The University of Central Oklahoma
Edmond, Oklahoma
Jackson College of Graduate Studies

The Relationship between Lower Extremity Muscular Power and Functionality in Older Adults

A Thesis

Submitted To The Graduate Faculty

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE IN WELLNESS MANAGEMENT

by

Matthew Robert Tecmire

Edmond, Oklahoma

2011

The Relationship Between Lower Extremity Muscle Power and Functionality in Older Adults

A THESIS

APPROVED FOR THE DEPARTMENT OF KINESIOLOGY AND HEALTH STUDIES

By

Dr. Paul House

Dr. Melissa Powers

Dr. Bryan Duke

Table of Contents

Contents **Page**

Tables

Figures

Acknowledgement

This research project was easily the largest and most detailed endeavor that I have had the opportunity to undertake in my young academic and professional career. A project of this scale for a student can seem overwhelming and at times endless without the proper support structure to propel and encourage them forward. I have been blessed beyond words to have that kind of support structure and encouragement within my thesis committee, family, and friends to help me complete one of the largest tasks of my life. I would first like to thank my committee, Dr. Paul House, Dr. Melissa Powers, and Dr. Bryan Duke. Without each of your input, encouragement, and insights into this project none of this would have been possible. Thank you Dr. House for your time and patience when meeting with me and discussing the logistics and details that were involved in the completion of this project. Thank you so much for taking the time out of your schedule to take on the chair position for my thesis, I have learned a great deal from your leadership and attitude during this experience. Thank you Dr. Duke for your participation and insight with the formatting and writing process within my thesis project. Working with you has been such a great experience and your calm professional encouragement each time we met and talked was such a calming influence during this process. I owe a special thank you to Dr. Melissa Powers for her incredible investment in not only my thesis project but also my education and development as a student and person. Thank you Dr. Powers for allowing me the opportunity to be involved in your research work throughout my studies at UCO. Your investment in to my academic career and future growth as a professional has provided me the confidence and knowledge to feel that I can accomplish anything. Your mentorship has meant so much to me over the years and I could never say thank you enough for all that you have done.

I would also like to take time to thank my family and friends who have provided the needed encouragement and counseling during my academic career. Thank you so much to my wonderful wife Jackson who has been there to listen and support me throughout my entire college career. You have been there for me each step of the way and always provided me with so much support and love. Thank you to my brothers who have given me a model to look up to, a shoulder to lean on when I needed it, and the encouragement to not give up throughout the last few years. To my friends, thank you so much for your help. This process would have never been possible without you and your patience. The times we have spent together studying, writing, and talking about school and life have been some of the most amazing and insightful times of my college career. I have had the opportunity to be involved with some of the most interesting and insightful professors, students, and people I have ever met and the experiences we have shared throughout this journey have meant so much to me. Thank You.

Abstract

As humans age we go through a process of muscle mass loss known as Sarcopenia. This process of muscle loss can lead to many different forms of functionality based health concerns that can leave an individual immobile and requiring assistance from others. The primary purpose of this study is to examine the relationship between lower limb muscular power and functionality in women 70 and older. For this study, 15 women who have previously completed at least three months of high intensity resistance training exercises through the participation of a local exercise study at the University of Central Oklahoma served as subjects. The women were recruited to complete a functionality test, the 8-Foot Up-and-Go, and four power testing procedures: Chair Stand, Squat, Leg Extension, and Lunge. Power testing was conducted using a Tendo Weightlifting Analyzer with testing being conducted on non-consecutive days of the week. Once testing was completed a Pearson's correlation coefficient statistical analysis test was conducted after data collection to determine if any relationships existed between lower limb muscle power and functional ability. The results showed a significant relationship between the Chair Stand ($r = -.672$, $p = .006$) and the 8-Foot Up-and-Go functionality test. All other relationships were determined to not be significant. From these results the primary investigator concluded that a strong negative relationship was evident between lower limb muscular power production and functional ability in older adults.

Chapter One: Introduction

Purpose

The purpose of this research investigation is to determine which measure of power most closely relates to functional capacity in a group of older female adults. While muscular power has been identified throughout literature as an indicator of functionality there has not been a specific field-testing method developed and then compared to a functional ability protocol.

Hypothesis

The hypothesis of this study is that the 10-repetition power chair stand will have the highest correlation to an individual's functional ability when compared to the other power testing measures. This is due to the 10-repetition chair stand protocol requiring a large amount of multi-joint movement while also mimicking certain aspects of the 8-Foot Up-and-Go functionality test.

Significance

Muscular power testing involves a procedure where an individual performs a specific movement (i.e. standing from a chair, knee extension, etc.) as quickly as possible. The amount of power produced by the individual is directly related to functional ability (Caserotti, Aagaard, Buttrup Larsen, & Puggaard, 2008) yet a specific field-testing method for the measurement of muscular power has yet to be identified. The aim of the present investigation is to determine which measure of power most closely relates to functional capacity in a group of older adults.

As we age our bodies begin to experience declines in both muscle power and functional ability and it is this aging process that leads to significant losses in the ability to independently perform activities of daily living (Hazel, Kenno & Jakobi, 2007). The loss of independence can result in the elderly experiencing increased falls, accidents, burns, and other serious injuries. Past research has suggested that muscular power is closely associated with the ability to perform activities of daily living followed by muscular strength (Hazel, et. al, 2007). Research has provided significant evidence that the age related decline in muscle power predicts falls, motor impairments, and disability among the elderly (Casserotti, et. al, 2008).

With evidence from research suggesting a powerful link between muscle power production and functional ability, there is a need for the assessment of different types of muscle power measures and their relationship to functional ability. To measure functional ability, researchers have turned to an easy field measure known as the Senior Fitness Test (Rikli, & Jones, 1999). The 8-foot-up-and-go test is one of the six individual assessments of the Senior Fitness Test and it specifically measures agility and dynamic balance. Since this specific test involves many of the characteristics associated with functional ability, researchers have used the 8-Foot Up-and-Go as an easy field test for establishing an individual's functional ability (Barr, Browning, Lord, Menz, & Kendig, 2005; Bates, Donaldson, Castel, Krolik, & Coleman 2009).

Over the past few years, research has begun to try to establish a specific method for measuring power. In the past, researchers have used either an isokinetic or isometric knee extension machine that would only measure muscle power at a single joint (Brown, Sinacore, & Host, 1995). Measuring muscle power has evolved from this single joint method to a more practical technique where muscle power is measured using a number of joints and mimicking the major muscle actions that replicate the specific motor tasks used in activities of daily living (Holsgaard Larson, Caserotti, Puggaard, & Aaguard, 2007). With this shift in power measurement to specific motor tasks, the literature has indicated a need to determine which of the functional capacity and specific power tests are most tightly linked to functional performance in the elderly (Holsgaard et.al, 2007).

Operational Definitions

The principle investigator has determined a need for the identification and definition of certain aspects of this research study. Power is defined as the ability of the body to produce force quickly (Holsgaard et. al, 2007). This study will measure lower body power, which is the force that can be produced quickly from the legs. The Tendo Weightlifting Analyzer unit is the device that will be used to measure power of the lower body in the participants. To measure the lower body power of the participants, four specific testing protocols were selected: squat, chair stand, lunge, and knee extension. The squat is a movement that requires the participant to stand with feet shoulder width apart and flex their hips and knees at the same time and then extend the hips and knees as quickly as possible. The chair stand requires the participant to go from a seated position in a chair, to a full upright standing position as quickly as possible without using their arms. This marks one repetition; the participant will proceed to complete 10 repetitions with one minute of rest between each repetition. The lunge will require the participant to stand with their legs spread in the sagital plane of motion. The participant will slowly lower their upper body by flexing the lower body joints at the hip and knee and then as quickly as possible, extending at the hips and knees causing the upper body to follow the extension up in a straight line. The final power testing method is the knee extension and is defined as the extension of the lower leg at the knee joint while in a seated position.

With this action the lower leg will become parallel to the floor and in line with the thigh. Participants for this study are defined as women over the age of 70 years old that have previously participated in resistance training.

Limitations / Delimitations

For this research study specific limitations and delimitations were identified. One specific delimitation of this study is the choice of the population that will be used for the research. Using women 70 years and older was decided upon by the primary investigator due to the need for power testing described by literature and the ease of recruitment and prior training of the participants. A second delimitation imposed upon the study by the primary investigator is the specific types of power testing that will be used. The power testing battery: squat, chair stand, and lunge were chosen because of their multi-joint movement patters and also their association with functional tasks. The leg extension was chosen as a fourth testing protocol because it will provide a measurement of the power behind the participant's quadriceps muscle, which is the largest muscle group of the lower body.

Limitations also exist in the design of this research study and the power testing protocol. Since a specific age and gender of participants are being used, the study is limited to only generalizing the results found to that specific population. A second limitation of this study is the varying influences of motivation and other variables that are outside the principle investigator's control. A final limitation that exists in the research protocol is that the power testing is limited to the lower body. Therefore, this does not translate to upper body power or different movement patterns that require power.

Chapter Two: Literature Review

Introduction

As life expectancy steadily increases, millions of Americans are living longer and with that comes the realization of how important it is to stay independent and maintain the ability to do the activities of daily life. At the beginning of the 20th century there were 3 million Americans over the age of 65, as of 2000 that number had jumped to 33 million, a 10% increase (Older Americans, 2000). It is estimated that by 2050 this number will triple to 93 million Americans alive over the age of 65 (Older Americans, 2000). This 3-fold increase in population in 40 years along with the increase in disease and loss of independence as we age, could have a crippling effect on the medical world. With this staggering increase in population, older adults are in need of an answer to the overwhelming problem of the loss of functional ability during the aging process.

It is from this overwhelming obstacle in the older population that the idea for this research project was born. Research has shown over many years that the loss of muscle force production during the aging process is directly related to one’s ability to stay independent and functional during later life (Caserotti, Aagaard, & Puggaard, 2008). The evidence of muscle power’s role in keeping the elderly independent and functional is clearly demonstrated throughout literature although measuring protocols for the field are lacking. While methods for measuring muscle power in athletes and younger populations have been clearly established, the same protocols do not transfer well to older populations due to their high impact nature. For this specific reason the review of literature for this research study will focus on providing documented evidence that substantiates the need for this research study and the reliability of the protocols used.

Muscle Power and Functionality

For decades researchers have studied the link between muscle force production and independence among aging individuals. However, recent studies have further developed the idea that muscle power and not strength is more closely related to functionality in elderly individuals. Since decreases in muscle power are associated with the inability to perform activities of daily living (ADL)(Bassey et al. 1992), this review will begin by looking at the relationship between power and functionality. In their 2007 study, Bonnefoy, Jauffret, and Jusot compared maximal leg extension power to the performance of functional tests such as: chair rise time, time to walk 6 meters, and steps necessary to cover 6 meters in 32 elderly women aged 65 years or older. The researchers reported that leg extension power was significantly correlated with all performance measures: chair rise time ($r = 0.57$, $p < 0.01$), time to walk six meters ($r = -0.56$, $p < 0.01$), and step number ($r = -0.46$, $p < 0.01$). The researchers concluded that low levels of muscle power negatively affect functional performance scores and, in turn, weak muscle power is predictive of poor functional status.

This research (Bonnefoy, Jauffret, & Jusot, 2007) provided a great example of the importance of muscle power in functionality and performing everyday ADLs. The researchers provided clear and concise results with specific values to show the correlation between muscular power and functional performance. This study, like the others to come, provides clear evidence for the need of muscle power production. Furthermore, improvement in power is key to maintaining the abilities that allow independence throughout later life.

Similar to the study previously mentioned, authors Bassey et al. (1992) examined the relationship between maximal power output of the leg extensors to functional performance measures. Participants (n = 26) were men and women in the eighth decade of life who performed several trials of the timed chair rise, stair climb, and six meter walk to obtain functional performance scores. Single repetition leg extension power was shown to be significantly correlated ($p < .05$) to all functional performance measures. The researchers also noted that women demonstrated significantly ($p < .05$) less extensor power than men. They further conclude that the measurement of leg extensor power in frail elderly men and women can be useful in focusing on an effective rehabilitation program.

The previous two studies are just another demonstration of the importance of not only the measurement of leg extensor power but also its relationship to elderly functional performance. It is from this evidence that the principle investigator chose to include the measurement of leg extension power in the proposed research study.

Other studies have also provided similar evidence to the relationship that is shared between muscle power and functional status. In their 1999 study authors Foldvari et al. researched the factors that were most relevant to functional independence in older adults. The researchers compared peak muscle power to self-reported functional status in 80 sedentary community-dwelling elderly women (mean age 74.8 ± 5.0 years). Data for this study was collected from a previous one year randomized controlled clinical trial that distributed participants to a strength, power, or endurance training program. Using a forward stepwise regression model the researchers reported that leg power had the strongest correlation to self-reported functional status, accounting for 40% of the variance in functional status. From these results the authors go on to state that leg power is a strong predictor of functional status in elderly women.

While the authors of this study did not carry out their own intervention for their study, the analysis they provide does lend significant credibility to the relationship that is shared between muscle power and functionality. While self-reported functionality is dependent on the participant's honesty (Foldvari et al., 1999), in analyzing their own functional status the research compiled by the authors does provide more of a foundation for determining the relationship between functionality and muscle power.

In a study by Fielding et al. (2002); the authors state that peak power declines more precipitously than strength with advancing age and is a reliable measure of impairment as well as a strong predictor of functional performance. Due to this decline in muscle power, the authors examined the effects of high-velocity resistance training compared to traditional resistance training on one repetition maximum (1-RM) and peak power production for the leg press and knee extension. Participants for the study were women (n = 30) aged 73 years old and over. They were placed in a 16-week exercise intervention. Participants were randomly assigned to either a high velocity or low velocity group with both groups performing three sets of eight to ten repetitions at 70% of 1-RM on three days of the week. After the intervention the authors report that the high velocity group had significantly higher power during training session ($p < .001$) than the low velocity group. Furthermore the high velocity group also had significantly higher leg press power at 40-90% of 1-RM load ($p < .05$). From these results the authors conclude that improvements in lower extremity peak power may exert a greater influence on age-associated reductions in physical functioning than other exercise interventions.

The authors of this study provide an example of the importance and benefits of power training for the lower extremities. The results of this study showed statistically significant differences between the two training groups providing more evidence for the need of this specific training modality (Fielding et al., 2002). The findings of this study and the others like it only signify the importance of power training for older adults and the significant relationship that exists between lower body muscle power and functionality in older adults.

Force Production Loss

As we age our bodies experience declines in both muscle power and functional ability. It is this process of muscle power loss that leads to significant losses in the ability to independently perform activities of daily living (Hazel, et al., 2007). This muscle power decline can be traced to two factors: the age related loss of muscle mass known as sarcopenia and more specifically the loss of fast twitch muscle fibers (Esposito, Malgrati, Veicsteinas, & Orizio, 1996). In their 1996 study authors Esposito et al. examined the influence of the aging process on the properties of surface electrical and mechanical activity of muscle. The authors compiled a population of 20 healthy elderly adults (n = 10 men, n = 10 women) between the age of 65 and 78 years old and 20 health young adults as a control. The researchers examined the root mean square (RMS) and the mean frequency (MF) of the distribution of the power density spectrum of the biceps brachii muscle using surface electromyogram (EMG) and sound myogram (SMG) during elbow flexion at maximal voluntary contraction (MVC). Results of the study showed that MVC was lower in the elderly subjects when compared to the young control. The elderly also displayed a lower RMS and MF of surface EMG and SMG. The authors conclude that these results are due to the reduction in the number of muscle fibers and specifically the lack of fast twitch muscle fiber units in the elderly.

Researchers know the important role of muscle power in maintaining functionality in the elderly, but the decline in the ability to produce muscle power has always been grouped into the generic category of sarcopenia. In this study however, Esposito, et al. (1996) provide specific evidence that the loss of muscle power is not only due to the overall loss of muscle mass as we age but specifically due to the loss of fast twitch muscle fibers throughout the aging process. While the authors' evidence depicts how an elderly individuals drop in muscle power is due to Type II muscle fiber loss, the question of gender differences in fast twitch muscle fiber deterioration need to be examined.

In their 2001 study Krivckas et al. determined the age and gender related differences in maximum shortening velocity (MSV) of Type I and IIa single muscle fibers among older adults. In their study the authors collected percutaneous needle biopsies of the vastus lateralis muscle in 31 healthy subjects and were broken up into categories of young men (YM)(n = 7), young women (YW)(n = 7), older men (OM)(n = 12), and older women (OW)(n = 12). The authors used a method referred to as the Slack Test to determine MSV of individual fibers while also identifying fiber type through myosin heavy chain isoform identification. Results of the study state that among men, MSV was significantly reduced with age in Type IIa fibers ($p < .05$) but unchanged in Type I fibers. The authors go on to state that OW had a significantly lower MSV when compared to OM in both Type I and IIa fibers ($p < .05$) and that the age and gender-related differences in MSV may partially explain the impairments in muscle function that occur with the aging process. Additionally, greater impairment in muscle function was observed in OW when compared to OM.

The importance of this study is evident since it demonstrates the difference between older men and women when it comes to the production of muscle power. From the author's research it can be determined that not only do older women produce less muscle power in Type I and IIa muscle fibers but that this specific loss of fast twitch muscle fibers may explain the decline in muscle function for older women. From the literature cited previously it is clear that the loss of muscle power production in the elderly is not only an issue of sarcopenia but also a distinct loss in fast twitch muscle fibers. Furthermore the literature has also demonstrated the need for muscle power measurements in elderly women since they experience a significant loss of fast twitch muscle fibers compared to elderly men.

Yet another study that examined the loss of explosive force through the aging process came from authors Hakkinen et al. (1998). In their study the authors examined cross sectional area, leg extension power from a sitting position, squat jump, and standing long jump in men and women (n = 42) between the ages of 40-70 years old. Conclusions of the study explain that the decrease in explosive force in the elderly is due to the atrophy of muscles throughout the aging process and with greater atrophy being present in the fast-twitch muscle fibers.

From this study and the others mentioned before the need to battle against the age related loss of muscle mass is specifically important when it comes muscle power. With evidence from all three studies suggesting that the decline in muscle force production in terms of muscle power coming from the deterioration of fast-twitch Type IIa muscle fibers, the design of a field test for measuring and monitoring muscle power over time is in high need.

Measuring Functionality

Different measures of functionality have been discussed throughout the review of literature when being compared to lower extremity muscle power. Due to the overwhelming amount of options provided in the literature for the measurement of functionality the 8-Foot Up-and-Go test (Timed up-and-go test) was chosen by the principle investigator for its simplicity and abundant backing by research literature. In their 1991 study authors Podsiadlo and Richardson evaluated the Timed Up-and-Go test as a valid test of functional mobility in older adults. Participant (n = 60) were men and women with a mean age of 79.5 years and assessed on how much time it took them to rise from a seated position, walk three meters, turn, walk back, and sit down again. Results of the study showed that the Timed Up-and-Go test has strong correlations with the Berg Balance Scale (r = -.81), gait speed (r = -.61), and Barthel Index of ADLs (r = -.78). The authors conclude at the end of their study that the Timed Up-and-Go test is a reliable and valid test for quantifying functional mobility. The authors go on to state that the test requires little special training or equipment and is a quick evaluator of functionality in older adults.

The 1991 study authored by Podsiadlo and Richardson provides a starting point for evaluating the ability of the 8-Foot Up-and-Go test to measure functionality. In their study Podsiadlo and Richardson provide clear results of the importance and validity of this test protocol while also providing the reader with detailed instructions for recreating the test protocol if one did not have prior knowledge of the test. Further review of the literature will continue to provide evidence of the reliability of the Timed Up-and-Go test as a measure of functionality.

In two more recent studies conducted by Mard et al. (2008) and Machado et al. (2010), the Timed Up-and-Go was used as a measure of functional mobility in older adults. In the 2008 study by Mard et al., the researchers used the Timed Up-and-Go test to assess functional mobility in 43 elderly adults that had experienced hip fractures. Similarly in the 2010 study by Machado, Garcia-Lopez, Gonzalez and Garatachea , they used the Timed Up-and-Go test as a measure of functional mobility in older adults. The authors recruited older women (n = 26) with a mean age of 77 years old. Participants were enrolled in a 10-week exercise intervention to determine its effects on mobility, muscle power, and muscular strength. Participant's best time out of two attempts in the Timed Up-and-Go test was recorded and used as the functional mobility score for the study.

These two studies represent more documented evidence of the Timed Up-and-Go test as a valid and reliable measure for functionality in older adults. Both studies specifically look at the role of the Time Up-and-Go test as a measure of functionality in elderly women over the age of 75 years old while Mard et al. documents the use of this functional mobility test in elderly women who have recently experienced hip fractures.

Even more evidence suggests that the Timed Up-and-Go test is reliable for elderly adults with functional disability. In their 2001 study Morris, Morris, and Lansek examined retest reliability, the inter-rater reliability, and sensitivity of the Timed Up-and-Go scores for detecting change in mobility of 12 participants with Parkinson Disease. Participants performed five trials of the Timed Up-and-Go and then had their scores compared to age matched individuals without Parkinson Disease. After comparison the Timed Up-and-Go interclass correlation level was reported as high ($r = .87$). The authors concluded the study by stating that the Timed Up-and-Go test was useful and reliable in detecting differences in mobility performance between participants with and with out Parkinson Disease.

The purpose of this proposed study was to provide more evidence to promote the Timed Up-and-Go protocol as a valid and reliable method for testing elderly individual's functionality. While no participants in the study were affected with mobility limiting disease, it is useful to determine that even those individuals that have limited mobility can take part in the Up-and-Go protocol. The Timed Up-and-Go protocol can be seen as valid and reliable for use with any condition an elderly individual might have as long as they are able to understand and follow the directions and instructions of the testing protocol.

While the last two studies (Mard et al., 2008; Morris, Morris, and Lansek, 2001) describe the use of the Timed Up-and-Go test as a measure of functional ability, the specific protocol used for the proposed research study by the principle investigator comes from a study conducted by Rikli and Jones (1999). In their study the authors described a comprehensive functional fitness test that provided specific information regarding a client's physical strength and weaknesses associated with functional tasks and activity goals important to everyday living. The authors went on to state that the 8-Foot Up-and-Go is a validated test that specifically measures agility and dynamic balance in the elderly. Normative values for the 8-Foot Up-and-Go among senior women are dependent upon age but for participants aged 65-89 years old, like the ones in this proposed study, Timed Up- and-Go scores can range from 4.8 - 9.0 seconds depending on age. In their results Rikli and Jones describe the interclass reliability of their testing protocol to be strong (r = .81 - .95) when measuring functional fitness in older adults.

The study conducted by Rikli and Jones (1999) provides a direct validation of the specific 8-Foot Up-and-Go testing protocol that was used by the principle investigator. Not only does this study validate the 8-Foot Up-and-Go test as a measure of functional ability but it also provides normative values for the testing protocol for the varying age ranges that were involved in the study. From this study and the ones prior, it can be determined that the 8-Foot Up-and-Go test is a valid and reliable tool for measuring functional ability in elderly adult women.

With the 8-Foot Up-and-Go test being determined as the best field test protocol for measuring functional ability in older adults, the need for determining the test's ability to measure large amounts of people quickly remains. In their 2006 study Belza et al. describes the effectiveness of a community-based exercise group had on functional performance and health status in older adults. Participants (n = 2,889) performed functional testing using the Senior Fitness Test (SFT) protocol described by Rikli & Jones (1999) at the four and eight month marks of the year-long program. Testing all seven protocols of the SFT proved to be too labor intensive with this large amount of participants so the authors describe that four of the seven tests were taken out of the functional testing protocol. Of the remaining three tests (Arm Curl, Chair Stand, and 8-Foot Up-and-Go), the 8-Foot Up-and-Go tests was chosen as the most reliable measure of functional balance and mobility.

The study conducted by Belza et al. demonstrates not only the reliability of the 8-Foot Up-and-Go test as a measure of functional ability, but it also cements the test protocol's ability to quickly and accurately measure large numbers of participants over a short amount of time. While the study did not include 2,889 participants like the study mentioned above, there would be a need to measure 15 or more participants at different sites across Edmond, Oklahoma. From this study and the others described in this section, the 8-Foot Up-and-Go test has shown to be the most accurate and feasible method for field-testing functional ability in older adults.

Measuring Power

With the development of research and literature showing the relationship between muscle power and functionality, different methods for measuring muscle power have been developed. Two specific studies conducted by Dr. Paulo Caserotti (2008) demonstrated what some might refer to as an extreme way of measuring muscle power in older adults through the use of the squat and counter movement vertical jumps. In their 2008 study Casserotti, Aagaard, and Puggaard examine the role that concentric muscle power plays in the frailty and functional impairments of elderly adults over a 36-week training intervention. The authors measured velocity, power, and the acceleration of body's center of mass using the squat (SJ) and countermovement (CMJ) vertical jumps in 161 healthy elderly males. Similarly another 2008 study conducted by Caserotti, Aagaard, Buttrup Larson, and Puggaard investigated the effects of a 12-week explosive resistance training program on maximal muscle power. The authors assessed maximal muscle power production in 28 community dwelling elderly women ranging in age from 60 – 89 years old using the countermovement vertical jump (CMJ). During the conclusion of this study the authors state that the findings of the study communicate that explosive resistance training is a well tolerated protocol for training and testing among community dwelling elderly women into their eighth decade.

Both studies described above provide a reference parameter for the testing of muscle power in elderly subjects. Both vertical jump protocols require a large amount of explosive force to propel the individual's body mass up in the air for a measureable vertical jump. These studies represent how extreme methods of measuring muscle power are acceptable and well tolerated in elderly men and women even though these protocols initiate a high impact force upon the lower body. For this research study, all power testing protocols involved zero impact force upon the participant's lower extremities since each testing protocol requires one or both feet to stay planted on the ground. The participants were required to complete a squat as a measure of muscular power, the SJ represents a close comparison to the squat method of measuring muscle power due to their similar movements and body position during the test.

While the studies conducted by Dr. Paulo Caserotti investigated power measures through the use of the vertical jump, many other studies use less ballistic movements in their muscular power measurements. The use of the leg extension as a means for measuring lower body muscular power is evident throughout literature due to the low impact involved in testing and the protocols requirement that the participant be seated during the exercise. In their 2008 study Reid et al. examined the impact of high-velocity high-power training on improving lower extremity muscle power in 57 older adults who ranged in age from 65-94 years old and suffered from mobility impairments. Peak power was measured using the seated leg extension and leg press with both protocols being well received by the participants during the 12-week training program. Similarly in 2009 authors Junichiro, Chizuko, Satoshi, and Naokata examined the force-velocity and force-power relationships between bilateral and unilateral knee extension movements between young and elderly women. Twelve healthy elderly women between 60-82 years old and 12 healthy young women between 19-31 years old performed unilateral and bilateral knee extension movements on a dynomometer against controlled resistance loads. Results of the study determined that maximum power output differences between young and elderly women in the leg extension were more dependent upon a loss of force generating capacity of the muscles.

Both of the studies (Reid et al. 2008; Junichiro et al. 2009) documented above speak to the usefulness and availability of low impact muscle power measures for elderly participants. Unlike the vertical jump protocols, the leg extension testing method provides the participants with the opportunity to remain seated during testing. The leg extension protocol also allows for elderly participants that experience mobility limitations to participate in muscular power testing unlike the vertical jump protocol. While the leg extension power testing protocol is documented throughout literature as a popular method for lower extremity power testing, validity and reliability figures are still needed to properly evaluate the protocol's inclusion in the proposed research study.

To determine the reliability and validity of the leg extension as a measure of power, the study by Bassey and Short (1990) was used. In their study the authors stated that the leg extension is a safe and acceptable explosive power measure for all age groups and levels of physical capability. Reliability of leg extension power measurements were evaluated in 46 individuals ranging in age from 20-86 years old. All participants performed five trials of maximal leg extension exercises on two separate occasions with a week of rest between each trial. Maximal leg extension power was recorded for the best score from each five trial performance and recorded by the researchers. Results of the study showed no significant difference ($p > .05$) between test re-test reliability with a coefficient of variation determined to be 9.4%. When leg extension power was compared to squat jump power on a force plate there was a highly significant correlation in Spearman's rank correlation (rho = .73, $p < .001$).

The importance of this study was determined due to its evaluation of the validity and reliability of the leg extension as a measure of lower extremity muscle power. The authors provide statistical evidence to the importance of this protocol's inclusion in this research study while also stating that the leg extension protocol is a safe and effective tool for measuring muscle power in all age groups and even those with functional limitations.

With the leg extension protocol for muscle power testing being determined as a valid and reliable test through the reviewed literature sources, the need for determining the role of the chair-stand as a lower extremity muscle power determinant is evident. In a study conducted by Nicholson and Emes (2000) the effect of strength training on the vertical force of a chair rise in the elderly was researched. Elderly adults ($n = 14$) with a mean age of 73 years were randomly assigned to either a strength training intervention or an active control group. The vertical force-time curve of a fast chair rise was measured before and after the 12-week intervention period with peak slope being used as an indicator of power in the elderly participants. While moderately intense resistance training was shown to provide improvements in power and force of a chair rise the authors go on to state that the chair rise test protocol provides a very sensitive evaluation of lower extremity performance over time.

The importance of this study by Nicholson and Emes (2000) comes from their use of the chair stand as a measure of lower extremity power. Another study examined for this literature review (Rikli & Jones, 1999) used the chair stand as a measure of lower body strength. Due to the use of the chair stand protocol being included as a measure of lower extremity power in the principle investigator's study the above mentioned research study provides a documented example of the reliability of the chair rise as a measure of power in the elderly.

To assess lower body power the participants will be performing the exercises examined above while attached to the Tendo Fitrodyne Power Analyzer (Fitrodyne). This machine will allow the principle investigator to get a direct digital measure of the lower body power output produced from each participants testing repetition. Literature has been identified that demonstrates the versatility of the Fitrodyne as a means of measuring power. Ghigiarelli et al. (2009) used the Fitrodyne as means to measure upper body strength in 36 college football players by attaching the Fitrodyne tether to the barbell during an explosive bench press testing protocol. Power testing involved a pre and post-test separated by eight weeks where participants performed a five-repetition maximal power bench press during each session.

In another study that examined the versatility of the Fitrodyne Jones, Fry, Weiss, Kinzev, and Moore (2008) used the machine to compare the kinestic characteristics of the power clean exercise using free or machine weights. The authors report that the Fitrodyne Power Analyzer was used to assess velocity by attaching the tether to the ends of either the free weights or barbell while having the participants perform an Olympic clean lift. All participants (*n*=14) were men (age = 24.9 ± 6.2 years) with no previous Olympic style lifting experience. The authors conclude in their methods section that the Tendo Weightlifting Analyzer provided a reliable method for measuring muscle power.

Both of the studies summarized above provide an example of the different ways the Tendo Weightlifting Analyzer has been used in different research studies. One important reason the Tendo Weightlifting Analyzer was chosen for this study was because of its versatility and reliability. The studies examined above echo the same thought by showing the Tendo Weightlifting Analyzer can be used for upper body power determination through the bench press and that it can be used in a complex Olympic lift modality. Both studies are using the Tendo Weightlifting Analyzer in a non-conventional way since much of the available research uses the Tendo Weightlifting Analyzer as a means of measuring lower body power through the squat or knee extension.

While the previous studies examined the versatility of the Tendo Weightlifting Analyzer, the following ones will provide evidence of the Tendo Weightlifting Analyzer's use in more conventional methods. The Tendo Weightlifting Analyzer is a relatively new piece of equipment and, to the best of the principle investigator's knowledge, has yet to be applied to lower body power assessment of elderly women. Due to this lack of literature the following reviews will include college age athletes.

Literature is available to assess the ability of the Tendo Weightlifting Analyzer as a way to assess lower limb muscle power in college men and women athletes (Rhea, Peterson, Oliverson, Ayllon, & Potenziano, 2008; Rhea, Peterson, Lunt, & Ayllon, 2008; Rhea & Kenn, 2009) and will be reviewed in the following studies. In a 2008 study authors Rhea, Peterson, Oliverson, Ayllon, & Potenziano used the Tendo Weightlifting Analyzer as a means of measuring lower body muscle power in 40 Division One male and female college athletes. The researchers measured lower body muscle power before and after a 12-week training intervention and then compared the power measure to the training variables to determine if a difference in lower extremity power existed. Lower limb muscle power was assessed by attaching the tether line of the Tendo Weightlifting Analyzer to a squat bar. As the participant performs a weighted squat the tether was pulled and power was measured by the Tendo Weightlifting Analyzer. In another 2008 study by Rhea, Peterson, Lunt & Ayllon the Fitrodyne was used as a measure of lower limb power in athletes. Sixty-four high school athletes (*n* = 50 boys, *n* = 14 girls) were divided into two groups for an assessment of a new training intervention on lower body muscle power. Once again the Tendo Weightlifting Analyzer was used to assess lower limb muscle power by attaching the Tendo Weightlifting Analyzer tether to the barbell during a weighted squat. In his most recently published study using the Tendo Weightlifting Analyzer, Rhea and Kenn (2009) used the Tendo Weightlifting Analyzer once again to analyze lower body power output during the squat of 16 college male athletes. Each participant performed two sets of three squats with three minutes of rest between each set. Lower body muscle power was analyzed with the same procedures as the previous two studies and then compared to the training variable that was being tested.

All three of these articles represent examples of the recent use of the Tendo Weightlifting Analyzer as a reliable measure of lower limb muscle power. These examples demonstrate that the power analyzer can be used in a similar fashion as this research study, and is appropriate for measuring large numbers of participants in a relative quick amount of time. While the studies reviewed above were conducted with a college aged population and not the specific population of the principle investigator's study, they do offer an example of the growing trend of the use for the Tendo Weightlifting Analyzer.

As the previous reviewed articles have demonstrated the use of the Tendo Weightlifting Analyzer is a growing trend for the assessment of muscle power. The previous articles have only demonstrated the versatility and procedures for using the Tendo Weightlifting Analyzer; however, the determination of the Tendo Weightlifting Analyzer as valid reliable tool still needs to be addressed. The 2005 study by Jennings, Viljoen, Durandt, and Lambert provide one such study that specifically answers that need from the literature. The authors examined the repeatability of measurements taken from 30 male subjects during the squat jump and biceps curl exercises. Each participant performed six repetitions of both exercises at varying loads of resistance. Maximum power measurements for each protocol had interclass coefficients of (r =.97). The authors stated in their conclusion that muscle power can be measured with a high degree of reliability using the Tendo Weightlifting Analyzer system.

This article was the only one found by the principle investigator that specifically tried to validate and demonstrate the reliability of the measurements from the Tendo Weightlifting Analyzer system. While the previous studies provided examples of its use in power measurements only Jennings, Viljoen, Durandt, and Lambert (2005) statistically examined the machines validity. From this research study it can be determined that using the Tendo Weightlifting Analyzer is a valid and reliable way of assessing the participant's lower limb muscular power for this study.

The articles for this literature review were chosen because of their relationship to the topic of measuring muscle power in elderly adults. The reviewed research has demonstrated that when it comes to the need of measuring muscle power in the elderly there is no specific field test designed. The articles above have provided evidence that the protocols and equipment for each test have been determined to be reliable and valid from past research. Due to this need for a field test to be determined and compared to functional ability in older adults, this study provided data that can help fill that need and provide useful tools for helping independent living seniors.

Chapter Three: Methods

Participants

The participants for the study (*n*=15) were females over the age of 70 years. The older adult participants for this study were fully functional with no limiting mobility issues when performing the required testing protocols. Participants were either living independently, living within the community of Edmond, or independently living within a retirement community or residence. Participants for this study were involved in a twice a week resistance training program and were familiar with the testing protocol. Medical clearance was granted prior to participation in the resistance training program and all testing procedures are similar to exercise performed during training. Informed consent was obtained from each participant in accordance with the guidelines set by the Institutional Review Board of the University of Central Oklahoma.

Instruments

To assess lower body power of the participants the Tendo Weightlifting Analyzer was used. The Tendo Weightlifting Analyzer unit requires the weight of the participants to be entered during the preparation before the testing protocol is to be started. Once the participant's weight in kilograms has been entered, the Tendo Weightlifting Analyzer until is ready for testing. The Tendo Weightlifting Analyzer unit utilizes a tether line that can be attached to the lower body during testing by a Velcro strap. When the attached tether is pulled quickly the Tendo Weightlifting Analyzer unit can determine the power output during the movement by measuring the distance the tether moved and the time it took to move over the specific distance. With the participants weight already entered the Tendo Weightlifting Analyzer unit will then display the participants: average power, peak power, average velocity, and peak velocity for that specific movement. During each individual repetition of an exercise, the Tendo Weightlifting Analyzer unit will take multiple measurements of power and velocity. The participants displayed peak power represents the highest amount of power that was produced during the specific exercise movement while the average power is the mean of the multiple power output measurements taken during each individual attempt. The velocity measurement is conducted in the same way as power, requiring the Tendo Weightlifting Analyzer unit to take multiple velocity measurements during each individual attempt. Average power and peak power are displayed on the Tendo Weightlifting Analyzer unit in Watts, (Jennings, Viljoen, et al, 2005) while average velocity and peak velocity are displayed in meters per second.

The principle investigator of this project had easy access to the University of Central Oklahoma Tendo Weightlifting Analyzer Training Unit through the Kinesiology Laboratory in the Wellness Center. Over the past two years the principle investigator has worked closely with University faculty and has become highly trained and familiar with the Tendo Weightlifting Analyzer unit and its assembly and performance evaluation.

Equipment needed for the 8 Foot Up and Go (up and go) is minimal. The up and go test instructs the participants to rise from a seated position on a chair and walk around a cone or marker eight feet from their chair and back to their seated position. A stopwatch was required for this specific test since functional ability was determined from the participant’s time to complete this testing protocol. A standard three-button stopwatch was utilized for this project to measure up and go time while a chair and cone were available for use through the Kinesiology Lab in the University of Central Oklahoma's Wellness Center.

Procedure

Each participant's name was placed into a Microsoft Excel spreadsheet and assigned to a testing order for each of the testing protocols through random assignment. Each participant's testing order and power testing protocol order were randomly assigned using this method. Participants were instructed to perform four different multi-joint movements using the Tendo unit to determine lower body power. Each multi-joint movement required the participant to perform 10 repetitions with one minute of rest being taken by the participant between each repetition. Testing was conducted on non-consecutive days and only one of the four protocols was measured each day to limit fatigue in the participants. It took between 10 and 13 minutes to complete each of the four multi-joint testing protocols with testing being conducted in either the Kinesiology Lab in the Wellness Center or the participant's resistance training exercise site location. The average of the ten trials for each of the four power tests was calculated and used during statistical analysis of the study.

The first multi-joint movement that was tested was the Tendo Weightlifting Analyzer chair stand. This movement required the participants to go from a seated position to a standing position with knees straight, as fast as possible. The Tendo Weightlifting Analyzer unit was attached to a light stick or rod that the participant was holding across their chest during the movement for power to be measured. Once the multi-joint power testing protocol was completed, the principle investigator conducted the squat protocol. This testing protocol required the participants to go from a standing position with feet shoulder width apart to a squatted position by flexing the knees. Participants were instructed by the principle investigator to squat down to a comfortable position without letting their knees “go over their toes” which would indicate that the participant is leaning too far forward and putting unintended stress on their knee joint. Once the participant achieved the appropriate squat position, the instructor commanded the participant to “explode up” when they were ready causing the participants to straighten their legs at the knee and hip joints ending at a fully upright standing position. The Tendo Weightlifting Analyzer tether was attached at the participant’s waist during this testing protocol by placing the Velcro strap through a belt loop or waist attachment that was available.

The Tendo Weightlifting Analyzer lunge testing protocol is similar to the squat in that it requires the participant to flex at the knees dropping their center gravity down and then raise back to the starting position as fast as possible. The lunge protocol however requires the participant to stand with their feet wider apart and toes facing out instead of straight ahead like in the squat. During the lunge protocol the participants had their feet past shoulder width apart with legs straight and knees extended. Once they were ready, the participant lowered their center of gravity and upper body down in a straight line by flexing at the knees and hips. Once in the “down” position the participants extended up as fast as possible back to the straight leg starting position. The Tendo Weightlifting Analyzer was attached to the participant in a similar way as the squat protocol so lower leg power could be determined.

The final Tendo Weightlifting Analyzer testing protocol required the participants to perform a single leg extension with the participant’s dominant leg while seated. The weight of the participant's dominant leg was utilized to determine their power output during this power testing protocol. The dominant leg weight was determined using a G.E. Dual X-Ray Absorptiometry Machine (iDexa). This protocol required the participants to start in a seated position with their dominant leg under their chair as far back as possible. Once the participant was in the proper starting position they were instructed to extend their foot out as fast as possible by straightening their leg. The participants will remain seated during this entire testing protocol with the Tendo Weightlifting Analyzer tether being attached around the ankle.

The final testing protocol that was used in the project was the 8 Foot Up and Go. This protocol required the participant to begin the test in a seated position with a cone or marker placed eight feet from the chair. On the "Go" command, the participant rose from the chair and walked as fast as possible around the cone located eight feet from the chair and then back to the chair and into a seated position. The principle investigator began timing once the participant started to move out of their seated position and ended timing once contact was made by the participant to the chair when sitting down again. A practice trial was given to the participant before two trials are timed and recorded for the study.

Design and Analysis

Analysis of the relationship between the four multi-joint lower body power testing protocols and functionality through the 8 Foot Up and Go protocol was conducted using the statistical analyzing software SPSS version 18. Using the average and peak power output that was measured for each of the four power testing protocols for each participant four Pearsons Product Moment Correlation Coefficient tests were conducted to determine which specific power testing protocol was most related to an individual's functional ability. Due to the inflation of the Alpha level when conducting multiple Pearsons Product Moment Correlation Coefficient tests the principle investigator utilized the Bonferroni Adjustment to maintain valid statistical findings. Due to the Bonferroni Adjustment being utilized in this study the level of significance is dropped for this study from .05 to .01. There were no specific studies identified by the principle investigator that evaluated lower body power of older adults using the Tendo Weightlifting Analyzer making validity and reliability difficult to determine from the past research using this specific unit.

Data does show, however, that similar methods to the ones found in this study have been shown to be valid measurements of lower leg power. In a 2007 study (Callahan, Phillips, Carabello, Frontera, & Fielding, 2007) it was determined that multiple attempt pneumatic power testing of the leg press and leg extension was significantly better than single attempt isokinetic muscle power testing procedures in older adults ($p<.001$)(Callahan, Phillips, Carabello, Frontera, & Fielding, 2007). Lower body muscle power testing using the leg extension and leg press protocols has also shown to be correlated with functional ability ($r=.74$, $r=.96$) in older adults (Shroeder et. al., 2007). These studies and other like them (Bassey et al., 1992; Bean et al., 2002) show that the effect size for power and functionality can range from $r=.65$-.88 and that the testing procedures used in this project are similar to other previous studies in older adults. To achieve an effect size of .65 a needed population for significant findings was 15 participants.

Chapter Four: Results

The primary objective of this research was to determine if there is a statistical relationship between any of the four field testing power measures and the functionality measurement. The field testing methods for determining power were the: Chair Stand, Squat, Leg Extension, and Lunge, while the method used to determine functionality was the 8-Foot Up-and-Go Test. The researcher compared the average power output from each field power testing protocol and the peak power output to the 8-Foot Up-and-Go Test individually to determine if a statistical correlation was present between one or more power and functionality measures. A secondary purpose of this study was to then examine these results to infer if one of the described field-testing methods for power could be used to also predict functionality.

Participants completing the Chair Stand field-testing protocol did so with an average power output of 497.63 ± 141.97 Watts. Mean power output for the Squat, Leg Extension, and Lunge power test protocols were 412.81 ± 147.17 Watts, 156.23 ± 34.99 Watts, and 334.90 ± 101.87 Watts respectively. Average time for the completion of the 8-Foot Up-and-Go Test was 5.43 ± 1.37 seconds. Descriptive statistics for the 8-Foot Up-and-Go Test and each of the power field-testing protocols can be found in Table 1.

Table 1

Descriptive Statistics of Average Power Testing Protocol

Variables	M±SD	Skewness	SE_{SKEW}	Kurtosis	SE_{KURT}	Minimum	Maximum
Up-&-Go	5.42±1.37	.865	.580	1.07	1.12	3.57	8.75
Chair Stand	497.63±141.97	-.134	.580	-.989	1.12	264.0	709.3
Squat	412.81±147.17	-.179	.580	-1.07	1.12	161.0	658.0
Leg Extension	156.22±34.99	.382	.580	-.975	1.12	109.0	223.2
Lunge	334.89±101.87	.014	.616	-.655	1.19	158.6	493.2

Note. SE_{SKEW} = Standard Error of the Skewness; SE_{KURT} = Standard Error of the Kurtosis; Up-&-Go = 8-Foot Up-and-Go Test.

Functionality and Power

The research hypothesis was the Chair Stand power test would be the most closely correlated with the 8-Foot Up-and-Go Test of functionality. The rationale was the Chair Stand's movement being the most similar to an everyday activity and its necessity for completion requires synchronized and coordinated multiple muscular contractions in an effort to forcefully rise from a seated position. A significant negative relationship was determined to exist between the 8-Foot Up-and-Go Test and the Chair Stand looking at the average power output (r = -.672, p = .006) and the peak power output (r = -.649, p = .009). This negative relationship indicates that participants who produced a higher power output during the Chair Stand were likely to have a lower (faster) 8-Foot Up-and-Go time score. Results from the Pearson's Product Moment Correlation tests can be found in Table 2 of this study.

In examining the secondary purpose of this study and trying to determine a field testing protocol that provided predictability of functionality through a power testing protocol, the principle investigator determined the chair stand provided that predictability. The chair stand utilizes the necessary coordination of the lower body muscles, the synchronization of lower body muscle power, and mimics the real world movement patterns and motion requirements to be predictive of functionality in older adult women. The principle investigator felt that the chair stand was more highly predictive in terms of functionality than the squat, lunge, or leg extension.

Table 2

Statistical Results of Pearson's Correlation Coefficient Test of Average Power Output

Variable	Up-and-Go	Chair Stand	Squat	Leg Extension	Lunge
Up-and-Go	----	-.672*	-.591	-.352	-.353
Chair Stand	-.672*	----	.880*	.604	.939
Squat	-.591	.880*	----	.593	.878*
Leg Extension	-.352	.604	.593	----	.545
Lunge	-.352	.939*	.878*	.545	----

Note. Up-and-Go = 8-Foot Up-and-Go Test of functionality; * $p < 0.01$;

Table 3

Statistical Results of Pearson's Correlation Coefficient Test for Peak Power

Variable	Up-and-Go	Chair Stand	Squat	Leg Extension	Lunge
Up-and-Go	----	-.649*	-.590	-.342	-.391
Chair Stand	-.649*	----	.820*	.591	.635
Squat	-.590	.820*	----	.703*	.858*
Leg Extension	-.342	.591	.703*	----	.747*
Lunge	-.391	.635	.858*	.747*	----

Note. Up-and-Go = 8-Foot Up-and-Go Test of functionality; * $p < 0.01$;

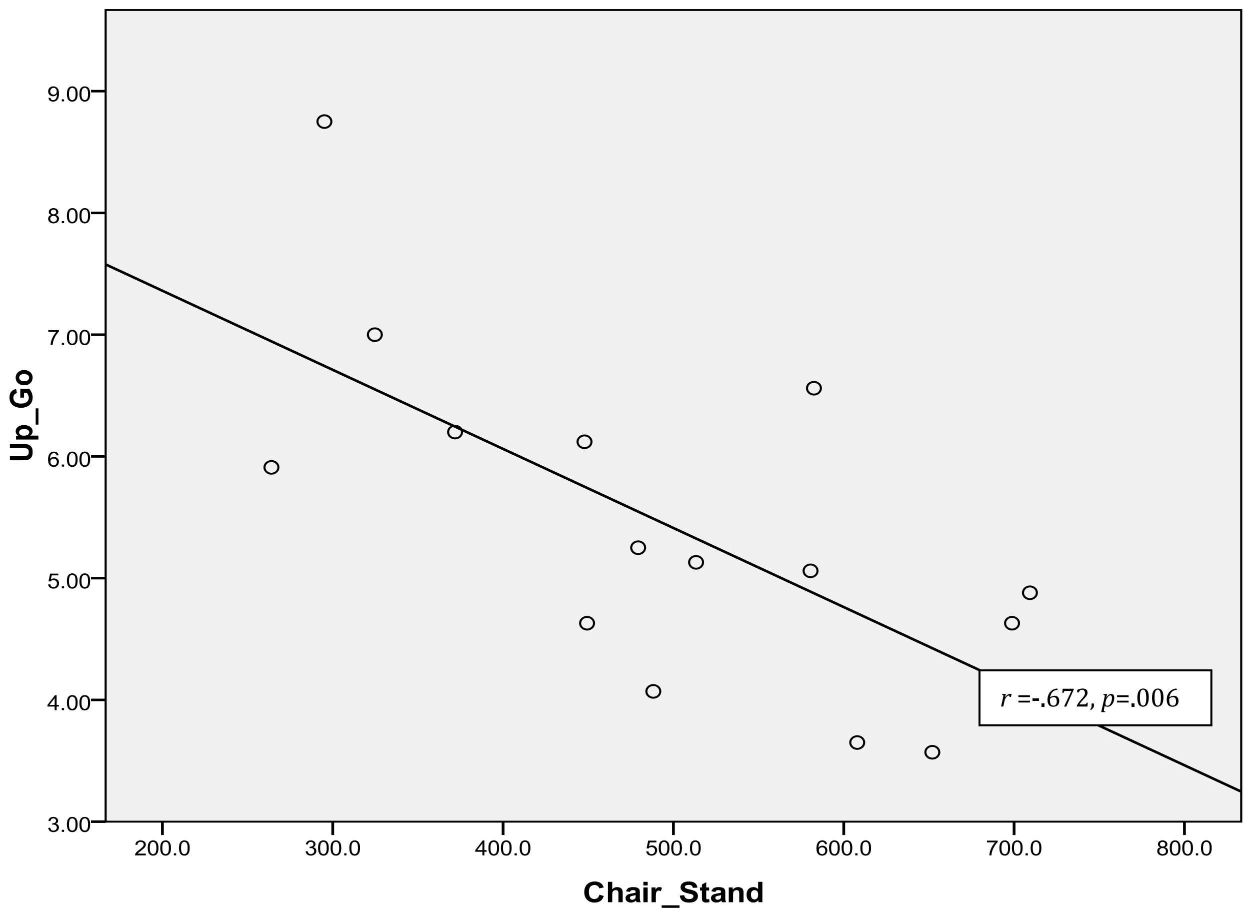


Figure 1. Scatter plot displaying the relationship between Chair Stand average power and 8-Foot Up-and-Go.

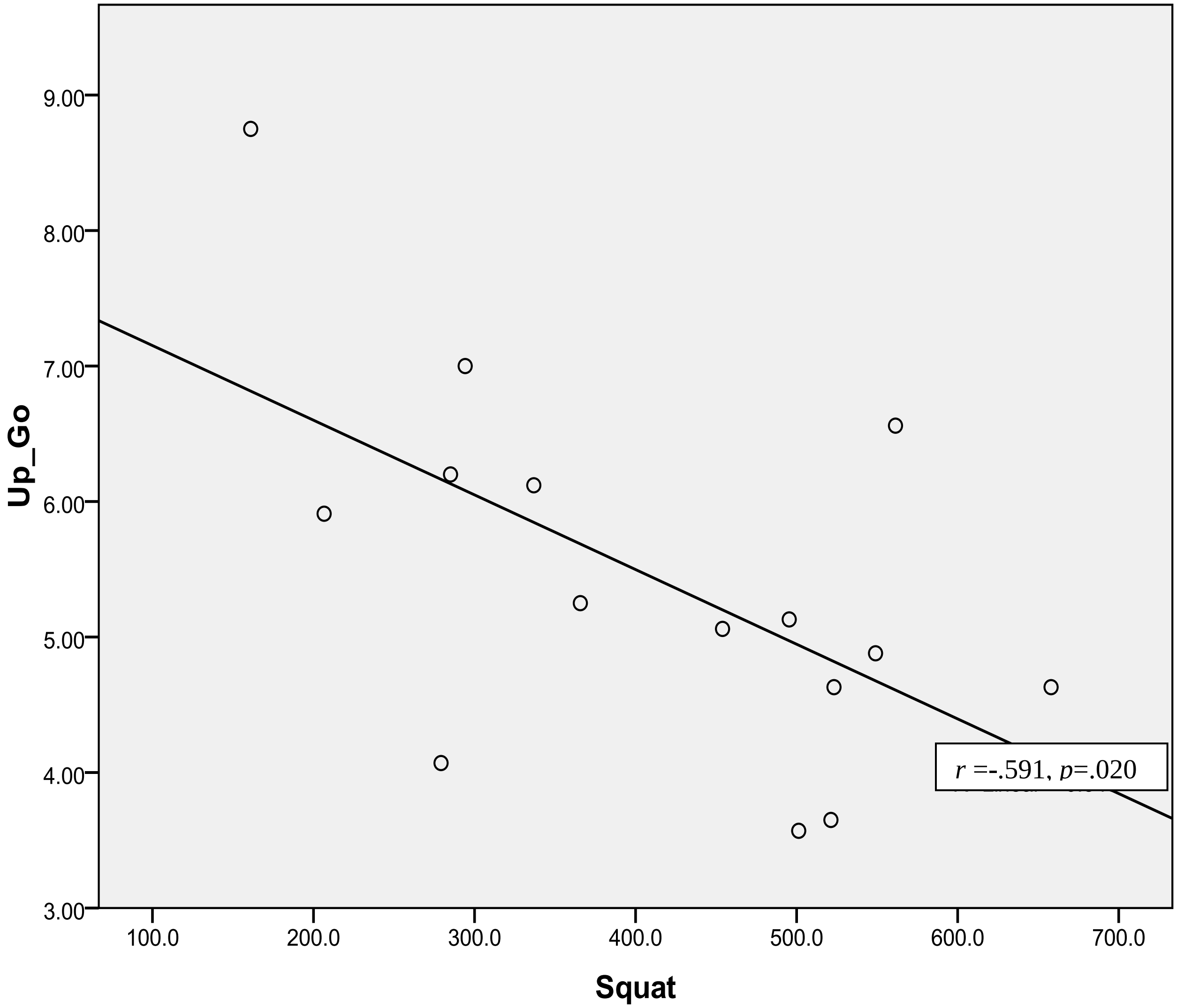


Figure 2. Scatter plot displaying the relationship between Squat average power and 8-Foot Up-and-Go.

Chapter Five: Discussion

The primary purpose of this research study was to determine if a relationship existed between multiple joint lower body power testing protocols and a validated functionality measurement. After data collection and statistical analysis, it was determined that one of the four power field testing protocols, the Chair Stand, showed a significant negative relationship with the 8-Foot Up-and-Go functionality test ($p = .006$). These results show that the participants', who produced a faster 8-Foot Up-and-Go score, also produced a higher power output during the testing sessions. Since the Chair Stand requires a generally higher level of muscular strength, power, and coordination to perform correctly and powerfully it is not surprising that this protocol showed a significant relationship with the 8-Foot Up-and-Go. As adults get older and begin to lose muscle mass, high-level functional tasks are most often the tasks that are the hardest to complete. The research shown here not only demonstrates that adult women over the age of 70 can complete high level power movements of increased difficulty but also that these field testing protocols for measuring power through the Tendo Weightlifting Analyzer can be compared and used to determine functional ability in older adult women.

Field Testing Methods

Using the described field-testing methods for measuring power was a process of ingenuity and patience. The Lunge proved to be the hardest testing protocol for the participants to accomplish since they were required to bend at both the knee and hip at wide angles. This puts increased stress on both of the joints and proved to be too difficult for some participants to complete. The Leg Extension testing protocol was the easiest for the participants to complete and required little previous practice or exposure for proper technique and completion since there was no hip movement or vertical component requiring the movement of the participant's body weight. Both the Chair Stand and Squat required the highest degree of skill since each protocol required enough strength to lift the participant's body weight, while maintaining balance, muscular coordination, and muscular power. When designing these field-testing protocols, each one was specifically chosen because of its difficulty or ease, required skill needed to complete, relationship to lower body functionality, and ease in administering the test in the field. Overall each test provided a clear picture into the relationship between lower body functionality and power in older adults.

From the results of the statistical analysis conducted and the experiences of the testing protocols it was determined that the chair stand power testing protocol provided the highest level of predictability for functionality through field assessment power testing protocols. The chair stand provides the researcher with the highest degree of lower body skill required to perform the power test. Because of this required skill and the chair stand's similarity to every day movements, the chair stand was shown to be the best predictor of functionality using a power test.

Limitations

After data collection and statistical analysis were completed the researcher identified some methodology limitations of the study. Data collection was to be conducted on 45 participants at four different resistance training exercise class sites over the course of the study. Once data collection started it was proven difficult to facilitate this amount of data collection at various sites due to scheduling conflicts between the site participants and the researcher. Two of the sites were located outside of the immediate area and initial planning called for data collection to be completed at the sites for the most convenience to the participants. This planning was put on hold due to unforeseen circumstances and the researcher was not able to fully accommodate all 45 participants in the attempt to collect all the necessary data. Due to these scheduling conflicts and travel distance the researcher was only able to collect full data sets on 15 participants. This still fell within the range to achieve a complete effect size for significant findings within the statistics.

A second limitation found with this study was the population utilized for this study. All women of this study were previously trained and over the age of 65 years old. Because of these limitations the author of this study could only apply the statistical findings of this study to older adult women over the age of 65 who had previous resistance training experience.

Other limitations found to be present within the study's design were found to be within the power testing protocols themselves. During the leg extension power testing protocol the participant's entire dominant leg weight was entered for power calculation. This did not represent a true representation of the power production since during the leg extension power testing protocol only the lower leg moved to produce power. Since the weight of the lower leg only could not be determined and the entire weight of the dominant leg had to be used this represented a limitation of this study.

The final limitation of this study was that the study examined only lower body power and did not examine any variables associated with upper body power. This limited the study results of this study to only the lower body and not total body power production.

Recommendations for Future Studies

Future studies involving lower body power and functionality in older adults can provide additional knowledge with regards to the study of Kinesiology. Examining the correlation between power and functionality in older male adults would prove future insight into this topic. The results of this study were determined using the average power output from the Tendo Weightlifting Analyzer but did not include the other figures produced during the testing procedures. The Tendo Weightlifting Analyzer provides a researcher with: average power, peak power, average velocity, and peak velocity. These measurements could be used in future studies to determine if any of the velocity or power measurements are correlated to functionality in older adults. Future research could also include the determination of which of the four measured outputs from the Tendo Weightlifting Analyzer are best at predicting functionality in older adults. Additionally, this line of research could examine various upper body power tests to determine which would correlate best with functionality in older adults and also provide a field-testing method that can predict functionality in older adults. Future researchers could also examine the differences and similarities between middle age adult population power production and senior adult power production. Examining these variables could provide future researchers with the ability to examine the potential relationships between disease contraction and the loss of power production. With the versatility of the Tendo Weightlifting Analyzer and the different validated measures available to future researchers, the limits on what can be accomplished in the area of power and functionality are only set by the researcher themselves.

Conclusions

From the results of this research project it can be concluded that there is a definite relationship present between one's ability to produce muscle power and their functionality in older adults. This is evidenced in the significant relationship present between the Chair Stand field-testing protocol when compared to the functionality test of the 8-Foot Up-and-Go. The use of the Tendo Weightlifting Analyzer to measure power output in adults has been tested and validated through past research (Jennings et. al., 2005). From this study it can be concluded that women over the age of 70 who produce higher levels of lower body muscular power will also have higher functional ability. Furthermore it can also be stated that there is a significant relationship between muscular power output and functional ability in older adult women.

References

Barr, E., Browning, C., Lord, S., Menz, H., & Kendig, H. (2005). Foot and leg problems are important determinants of functional status in community dwelling older people. *Disability & Rehabilitation, 27*(16), 917 – 923. Retrieved from http://www.informedwold.com/smpp/totle~content=t713723907

Bassey, E. J., Fiatarone, M. A., O'Neil, E. F., Kelly, M., Evans, W. J., & Lipsitz, L. A. (1992). Leg extensor power and functional performance in very old men and women. *Clinical Science*, *82*, 321 – 327. Retrieved from http://www.clinsci.org/cs/default.htm

Basey, E. J., & Short, A. H. (1990). A new method for measuring power output in a single leg extension: feasibility, reliability, and validity. European Journal of Applied Physiology and Occupational Physiology, 60(5), 385-390. doi: 10.1007/BF00713504

Bates, A., Donaldson, A., Castel, B., Krolik, P., & Coleman, R. (2009). Staying active, staying strong: pilot evaluation of a once-weekly, community-based strength training program for older adult. *Health Promotion Journal of Australia, 20,* 43 – 47. Retrieved from http://www.healthpromotion.org/au

Bean, J., Herman, S., Kiely, D., Callahan, D., Mizer, K., Frontera, W., & Fielding, R. (2002). Weighted stair climbing in mobility-limited older people: a pilot study. *Journal of the American Geriatrics Society, 50,* 663 – 670. Retrieved from http://www.wiley.com/bw/journal.asp?ref=0002-8614

Belza, B., Shumway-Cook, A., Phelan, E., Williams, B., Snyder, S., & LoGerfo, J. (2006). The effects of a community-based exercise program on function and health in older adults. *Journal of Applied Gerentology, 25*(4), 291-306. doi: 10.1177/0733464806290934

Bonnefoy, M., Jaffret, M., & Jusot, J. F. (2007). Muscle power of lower extremities in relation to functional ability and nutritional status in very elderly people. *The Journal of Nutrition Health & Aging*, *11*(3), 223 – 228. Retrieved from http://www.serdi-fr.com/jnha/

Brown, M., Sinacore, D., & Host, H. (1995). The relationship of strength to function in the older adult. *The Journal of Gerontology. Series A, Biological Sciences and Medical Sciences, 50,* 55 – 59. Retrieved from http://biomedgerontology.oxfordjournals.org/

Callahan, D., Phillips, E., Carabello, R., Frontera, WR., & Fielding, RA. (2007). Assessments of lower extremity muscle power in functionally-limited elders. *Aging Clinical and Experimental Research, 19*(3), 194 – 199. Retrieved from http://www.kurtis.it/aging/it/

Caserotti, P., Aagaard, P., Buttrup Larson, J., & Puggaard., L. (2008). Explosive heavy resistance training in old and very old adults: changes in rapid muscle force, strength, and power. *Scandinavian Journal of Medicine & Science in Sports, 18*(6), 773-782. Retrieved from http://www.wiley.com/bw/journal.asp?ref=0905-7188.

Caserotti, P., Aagaard, P., & Puggaard, L. (2008). Changes in power and force generation during coupled eccentric-concentric versus concentric musle contraction with training and aging. *European Journal of Applied Physiology, 103*(2), 151-161. Retrieved from http://www.springer.com/biomed/human+

physiology/journal/421

Esposito, F., Malgrati, D., Veicsteinas, A., & Orizio, C. (1996). Time and frequency domain analysis of electromyogram and sound myogram in the elderly. European *Journal of Applied Physiology & Occupational Physiology, 73*(6), 503-510. Retrieved from http://jap.physiology.org/

Federal Interagency Forum on Aging-Related Statistics. (2000). Older Americans 2000: Key IndicatorsOf Well-Being. Available at: www.agingstats.gov/Agingstatsdotnet /Main_Site/Data/2000_Documents/entire_report.pdf

Fielding, R., LeBrasseur, N., Cuoco, A., Bean, J., Mizer, K., & Fiatarone Singh, M. (2002). High-velocity resistance training increases skeletal muscle peak power in older women. *Journal of American Geriatric Society, 50*(4), 655-662. Retrieved from http://www.americangeriatrics.org/

Foldvari, M., Clark, M., Laviolette, L., Bernstein, M., Kaliton, D., Castaneda, C., & Fiatarone Singh, M. (1999). Association of muscle power with functional status in community-dwelling elderly women. *The Journal of Gerontology, 55*(4), 192-199. Retrieved from http://biomedgerontology oxfordjournals.org/content/55/4/M192

Ghigiarelli, J., Nagle, E., Gross, F., Robertson, R., Irrgang, K., & Myslinski, T. (2009). The effects of a seven-week heavy elastic band and weight chain program on upper-body strength and upper-body power in a sample of Division 1-AA football players. *Journal of Strength and Conditioning Research, 23*(3), 756 – 764. doi:10.1519/JSC.0B013e318a2b8a2

Hakkinen, K., Alen, M., Kallinen, M., Izquierdo, M., Jokelainen, K., Lassila, H., … Newton, R. (1998). Muscle cross sectional area, force production, and activation of leg extensors during isometric and dynamic actions in middle-aged and elderly men and women. *Journal of Aging and Physical Activity*, *6*(3), 232-247. Retrieved from http://hk.humankinetics.com/JAPA/currentIssue.cfm

Hazel, T., Kenno, K., & Jakobi, J. (2007). Functional Benefits of Power Training for Older Adults. *Journal of Aging and Physical Activity, 15*, 349 – 359. Retrieved from http://hk.humankinetics.com/JAPA/currentIssue.cfm

Holsgaard Larsen, A., Casserotti, P., Puggaard, L., & Aaguard, P. (2007). Reproducibility and relationship of single-joint strength vs. multi-joint strength and power in again individuals. *Scandinavian Journal of Medicine & Science in Sports, 17,* 43 -53. Retrieved from http://www.wiley.com/bw/journal.asp?ref=0905-7188

Jennings, C., Viljoen, W., Durandt, J., Lambert, M (2005). The reliability of the Fitrodyne as a measure of muscle power. *Journal of Strength and Conditioning Research, 19(*4), 859 – 864. Retrieved from http://journals.lww.com/nsca-j scr/pages/default/aspx

Jones, M., Fry.A., Weiss, L., Kinzey, S., & Moore, C. (2008). Kinetic comparison of free weight and machine power cleans. *Journal of Strength and Conditioning Research, 22*(6), 1785 – 1789. doi:10.1519/JSC.0b013e3185f068

Junichiro, Y., Chizuko, M., Satoshi, N., & Naokata, I. (2009). Force-velocity, force-power relationships of bilateral and unilateral leg multi-joint movements in young and elderly women. Journal of Biomechanics, 42(13), 2151-2158. Retrieved from http://www.jbiomech.com/

Krivckas, L., Suh, D., Wilkins, J., Hughes, V., Roubenoff, R., & Frontera, W. (2001). Age-and gender-related differences in maximum shortening velocity of skeletal muscle fibers. *American Journal of Physical Medicine & Rehabilitation*, *80*(6), 447-455. Retrieved from http://journals.lww.com/ajpmr/pages/default.aspx

Machado, A., Garcia-Lopez, D., Gonzalez-Gallego, J., & Garatachea, N. (2010). Whole body vibration training increases muscle strength and mass in older women: a randomized-controlled trial. *Scandinavian Journal of Medicine & Science in Sports*, *20*(2), 200-208. Retrieved from http://www.wiley.com/bw/journal.asp?ref=0905-7188.

Mard, M., Vaha, J., Heinonen, A., Portegijs, E., Sakari-Rantala, R., Kallinen, M., … Sipila, S. (2008). The effects of muscle strength and power training on mobility among older hip fracture patients. *Advances in Physiotherapy*, *10*(4), 195-203. Retrieved from http://www.informaworld.com/smpp/title~content=t713691431~db=al

Morris, S., Morris, M., & Lansek, R. (2001). Reliability of measurements obtained with the Timed Up-and-Go test in people with Parkinson Disease. *Physical Therapy*, *81*(2), 810 – 818. Retrieved from http://ptjournal.apta.org/

Nicholson, J., & Emes, C. (2000). Effect of strength training on the vertical force of a chair rise in the elderly. Clinical Kinesiology, 54(2), 36-43. Retrieved from http://www.clinicalkinesiology.org/

Podsiadlo, D., & Richardson, S. (1991). The timed up and go: a test of basic functional mobility for frail elderly persons. *Journal of American Geriatric Society, 39*(2), 142-148. Retrieved from http://www.americangeriatrics.org/

Rikli, R., & Jones, J. (1999). Development and validation of a functional fitness test for community-residing older adults. *Journal of Aging and Physical Activity, 7*, 127-159. Retrieved from Retrieved from http://hk.humankinetics.com/japa/journal About.cfm

Reid, K, Callahan, D., Carabello, R., Phillips, E., Frontera, W., & Fielding, R. (2008). Lower extremity power training in elderly subjects with mobility limitations: a randomized controlled trial. *Aging Clinical and Experimental Research, 20*(4), 337-343. Retrieved from http://journalseek.net/cgi-bin/journalseek/ journalsearch.cgi?field=issn&query=1594-0667

Rhea, M., & Kenn, J. (2009). The effect of acute applications of whole-body vibration on the iTonic platform on subsequent lower-body power output during the back squat. *The Journal of Strength and Conditioning Research, 23*(1), 58 – 61. doi:10.1519//JSC0b013e3181875045

Rhea, M., Peterson, M., Lunt, k., & Ayllon, F. (2008). The effectiveness of resisted jump training on the Vertimax in high school athletes. *The Journal of Strength and Conditioning Research, 22*(3), 731 – 734. doi:10.1519/JSC.0b13e3181660c59

Rhea, M., Peterson, M., Oliverson, J., Ayllon, F., Potenziano, B. (2008). An examination of training on the Vertimax resisted jumping device for improvements in lower body power in highly trained college athletes. *The Journal of Strength and Conditioning Research, 22* (3), 735 – 740. doi:10.1519/JSC.0b01316660d61

Schroder, E., Wang, Y., Castaneda-Sceppa, C., Cloutier, G., Vallejo, A., Kawakubo, M. Jensky, N., Coomber, S., Azen, S., & Sattler, F. (2007). Reliability of maximal voluntary muscle strength and power testing in older men. *Journal of Gerontology*

Biological Sciences and Medical Science, 62(5), 543- 549. Retrieved from http:biomedgerontology.oxfirdjournals.org/

Figure 3. Picture representation of Tendo Weightlifting Analyzer Power Analyzer Equipment

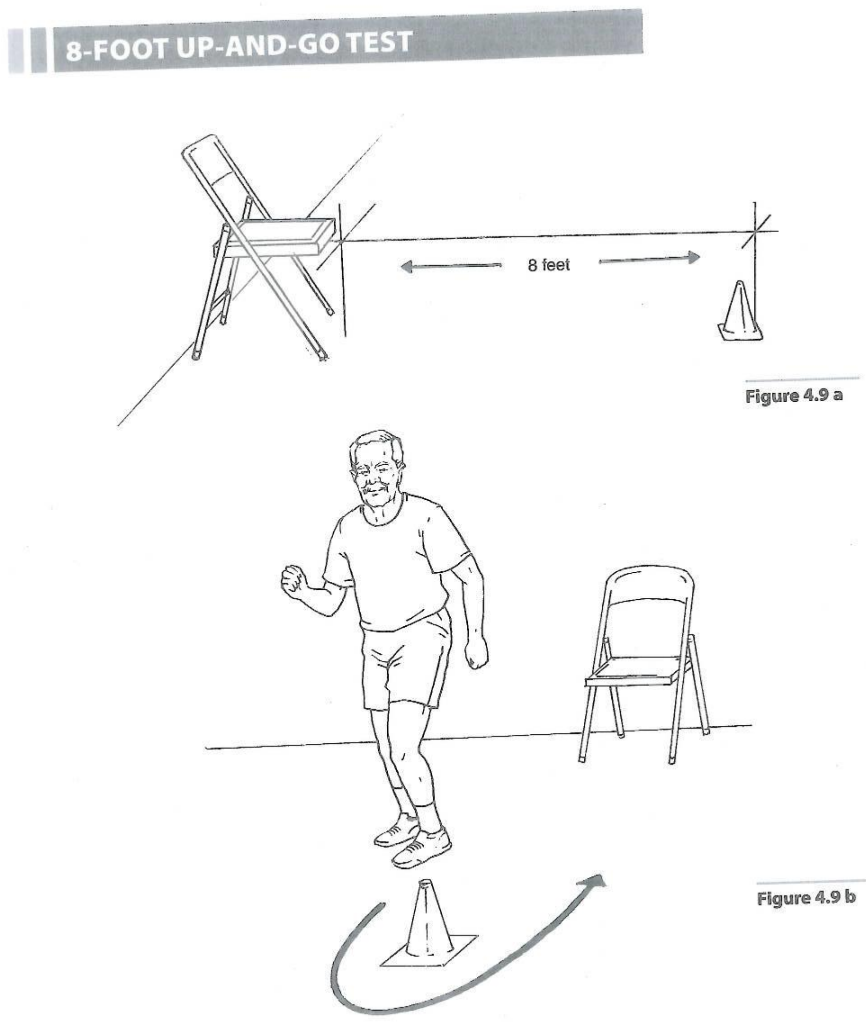


Figure 4. Diagram of 8-Foot Up-and-Go functionality test

Appendicies

Appendix A

Informed Consent Form

UNIVERSITY OF CENTRAL OKLAHOMA

INFORMED CONSENT FORM

Research Project Title: The relationship between power and functionality in older adults.

Researcher (s): Matt Tecmire

A. Purpose of this research: The purpose of this research investigation is to find a power test that is easy to perform on the general public and to examine which power test is the most related to functional ability. Past research has indicated a relationship between an individual's functional ability to perform activities of daily living and that individuals lower body muscle power. This study hopes to examine that relationship further and try to develop a way to test lower body muscle power more easily in a real world setting.

B. Procedures/treatments involved: To assess your lower body power during this study you will be prompted to perform four different lower body movements. You will be asked to stand up from a chair, perform a standing lunge and squat, and a seated leg extension. All four of these movements have been designed to simulate movements that you would perform during a normal active day. Before testing you will be weighed on a scale so the actual power output you perform can be recorded properly. A small Velcro strap will be secured to your waist and be attached to our instruments that measure power through a very thin tether line. When you perform a power movement the tether line will be pulled, from that pulled tether line that is secured to your body we will get a numerical power output of that power movement. During each of the four power tests you will be asked to perform a total of ten repetitions for each of the four different power tests. You will rest for one minute between each repetition in order to allow you the opportunity to give a full effort. Before testing you will be shown how to perform each power test correctly and be allowed to practice each movement before actual testing. You will only perform one power test at a time with each of the four power tests taking a total of ten minutes to complete. You will also be asked to perform a functionality test where you will stand from a seated position, walk 8 feet, then come back to your chair and sit down. This test will be timed using a stopwatch and you will perform three repetitions of this test with a rest period between each repetition. This test will take a total of three minutes to finish and you will only be asked to perform this functionality test once.

C. Expected length of participation: The total participation time for a participant in this study will be 40 minutes. The 40 minutes of participation time will be broken up into four ten minute sessions. These ten minute sessions will be conducted over a five week period.

D. Potential benefits: No direct benefits will be available to the participants of this study. Results will not be shared with any of the female participants who participate in this study. As a research tool this study does benefit the research community and other exercise or geriatric researchers. This study can provide the research community with a potential field testing method that could indicate accurate insight into an elderly individual's level of functionality and power output.

E. Potential risks or discomforts: The risks associated with this research protocol are minimal in nature but include muscle soreness or injury. If you decide to participate in this study the University of Central Oklahoma hold a non-liability position with this study and can not be held responsible in any way for injuries. You will be led through a cool down exercises routine in order to minimize any muscle soreness associated with participation in this study.

F. Medical/mental health contact information (if required): All participants of this study will be instructed to contact their primary care physician if any medical concerns arise.

G. Contact information for researchers and UCO IRB: Matt Tecmire - Day Time Phone Number: (405) 808 0032; emial- mtecmire@uco.edu; or Dr. Paul House (405) 974 5259; email - phouse@uco.edu & Dr. Jill Devenport with the IRB Office of the University of Central Oklahoma (405) 974 5479

H. Explanation of confidentiality and privacy: All information that will be public will be in the form of group data. All paper data collection information will be shredded after the study and all electronic data will be kept under a password locked data storage flash drive. After all information is finished being used all data will be thoroughly deleted and completely wiped from the data storage device.

I. Assurance of voluntary participation: All participation or non participation in this study is completely voluntary. Your decision to participate allows you the opportunity to discontinue participation at any time during the study without any negative consequences. This research project is completely independent from Dr. Powers' research study that you are currently participating in. Your decision to participate or not participate in this study will hold no negative effects on your participation with Dr. Powers' study in any way.

AFFIRMATION BY RESEARCH SUBJECT

I hereby voluntarily agree to participate in the above listed research project and further understand the above listed explanations and descriptions of the research project. I also understand that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time without penalty. I acknowledge that I am at least 18 years old. I have read and fully understand this Informed Consent Form. I sign it freely and voluntarily. I acknowledge that a copy of this Informed Consent Form has been given to me to keep.

Research Subject's Name: ____

Signature: ________________________________ Date

APPROVED FEB 22 2011 UCO IRB

APPROVAL FEB 22 2012 EXPIRES

Revised 9/1/09

Appendix B

Data Collection Sheet

Data Collection: Squat

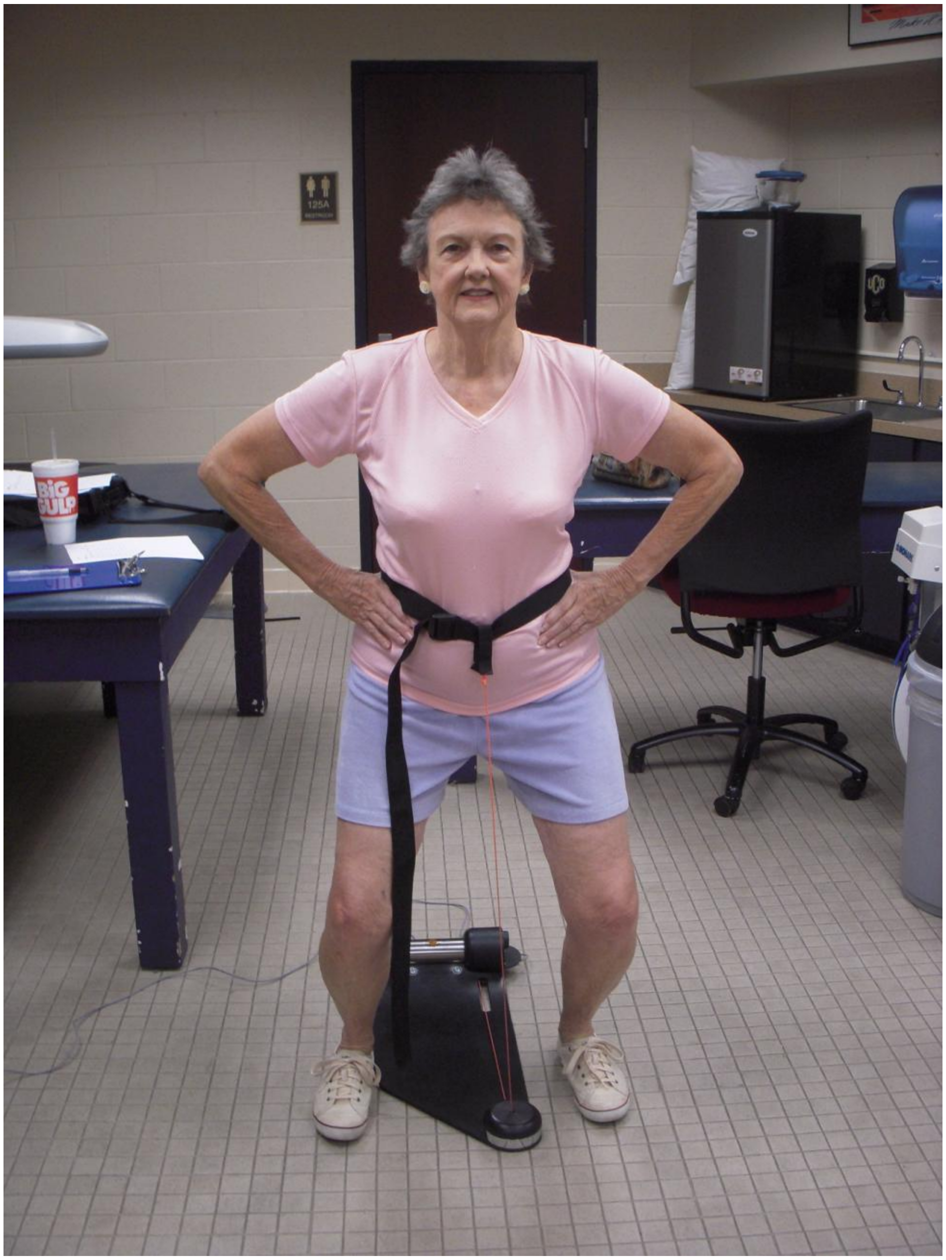
Code # ____________

	Average Power	Average Velocity	Peak Power	Peak Velocity
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Appendix C
Depiction of Chair Stand Power Test


Ergomedic 82

Appendix D
Depiction of Squat Power Test


125A
BIG
GULP

Appendix E
Depiction of Leg Extension Power Test

Appendix F

Depiction of Lunge Power Test