Advertisement

PARTICIPANTS NEEDED
To participate in a research study at Wake Forest University

The goal of the Strength Assessment Study is to assess muscular strength and individual differences in the relationship between repetitions and exercise load in younger and older adults.

What Is Involved?

| Four visits over a 2 week period to Reynolds Gymnasium, WFU Reynolda campus. | Visits will involve resistance training exercises and should last no more than 2 hours | Compensation of $80 in gas cards paid out over the study ($20 per visit) |

You may qualify if you are:

| Between the ages of 21-29 or 65-89 | Willing and able to perform the strength assessment exercises | Are able to commit to attending the four assessment sessions |

If you are interested in participating please contact Gregory Grosicki at 703-303-7812 for more information!

IRB00019708
EDUCATION

**Wake Forest University** – Winston-Salem, NC
Masters of Science in Health and Exercise Science, May 2013
Thesis: “The Strength Assessment Study: Understanding Variability in Muscular Endurance in Older Adults”
Faculty Advisor: Professor Anthony P. Marsh
GPA: 3.54

**College of William and Mary** – Williamsburg, VA
Bachelor of Science in Kinesiology and Health Science, May 2011
GPA: 3.34

**The University of Miami** – Coral Gables, FL
Transferred; August 2007 - May 2008
GPA: 3.70

RESEARCH EXPERIENCE

**Wake Forest University Department of Health and Exercise Science**, Winston-Salem, NC
August 2011 - Present
*Lead interventionist, The Strength Assessment Study: Understanding Variability in Muscular Endurance in Older Adults*
- Wrote protocol and informed consent documents and obtained study approval from the Internal Review Board
- Procured grant from the Department of Research and Sponsored Programs at Wake Forest University with professor and mentor Anthony Marsh
- Purchased study equipment such as weight lifting items and organized a testing facility
- Recruited 48 participants; 16 younger and 32 older adults and scheduled all testing visits
- Performed four assessment sessions for each participant; two one-repetition maximum testing sessions and two sessions of repetitions to failure using a selected percentage of one-repetition maximum
- Performed statistical analysis of research data

*Research Assistant, Brain Boot Camp: The Effect of Multi-Sensory Training on Physical Function in Older Adults*
- Served as an interventionist for this pilot study looking at the effect of multi-sensory intervention in older adults
- Scheduled participants for visits
- Conducted Short Physical Performance Battery (SPPB) in sample population before and after training intervention
College of William and Mary, Williamsburg, VA  August 2010 – December 2010
Research Assistant, Jack Borgenicht Altitude Research Facility
• Assisted with a study looking at the persistence of intermittent hypoxia exposure acclimation to simulated high altitude
• Recruited new participants and helped conduct interventions

HONORS AND AWARDS
• WFU Internal Science Research Fund Grant - Wake Forest University
• Summer Bridge Scholarship - Wake Forest University Health Active Living Program (2012)
• Graduate Scholarship - Wake Forest University (2011-2013)
• Duathlon World Champion - Age group (Edinburgh, Scotland 2010)

PROFESSIONAL EXPERIENCE
Wake Forest University, Winston-Salem, NC  August 2011 – Present
Teaching Assistant
HES 101 Exercise for Health, Department of Health and Exercise Science
• Instruct 32 students in a half-semester introduction to health science class
• Present lectures on topics relevant to different components of health and fitness such as how to assess personal fitness, cardiovascular and muscular fitness, and flexibility.
• Supervise labs to reinforce the topics covered in lecture
• Grade quizzes, personal exercise programs, and final exams

HES 354 Assessment Techniques in Health Sciences, Department of Health and Exercise Science
• Assist course instructor with teaching this 24 student senior class to educate seniors in the Health and Exercise Science department about various assessments techniques used in the health science field
• Lead laboratory classes to reinforce topics covered in class such as 12-lead ECG monitoring, metabolic testing, and pulmonary function testing
• Tutor students needing help outside of class instruction time

Healthy Exercise and Lifestyle Program, Winston-Salem, NC  August 2011 – August 2012
Staff Member
• Developed experience in clinical health care with primarily older adults, most of whom were afflicted by some type of chronic disease(s)
• Monitored blood pressure and ECG rhythms on patients at rest and during maximal graded exercise testing
• Assisted in graded exercise testing to help with exercise prescription and identification of risk factors for chronic disease
• Conducted fitness assessments on patients to help with exercise prescription
InMotion Physical Therapy, Williamsburg, VA August 2010 – May 2011
Physical Therapy Technician
• Gained experience in clinical health care working with individuals with various levels of physical function, from people with diseases such as MS to elite athletes
• Assisted physical therapists by conducting exercise sessions with patients, retrieving heat and ice packs for patients, and placing electrodes on patients for electrical stimulation

Lifetime Fitness, Fairfax, VA May 2007 – August 2007
Personal Training Intern
• Learned to conduct personal fitness assessments and write program design working with diverse group of clients with various fitness goals from weight loss to qualifying for the Boston marathon
• Developed manageable programs for clients tailored to individual fitness goals

TECHNICAL SKILLS
• Exercise Prescription & Program Development
• Blood Pressure Monitoring
• Graded Exercise & Metabolic Testing
• Cardiac Rhythm Identification
• American Heart Association CPR/First Aid Certified
• Proficient in Microsoft: Word, Excel, Publisher, Outlook; IBM SPSS Statistics software

ACTIVITIES
Wake Forest University, Winston-Salem, NC
• Cycling Club Road-Season Captain (2012 - 2013 Academic Year)
• Running Club Member (Fall 2012)
• Graduate Student Association (Fall 2011)

College of William and Mary, Williamsburg, VA
• Triathlon Club President (2010 - 2011 Academic Year)
• Cycling Club Vice-President (2010 - 2011 Academic Year)
• Swim Club Member (2009 - 2011)

University of Miami, Coral Gables, FL
• Varsity Cross-Country and Track and Field (2007 - 2008 Academic Year)

PROFESSIONAL ASSOCIATIONS
• American College of Sports Medicine (2012 – Present)