STRENGTH AND POWER TRAINING TO IMPROVE PERFORMANCE ON
RECOVERY FROM A SIMULATED TRIP

BY

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ABSTRACT

Age related sarcopenia contributes to the etiology of falls in older adults. Improving muscle strength and power may mitigate the effects of sarcopenia and improve one’s ability to recover from a postural perturbation. A forward leaning task has been used to simulate the biomechanical requirements of a slip, trip or perturbation and quantify maximum recoverable forward lean angle (FLean_max). We also used a lateral leaning task to determine maximum recoverable lateral lean angle (LLean_max). Twenty-three older adults (age range 65-79 yrs) were recruited to participate in a six week lower extremity resistance training intervention (three times per week). They were randomly assigned to either strength training (ST) or power training (PT). Measurements of FLean_max, LLean_max, strength and power in knee extension and leg press were recorded at baseline and at the completion of the intervention. Fifteen participants completed the study (ST=7, PT=8). Muscle strength and power improved in both groups and there were trends towards greater improvements in strength in the power training group. There were no significant differences in the change in FLean_max between the strength training group and power training group following training (+3.57° vs. +1.09°, p=0.422) or in LLean_max (+1.98° vs. 2.82°, p=0.587). These results suggest that strength and power training do not result in different changes in balance recovery in older adults.
LITERATURE REVIEW

An Aging Population

The number of adults aged 65 and older in the United States continues to rise. By the year 2030, this demographic is expected to grow to 71 million people (Centers for Disease Control and Prevention, 2008). This represents nearly 20% of the US population. Furthermore, people are living longer. The average lifespan is expected to climb to 84.3 and 79.7 years for women and men, respectively. Older adults are at greater risk for a number of chronic diseases and health risks such as slips, trips or falls. A fall can be defined as an unexpected event in which an individual comes to rest on the ground or lower level whether an injury is sustained or not. The prevalence of falls is elevated among this population. Moreover, the consequences of a fall are more severe for older adults. An older adult is more susceptible to morbidity or mortality as a result of a serious fall.

Also of concern is the growing rate of obesity among older adults (Lang, Llewellyn, Alexander, & Melzer, 2008). About one third of those 60 years or older are obese; defined by a body mass index (BMI) of greater than or equal to 30 kg·m⁻². Obesity can impair balance and physical function (Fjeldstad, Fjeldstad, Acree, Nickel, & Gardner, 2008; Sharkey, Ory, & Branch, 2006). Therefore, obesity can be considered a risk factor for falls in older adults (Fjeldstad et al., 2008; Lang et al., 2008; Singh, Park, Levy, & Jung, 2009).

When balance is disrupted one must act quickly to recover through lower limb activity in order to prevent a fall. Muscular strength is important to the maintenance of
balance (Mayson, Kiely, LaRose, & Bean, 2008; Perry, Carville, Smith, Rutherford, & Newham, 2007; Wolfson, Judge, Whipple, & King, 1995). However the onset and speed of contraction must be high so that balance is regained quickly. Considering that muscle power is the product of muscle force and velocity, that is, speed of contraction, muscle power may be more influential for maintaining balance in situations where there is a significant balance perturbation (Bean et al., 2002; Bean, Kiely, LaRose, & Leveille, 2008; Bean et al., 2009; Bean et al., 2003; Hanson et al., 2009; Henwood, Riek, & Taaffe, 2008; Perry et al., 2007).

**Falls: A Threat to Public Health**

Older adults experience a greater number of falls and are more susceptible to morbidity and mortality as a result of falls. The Center for Disease Control (CDC) reports that in 2005, 15,802 people aged 65 or older died from complications of falling (Centers for Disease Control and Prevention, 2008). Additionally, approximately 15.9% (95%CI: 15.4-16.4) of adults 65 or older fell within the three month period of this study, with 31.3% (95%CI: 29.7-32.8) of those falls requiring a doctor visit (Centers for Disease Control and Prevention, 2008). Falls are the most common cause of hospital admissions for adults over 65 and the leading cause of death from unintentional injury (National Center for Injury Prevention and Control Centers for Disease Control and Prevention, 2006). The risk of fall mortality increases with age. In 2006, those aged 65-69 years were subject to 9.51 fall related deaths per 100,000 years. Prevalence is elevated 3.5 times and 16 times for those aged 75-79 and >85, respectively (National Center for Injury Prevention and Control Centers for Disease Control and Prevention, 2006). Falls also lead to significant costs; direct costs reported in 2000 were 179 million dollars for fatal
falls and 19 billion dollars for non-fatal falls (Stevens, Corso, Finkelstein, & Miller, 2006).

Falls are related to a variety of chronic diseases. The combined effects of aging, osteoporosis, sarcopenia, and obesity can make falls more likely. Nearly 10% of falls result in serious injuries such as hip fractures, joint dislocations, subdural hematoma or head injury (Sattin, 1992). Traumatic brain injuries (TBI’s) and lower extremity injuries are the most common and account for the majority of fall related mortality (Langlois, Rutland-Brown, & Wald, 2006). Approximately 90% of all hip fractures each year are attributed to falls (Magaziner et al., 2000). More importantly, approximately 20-30% of those who fall and suffer a hip fracture die within one year (Magaziner et al., 1997). This is a concern for patients with osteoporosis who are already at an elevated risk for fracture. Even those who survive a hip fracture will experience some functional impairment. Next, TBI’s can be disabling and result in long term cognitive and physical complications. Falls result in 52% of TBI’s in adults over 65 (Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations and Deaths, 2006). Moreover, nearly half of falls that result in mortality are attributed to TBI’s (Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations and Deaths, 2006).
Risk Factors for Falls

Age and Sarcopenia

The etiology of falls in older adults is multifactorial (Sattin, 1992) (Figure 1).

![Etiology of Falls Diagram](image)

Many studies show that the elderly are at an elevated risk for falling (National Center for Injury Prevention and Control, Centers for Disease Control and Prevention, 2006; Centers for Disease Control and Prevention, 2008). This can be attributed to the physiologic changes within muscles that occur naturally with age (Deschenes, 2004; Wolfson et al., 1995).
Laughton et al., 2003; Moreland, Richardson, Goldsmith, & Clase, 2004; Perry et al., 2007; Sattin, 1992). Both the neuromuscular and musculoskeletal systems experience functional declines with age. These temporal changes in bone and muscle tissue result in chronic disease such as osteoporosis, sarcopenia, and arthritis. Sarcopenia results in reductions in muscle mass and strength (Deschenes, 2004); while osteoporosis reduces bone integrity and thus elevates the risk for fracture and morbidity (Moreland et al., 2004). More recently, authors have postulated that reductions in muscle power from sarcopenia may be more important than reductions in muscle strength in falls in older adults (Bean et al., 2009; Bean et al., 2003; Hanson et al., 2009; Marsh, Miller, Rejeski, Hutton, & Kritchevsky, 2009; Perry et al., 2007). A combination of these factors increases the risk to slip or fall (Tinetti et al., 1988).

_Gait Abnormality_

Abnormalities with gait and balance - reported problems with strength, sensation or balance - are often associated with falls risk. Tinetti and colleagues (Tinetti et al., 1988) showed that those with 3-5 and 6-7 gait or balance abnormalities had a 1.7 (95% CI: 1.1-2.7) and 2.5 (95% CI: 1.7-3.8) greater risk of falling compared to those who only had 0-2 abnormalities. Furthermore, older adults display a gait pattern with greater step variability and a decline in postural control, which may reduce the ability to recover balance from an external perturbation or a fall (Singh et al., 2009).
The Role of Obesity

Nearly one third of adults older than 60 years old are considered obese (Ogden, Yanovski, Carroll, & Flegal, 2007). Obesity is defined by the World Health Organization (WHO) as a BMI as greater than or equal to 30.0 kg·m⁻². To compare, a normal BMI is considered 20-24.9 kg·m⁻². Obesity has been identified as a risk factor for many chronic diseases such as type II diabetes, cancer, coronary artery disease, stroke, hypertension, osteoarthritis and sleep apnea (Lang et al., 2008). Obesity is also related to reductions in physical function and is a risk factor for falls (Lang et al., 2008). Fjeldstad and colleagues (Fjeldstad et al., 2008) reported a higher prevalence of falls (27% versus 15%) and ambulatory stumbling (32% versus 14%) in obese individuals (mean age=60 years) when compared to non-obese (mean age=55 years). Additionally, Fjeldstad and colleagues reported a lower physical health related quality of life and lower physical activity level in obese older adults.

Lang and colleagues (Lang et al., 2008) reported that 44.8% of males and 45.6% of females with a BMI greater than 30 had self reported functional impairment compared to 29.5% of males 34.8% of females of normal BMI. They used the Short Physical Performance Battery (SPPB) (Guralnik et al., 1994) to measure functional performance on three tests: balance, gait speed and chair stands, and reported that an inverse relationship existed between SPPB score and BMI (Lang et al., 2008). Obese older adults are more likely than normal BMI older adults to report difficulty with activities of daily living such as bathing (Lang et al., 2008). They were also more likely to have reduced lower extremity function as indicated by a score of less than or equal to 7 on the SPPB (Lang et al., 2008).
Obese individuals also demonstrate increased postural sway as measured through changes in center of pressure during quiet standing (Singh et al., 2009). Singh and colleagues (Singh et al., 2009) measured postural sway in obese and normal BMI subjects over 18 minutes of quiet standing time. The obese group had higher levels of postural sway at the beginning of the test and increased their sway more throughout the test (p<0.0001). This is an important finding because greater postural sway suggests impaired postural control (Singh et al., 2009). Therefore the ability of an obese older adult compared to a normal older adult to recover balance when the center of gravity approaches or moves outside their base of support becomes more difficult. The authors suggested that increases in postural sway in obese individuals can be attributed to extra fat mass. Additional fat mass acts as dead weight which increases the joint torques and muscle forces needed to recover from perturbation (Singh et al., 2009). This interpretation of data by the authors is speculative and prospective research is needed on this topic.

Reduced lower limb strength is related to an increased fall risk in older adults (Moreland et al., 2004). Absolute knee extensor strength is higher in obese older adults compared to normal BMI subjects (Hulens et al., 2001). This is understandable because greater mass would require greater muscle strength to support the added mass and facilitate movement (Corbeil, Simoneau, Rancourt, Tremblay, & Teasdale, 2001). However, despite greater absolute strength, obese individuals are at a higher risk for falls.
Other factors

A number of other risk factors for falls have been identified including the use of sedatives, chronic musculoskeletal pain and a prior history of falls. In a study of 336 adults older than 75, Tinetti and colleagues (Tinetti et al., 1988) reported that those using sedative medications were 28.3 (95% CI: 3.4-239.4) times more likely to fall compared to those that do not use sedatives. Sedatives may impair alertness and potentially impact neuromuscular function. Secondly, Levielle and colleagues (Leveille et al., 2009) reported that those with polyarticular muscle pain were 1.53 (95% CI 1.17-1.99) times more likely to have suffered a fall compared to those with no pain at all.

Muscle Strength and Power

Muscle strength is the ability of a muscle to produce force, whereas muscle power is the product of force and velocity. More specifically, muscle power is muscular work per unit of time and can be calculated by the product of force (muscle strength) and velocity of movement. To recover from a perturbation and prevent a fall, a muscle must be strong enough to sustain the external load and it must respond quickly. It has been suggested that age related reductions in muscle power may be more important in the etiology of falls and physical function compared to reductions in muscle strength (Bean et al., 2002; Grabiner, Owings, & Pavol, 2005; Marsh et al., 2009; Moreland et al., 2004; Sayers, 2008).

With increasing age, there is a decline in muscle mass. This is known as sarcopenia (Rosenberg, 1997). The decline in muscle mass is, in part, responsible for the decline in muscle strength. Muscle mass declines by 30-50% between the third and eighth decade of life (Deschenes, 2004; Lexell, Taylor, & Sjostrom, 1988). However the rate of
loss accelerates beyond the fifth decade of life. For instance, typically muscle mass declines by 10% between the ages of 25 and 50, and a further 40% is lost by the age of 80 (Lexell et al., 1988). In addition to a loss of strength, there is also a loss of muscle power. Muscle power is related to the maximal velocity at which one can contract a working muscle. A loss of power is often seen by age 40 (Deschenes, 2004). This loss of power is related to the preferential loss of type II muscle fiber that occurs with aging and sarcopenia. Type II muscle fibers are often referred to as fast twitch muscle. The decline in fiber number is inconsistent between type I and type II. Lexell and colleagues (Lexell et al., 1988) found that type II fibers lose 26% of their cross sectional area while type I fibers did not vary between those aged 20 and 80.

While the absolute amount of muscle mass is reduced with age, it is also important to note the loss of strength per unit of cross sectional area and the loss of endurance through increased fatigability (Brooks & Faulkner, 1991, 1994). The ability to maintain balance and avoid falling is dependent on the capacity of the lower limb muscles to generate force. La Roche and colleagues (LaRoche, Cremin, Greenleaf, & Croce) examined a group of older women with a reported history of falls and found that they demonstrated 19% lower peak torque across the major muscles of the lower limbs compared to those without a history of falls. Additionally, Wolfson and colleagues (Wolfson et al., 1995) compared relative muscle strength to performance on a balance platform. They summed the isokinetic strength in the lower limb muscles and expressed results relative to body weight. A negative relationship was found between reduced strength and poor balance performance. While these results suggest a relationship between balance and muscle weakness, the designs are cross sectional.
A narrative review and meta-analysis by Moreland and colleagues (Moreland et al., 2004) examined the relationship between muscle weakness and the occurrence of falls. This review examined 13 prospective studies of older adults (65 years or greater) where falling was a primary outcome and muscle strength was identified as a risk factor. The authors found that when compared to non fallers, fallers were 1.76 (95% CI: 1.31-2.37) times more likely to exhibit lower extremity muscle weakness. Furthermore, recurrent fallers were 3.06 (95% CI: 1.86-5.04) times more likely to have lower extremity muscle weakness compared to non-fallers. This paper offers strong evidence that lower extremity muscle weakness is a risk factor for falls in this population. It is important to note that muscle strength is a modifiable variable that can be targeted using resistance training interventions. However, a review by Gillespie and Handoll (Gillespie & Handoll, 2009) suggests that resistance training for muscle strength does not reduce the risk for falls in older adults. Some authors postulate that improving muscle power may be more influential on fall prevention (Izquierdo, Aguado, Gonzalez, Lopez, & Hakkinen, 1999).

Izquierdo and colleagues (Izquierdo et al., 1999) demonstrated that age related decline in muscle power was greater than muscle strength and that power showed a stronger relationship to declines in balance. Furthermore, Metter and colleagues (Metter, Conwit, Tobin, & Fozard, 1997) presented longitudinal data that demonstrated a greater decline in muscle power compared to muscle strength. This decline in muscle power can be attributed to sarcopenia and age related declines in neuromuscular activity. To explain, Vaillancourt and colleagues (Vaillancourt, Larsson, & Newell, 2003) examined the relationship between aging and muscle firing rate and found that motor units in older adults fire at a slower rate during maximal voluntary contraction compared to younger
adults. Muscle firing rate which can influence the onset of muscle contraction may be related to an impaired ability to recover from a fall.

In a review by Steib and colleagues (Steib, Schoene, & Pfeifer, 2009) on resistance training in older adults, improvements following training in muscle power when compared to improvements following training in muscle strength were found to have a stronger association with functional variables such as stair climb, walking speed and chair rise. Bean and colleagues (Bean et al., 2003) compared leg power and strength in 1032 adults aged 65 or older. Leg power consistently showed a stronger relationship than hip and knee strength when adjusting for age, weight and gender in SPPB, stair climb, habitual gait, balance and chair rise time (p<0.001). Additionally, those in the lowest quartile of leg power demonstrated the greatest percentage of moderate-severe mobility limitations as measured by the SPPB. Bean and colleagues (Bean et al., 2002) also examined leg power and physical performance in mobility limited older adults, and reported that leg power explained 2-8% more of the variance compared to muscle strength in the performance of stair climbing time, chair stands, tandem gait velocity, habitual gait velocity, maximal gait velocity and SPPB score.

Perry and colleagues (Perry et al., 2007) examined associations between strength, power output, and symmetry of the leg muscles, age and history of falling. The sample included 44 healthy young adults, 44 older non-fallers, and 34 older fallers. Isometric, concentric, and eccentric strength of the knee and ankle muscles and leg extension power were measured bilaterally. Fallers generated 85% of the force of the non fallers, but only 79% of the power. Also, fallers generated less power than non-fallers (120.3 vs. 150.7 W, p<0.0001). These data suggest that declines in power are relevant when considering fall
risk in older adults. Further evidence is reported by Chan and colleagues (Chan et al., 2007) in a large scale prospective study. This study examined a cohort of 5995 community dwelling men in the United States aged 65 or older for 4.5 years and falls were recorded every four months. Men in the highest quartile of leg power had a reduced falls risk of 18% compared to those in the lowest quartile (95% CI: 0.73-0.92).

**Balance Recovery and the Forward Leaning Task**

Researchers have attempted to mimic the act of balance recovery following a perturbation in many ways. A common method is to release an individual from a forward leaning position (Grabiner et al., 2005; Madigan & Lloyd, 2005a, 2005b; Thelen, Wojcik, Schultz, Ashton-Miller, & Alexander, 1997; Wojcik, Thelen, Schultz, Ashton-Miller, & Alexander, 1999, 2001). Subjects lean forward while supported by a support cable until the desired lean angle is achieved. Tension in the support cable is measured using a force transducer and shows a positive, linear relationship with lean angle. At a time unknown to the subject, the lean cable is released and the participant must regain their balance by taking a single step. Any additional steps or the use of harness support is considered a failed attempt. The maximum angle achieved is used to operationalize one’s ability to recover balance. This task is suggested to utilize the same kinematics necessary to restore balance following an external perturbation in the sagittal plane. The forward leaning task allows for a high degree of experimental control and safety while allowing for an accurate assessment of balance recovery (Grabiner et al., 2005; Madigan & Lloyd, 2005a, 2005b; Thelen et al., 1997; Wojcik et al., 1999, 2001).

Older adults have a reduced ability to recover from a forward leaning position compared to younger adults (Thelen et al., 1997). Thelen and colleagues (Thelen et al.,
1997) used the forward leaning task to study age differences among ten young (mean age=24.3 years) and ten old (mean age=72.8 years) men. Participants completed three trials at each of three lean-control cable loads equivalent to 15, 20 and 25% of body weight. From there, the load was increased by 5% of body weight until a maximum lean angle was achieved. A failure was defined as any attempt where the subject placed 18.5% or more of their body weight on the safety harness support, taking an additional step to recover or a step with their back foot where the horizontal length exceeded 30% of body height. The reaction times of the older adults were 8-10ms slower compared to the younger subjects (p<0.005). All young participants were able to recover from a load equal to 35% of their body weight, but some of the old participants were unable to regain balance from a load equal to 20% of body weight. The average maximal lean angle for younger adults was 32.5 degrees versus 23.9 degrees for the older adults (p<0.0005). This data is limited due to its small sample size and because it was comprised of healthy males only.

Wojcik and colleagues (Wojcik et al., 1999) expanded on these findings and examined the relationship between age and gender in single-step recovery from a forward leaned position. A similar design was used except the sample was 10 young (mean age=25.0) and 10 old healthy females (mean age=73.7). These data were then compared to results from Thelen and colleagues (Thelen et al., 1997). The only difference in experimental protocol was that 30% (compared to 18.5% in the prior study) of body weight on the harness support cable signified a failure from harness support. This value was selected arbitrarily as an estimate of the magnitude needed for a perturbation to cause a fall. Five of ten older females were unable to recover from any of the imposed lean
angles; and only one was able to recover from a load equal to 25% body weight. The five remaining older females had a maximum lean angle of 16.2 degrees versus 30.7 degrees for the young females (p<0.001). Furthermore, the old females produced a smaller lean angle than the old males (16.2 versus 23.9 degrees, p=0.014) in the study by Thelen and colleagues (Thelen et al., 1997). Interestingly, there were no significant differences in maximum lean angle between the young females and young males as both were approximately 31 degrees. Lastly, the reaction time of the older females was slower than the younger females (72 vs. 49ms, p<0.001). From these studies, it can be concluded that forward lean angle is greater in young male and female adults and that older male adults exhibit a greater forward lean angle than older females. Females also have slower step velocity than older males and younger females, but it is unclear why.

Wojcik and colleagues (Wojcik et al., 1999) used data from their previous study to evaluate age and gender differences in lower extremity joint torques and ranges of motion during single step recovery from a forward fall. Lower extremity strength was tested in a recumbent position and isometric and isokinetic strength was measured in left ankle plantarflexion and right hip flexion. Isokinetic tests were conducted at an angular velocity of 120 degrees per second. Data was collected for lower extremity body segment motions, foot-floor reactions and moments and support cable loadings. There were no significant age or gender differences found in the mean range of motion used at any lean angle. When lean angle was increased, a larger knee range of motion and significantly larger hip range of motion were used for successful balance recovery. Both the young and older females used near maximal joint torques to recover balance. However, the authors concluded that maximum joint strength in plantarflexion and hip flexion were not good
predictors of balance recovery, especially in female subjects. It is possible that the two joint strength assessments may not be pertinent to balance recovery and that volitional strength may not be indicative of performance on this task. For instance, knee or hip extensor strength or the velocity and power of contraction may be more important to the performance of this task.

Madigan and Lloyd measured peak extensor torques during the support phase of balance recovery during the forward leaning task in a small cohort of young and old adults (Madigan & Lloyd, 2005a, 2005b). Similar balance recovery patterns were evident for all participants. Hip, knee and ankle torques during the support phase were predominantly extensor for the first 60ms after stepping and all increased with increasing lean angle. The older group produced a smaller average knee extensor torque and there was a trend toward greater hip and ankle extensor torques. This suggests that age related reductions in muscle strength influence the balance recovery pattern of this task.

Grabiner and colleagues (Grabiner et al., 2005) have also compared performance on the forward leaning task to isometric and isokinetic strength of the hip, knee, and ankle flexors and extensors. Two trials of isokinetic strength were measured concentrically at 30 degrees and 90 degrees per second and eccentrically at 30 degrees per second for each joint motion. Independent t-tests were used to assess the differences between the highest and lowest quartile of performance on the forward leaning task (20±3° vs. 11±2°). Using a stepwise multiple regression analysis, it was reported that maximum isokinetic dorsiflexion strength at 90 degrees per second explained 29.5% (p<0.001) of the variance in maximal recoverable lean angle. The remaining 70.5% of variance in maximal recoverable lean angle was unaccounted for by lower extremity
strength. The large variance unaccounted for suggests that other non-strength related variables may contribute to the performance of this task, for example, lower extremity coordination and the ability not only to create necessary joint moments but also to do so in a timeframe that allows for a successful recovery of balance.

Madigan examined age related differences in muscle power generated during single-step recovery on the forward leaning task (Madigan, 2006). This study used ten healthy young (19-23 years) and ten healthy older men (64-83 years). Muscle power at the hip, knee and ankle of the stepping limb was determined from the product of joint angular velocity and joint torque. It was hypothesized that muscle power would be lower in the older men. Madigan divided the pattern of recovery into nine distinct phases. In six of the nine recovery phases at the hip, knee and ankle, muscle power was found to be lower in the older men. However, in three of the phases older adults had a greater peak power. Madigan suggested that this could be due to an age-related neuromuscular adaptation to mitigate the effects of aging on muscle strength, power, rate or torque development and movement speed. Madigan concluded that smaller peak muscle power in older men during recovery from FLean\textsubscript{max} may be causally related to the smaller FLean\textsubscript{max}. Therefore increasing peak muscle power may lead to an increase in FLean\textsubscript{max} and potentially an increase in trip recovery capability. There is a need to better understand the relationship between muscle strength and power and balance recovery and to determine which interventions are best suited to target muscle power and provide the greatest aid to fall prevention.

As presented above, performance on the forward leaning assessment has been compared between age and gender and to strength measures of the hip, knee and ankle.
muscles. However, no studies have compared muscle power using leg extension and leg press to forward leaning performance. Additionally, no studies have been conducted on diseased versus healthy population or in obese and non-obese older adults.

**Lateral Stability in Older Adults**

Much attention has been devoted to studying balance and stability in the anterior-posterior direction. However, measures of medial-lateral stability in older individuals have also been associated with falls and future risk of falling (Lord, Rogers, Howland, & Fitzpatrick, 1999; Maki, Holliiday, & Topper, 1994; Maki & McIlroy, 2006; Rogers, Hedman, Johnson, Cain, & Hanke, 2001; Rogers & Mille, 2003). This may be an important factor as falls in the lateral direction are more often associated with hip fracture (Rogers & Mille, 2003). Lord et al completed a cross sectional analysis of maximal lateral sway of 165 community dwelling older adults aged 63-90. Fallers demonstrated significantly greater (p<0.01) lateral sway (sway score=35.3) compared to non fallers (sway score=29.8) (Lord et al., 1999). However, the cross sectional and retrospective nature of this study cannot be regarded as strong evidence.

Maki and colleagues (Maki et al., 1994) conducted a prospective analysis of postural sway and the risk of falling in an ambulatory elderly population. Balance measures were performed at baseline on 100 older adults aged 62-96. Data was collected on spontaneous sway, induced anterior-posterior sway, rapid volitional raising of one arm, timed one-leg stance, induced medial-lateral sway and clinical balance performance. All tests were conducted using a movable force platform that was controlled to move back-and-forth or side-to-side to induce sway. The primary outcome measure was fall occurrence during the one year prospective monitoring period. Overall, 120 falls were
recorded and 4 subjects died during follow-up. Subjects reported whether or not they had experienced a fall each week by filling out a postcard which they deposited in a drop box at their residence. There were 59 fallers and 37 non fallers identified. Additionally, 45 subjects reported a history of one or more falls. Differences between fallers and non-fallers were most pronounced in measures related to lateral stability. Lateral spontaneous sway amplitude was reported as the best predictor of future falling risk. It is important to note that the sample was predominantly female and therefore does not account for differences in biomechanics attributed to gender.

Lateral balance recovery has been studied in older adults (Maki et al., 1994; Rogers & Mille, 2003). Maki and McIlroy identified that older adults tend to be more reliant on upper extremity activity than younger adults in response to a perturbation in the lateral direction (Maki & McIlroy, 2006). Mille and colleagues (Mille, Johnson, Martinez, & Rogers, 2005) examined the differences in lateral balance recovery through protective stepping in a small cohort of 10 healthy older and 10 younger adults. Participants were instructed to stand on a force platform with their feet parallel and a motor-driven waist pull system was use to deliver a lateral pull. Subjects received 10 perturbation trials to each side and no practice trials were given to minimize learning effects. Pattern of response was studied as an outcome. Older adults had larger lateral displacement and took more steps to recover compared to younger adults. These results suggest that older adults are less efficient at recovering from a lateral perturbation. Furthermore, older subjects exhibited a greater peak hip abduction torque suggesting that hip abduction is an important contributor to medial-lateral stability.
Currently, no study has attempted to mimic a fall in the lateral direction and further examine its relationship with muscle strength, power and other participant characteristics. Further, there have been no interventions designed to alter performance on a lateral leaning task.

**Resistance Training Interventions**

Muscle strength and power are modifiable risk factors for falls in older adults. Further, it has been demonstrated that resistance training can reduce the consequences of sarcopenia by improving muscle strength and power, body composition and physical function (Hanson et al., 2009). Traditionally, strength training has been the method used to target sarcopenia. Hanson and colleagues (Hanson et al., 2009) completed a 22 week strength training program in 81 adults aged 65 to 85 to evaluate the effect on strength, power, body composition, and physical function. Participants were randomized to the strength training intervention or control group. Strength training sessions involved 5 sets with the first being a warm up of 5 repetitions at 50% of one repetition maximum (1RM). This is considered the most amount of resistance one can lift in one effort. The subsequent 4 sets were 5, 10, 15, and 20 repetitions at 85% 1RM. At follow-up, the strength group showed significant improvements in leg press strength, knee extensor strength, and knee extensor power (p<0.01). Additionally, significant improvements in the strength training group were seen in 6-m usual walk, 6-m rapid walk, and chair stand time. Overall, this study presents strong evidence for the use of strength training to improve strength and physical function. However, power training may be more pertinent to improving physical function and reducing falls (Bean et al., 2002; Bean et al., 2008; Henwood et al., 2008; Henwood & Taaffe, 2006; Marsh et al., 2009; Orr et al., 2006;
Sayers, 2008). Orr and colleagues (Orr et al., 2006) completed a study of 112 community dwelling health older adults randomized to 8-12 weeks of power training or a non-training control group. The primary outcome was balance which was assessed on a computerized force platform that measured body sway. Participants trained twice per week for 10 weeks and completed explosive resistance training at one of three intensities equivalent to 20% 1RM, 50% 1RM and 80% 1RM. In addition, participants completed a one repetition maximum test every week to ensure a proper training load. Movements were completed as fast as possible on the concentric phase of contraction and slowly on the eccentric phase. Orr and colleagues reported that balance improved at all three levels of intensity (p<0.0001), with the greatest improvements coming from the low group at 20% 1RM (pre-Balance Index=90.4, post=79.6, p<0.006 group x time interaction). Peak power improved equally among intensity groups; however, muscular strength improved the most in the highest intensity group. The authors suggested that balance may be more attributable to velocity of contraction which explains why the lowest intensity group performed the best on the balance index following training. Furthermore, the high intensity group showed the greatest improvement in strength yet had the least improvement in balance. This implies that strength is not associated with improvements in balance to the same degree as power.

Stronger evidence comes from randomized controlled trials evaluating strength versus power training protocols. Bean and colleagues compared the effects of a traditional National Institute on Aging (NIA) resistance training program versus an increased velocity specific to task (InVEST) program on 138 mobility limited community dwelling older adults (Bean et al., 2009). Participants were aged 65 or greater and had an
SPPB score between 4 and 10. Both groups completed exercise sessions over 16 weeks for 3 sessions per week, and both groups had exercises that targeted every major muscle group. The InVEST program consisted of exercises while wearing a weighted vest. Exercise intensity was monitored using a rating of perceived exertion (RPE) scale and the target intensity was 11-16. The concentric phase of these exercises was completed as fast as possible and targeted specific movement patterns. In contrast, the NIA program consisted of 11 different exercises that targeted major limb muscle groups. Barbells and ankle weights were used except with the chair stand where no external weight was used. For the NIA program the concentric and eccentric phase lasted the same amount of time.

The primary outcomes of this study were changes in limb power and changes in SPPB. Following 16 weeks of training, the InVEST group showed significantly greater improvements in limb power compared to the NIA group (p=0.02). Both groups showed improvements in SPPB score and there was no significant group by time interaction (p=0.44). However, a post hoc analysis analyzed the impact of any strength or velocity impairment at baseline. Velocity impaired individuals in the InVEST group improved 0.73 units more than the NIA group in SPPB score (p=0.05). However, no interventions have specifically targeted the forward leaning task described above as an outcome.

**Specific Aims and Hypotheses**

The population of the United States is aging. Age related declines in strength and power influence balance and increase the risk for falls. The overarching goal of this study is to assess the feasibility and determine variances and effect sizes of two different resistance training protocols on the ability to recover balance from a forward leaning position and a lateral leaning position. We provide hypotheses that would be tested in an
adequately powered randomized controlled trial. Balance recovery capability will be operationalized as the greatest body lean angle from which balance can be regained by taking a single step following release from this forward leaning position. Subjects will be tested before and following randomization to 18 sessions of resistance training (3x/week for 6 weeks).

**Specific Aim 1**: To determine whether strength or power training improves the capacity of older adults to recover balance from a forward leaning position.

**Hypothesis 1**: The improvement in maximal forward lean angle will be greater in the power training group compared to the strength training group.

**Specific Aim 2**: To determine whether strength or power training improves the capacity of older adults to recover balance from a lateral leaning position.

**Hypothesis 2**: The improvement in maximal lateral lean angle will be greater in the power training group compared to the strength training group.

**Specific Aim 3**: to determine whether strength or power training improves muscle strength and power

**Hypothesis 3**: Both interventions will improve in muscle strength and power; but greater improvements in muscle power will be seen in the power training group.
METHODS

Overview of the Design

Twenty–three males and females were recruited to participate in a forward lean and lateral lean assessment and subsequent 6 week resistance training intervention. All subjects were aged 65-79 years with a range of BMI. Subjects were tested on their ability to recover from a forward and lateral leaned position. Upon receiving physician clearance, they were randomized to either power or strength resistance training for 6 weeks. Assessment of the maximal forward and lateral lean angle was repeated following the completion of the intervention.

Subject Recruitment and Measurement of Characteristics

Subjects were recruited from Forsyth County, North Carolina. Past participant databases were used to recruit subjects who had previously been involved with research studies conducted by the Wake Forest University Department of Health and Exercise Science. Local newsletters were used to recruit subjects. In total, 23 subjects were recruited aged 65-79; 13 were male and 10 were female (Figure 2). Subjects who met the initial eligibility (Table 1) were scheduled for a testing visit at Wake Forest University Health and Exercise Science Human Performance Laboratory. The exclusion criteria were designed to exclude subjects that may be unfit for the forward and lateral lean assessment.
Table 1: Inclusion and Exclusion Criteria

<table>
<thead>
<tr>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong>: 65-79 yrs</td>
<td><strong>Psychiatric Illness</strong></td>
</tr>
<tr>
<td><strong>Activity Status</strong>: sedentary (fewer than 60 minutes</td>
<td><strong>Severe Symptomatic Heart Disease</strong></td>
</tr>
<tr>
<td>of structured, moderate physical activity each week</td>
<td><strong>Blood Pressure</strong>: a resting blood pressure &gt;160/100 mmHg</td>
</tr>
<tr>
<td>that occurs in no more than 10-minute blocks)</td>
<td><strong>Severe Systemic Disease</strong>: that would preclude safe participation in the protocol or jeopardize study completion</td>
</tr>
<tr>
<td><strong>Stability of Residence</strong>: living within a 35 mile</td>
<td><strong>Severe orthopedic impairment</strong>: severe orthopedic impairment that would prevent person from doing the testing</td>
</tr>
<tr>
<td>radius of WFU for the duration of the study</td>
<td><strong>Fractures/Amputations</strong>: fracture in upper or lower extremity within the last 6 months, upper or lower extremity amputation</td>
</tr>
<tr>
<td><strong>Agreeableness</strong>: willing and able to participate in all aspects of the trial</td>
<td></td>
</tr>
<tr>
<td><strong>Consents</strong>: willing to give an informed consent.</td>
<td><strong>Cancer</strong>: active treatment for cancer other than nonmelanotic skin cancer</td>
</tr>
<tr>
<td><strong>Physician clearance</strong>: received from primary care</td>
<td><strong>Hearing or Sight Impairments</strong>: significant visual or hearing impairment that cannot be corrected and results in inability to use the telephone or to hear normal conversation</td>
</tr>
<tr>
<td>physician prior to exercise intervention</td>
<td><strong>Cognitive Impairment</strong>: dementia, delirium, or impaired cognitive function as defined by a score on the Folstein Mini-Mental Status Exam &lt;24 (appendix G)</td>
</tr>
<tr>
<td></td>
<td><strong>Participation in Other Trials</strong>: currently participating or planning to participate in another medical intervention study</td>
</tr>
<tr>
<td></td>
<td><strong>Medications</strong>: current use of medications which effect balance</td>
</tr>
<tr>
<td></td>
<td><strong>Alcohol Intake</strong>: consuming more than 21 alcoholic drinks per week or alcoholism</td>
</tr>
<tr>
<td></td>
<td><strong>Functional Limitations</strong>: unable to walk unassisted</td>
</tr>
<tr>
<td></td>
<td><strong>English Literacy</strong>: unable to speak or read English</td>
</tr>
<tr>
<td></td>
<td><strong>Judgment of Clinical Center Staff</strong>: judged to be unsuitable for the trial for any reason by the clinic staff</td>
</tr>
</tbody>
</table>
At testing visit one subjects completed an informed consent (Appendix A), demographics questionnaire (Appendix B), medical history questionnaire (Appendix C), and the American Heart Association Health/American College of Sports Medicine/Fitness Facility Pre-participation Screening Questionnaire (Appendix D). Self reported difficulty with activities of daily living was assessed using the Pepper Assessment Tool for Disability (PAT-D): a 19 item self-reported disability questionnaire (Appendix E) that has been used in the Lifestyle Interventions and Independence for Elders (LIFE) Study (Rejeski et al., 2005) and other randomized controlled trials at Wake
Forest University (Miller et al., 2003; Miller, Rejeski, Messier, & Loeser, 2001; Rejeski et al., 2003). Each question on the PAT-D is scored 1-6 and the score reported is the mean score for all 19 activities of daily living. Self efficacy in completing activities of daily living without falling and fear of falls were measured using the Fear of Falls Questionnaire (Tinetti et al., 1990) (Appendix F). Cognitive function was measured using the Folstein Mini-Mental Status Exam (Folstein, Folstein, & McHugh, 1975) (MMSE – Appendix G). Subjects self-reported levels of physical activity from a typical week from the past month using the Community Health Activities Model Program for Seniors (CHAMPS) Questionnaire administered interview style (Stewart et al., 2001). The number of minutes per week spent doing physical activities with an intensity considered to be moderate or greater (>3 metabolic equivalents or greater) was recorded.

Height without shoes was measured to the nearest 0.1 centimeter using a Tanita stadiometer (Model 5,226,881B1, Arlington Heights, IL). Body mass was measured to the nearest 0.1 kilogram using a calibrated and certified Health-o-meter balance-beam scale (Model 4,083,413 4,196,521, Bridgeview, IL). Body mass was measured with the subject wearing light indoor clothing without shoes and pockets emptied. Height and body mass were used to calculate body mass index.

**Forward Lean Assessment**

Subjects were placed in a Miller full body non-stretch harness (Model/Size 751/UYK, Franklin, PA) which was tethered to the ceiling using a climbing grade safety rope and two Black Diamond Freewire Quickdraws (Model BD38103000000ALLa, Salt Lake City, UT). The height of the harness and safety rope were adjusted so that the participant could not touch the ground with their hands should a true fall occur. A Miller
safety belt (Model/Size 123N/XLBK and T3010/SAXF, Franklin, PA) was placed around the waist of the subject at the level of the naval. A lean-control cable extended from the back of the belt to a stable metal pole. In series with the pole was a Chatillon CSD500 Dynamometer (Largo, FL). This device was used to measure lean-control cable tension. The tension was first calibrated to zero and tension was recorded in kilograms and expressed as a percent of body mass. The lean-control cable was adjusted to be horizontal when under tension. A Scott double-caliper release device (Model 1001, Clay City, KY) connected the lean-control cable to the dynamometer. This device was used as a trigger to release the subject from the lean-control cable.

Subjects were instructed to keep their feet together and flat on the ground with their body mass evenly distributed between both feet. Furthermore, they were instructed to maintain their posture as straight as possible while bending forward at the ankles only. Subjects’ feet were moved closer to or further from the metal pole in order to adjust the forward lean angle. Once the appropriate position was attained, subjects were instructed to look straight ahead at a visual target placed on the wall in front of them with their arms folded across their chest.

The forward body lean angle was measured from the vertical using an electrical inclinometer (Craftsman Digital Torpedo Level, model 48295, Hoffmann Estates, IL) which was attached to a 6 foot by 2 inch by 2 inch timber. The inclinometer measured angles to the nearest 0.1 degrees. Markers were placed on the subjects’ left acromion process, greater trochanter and lateral malleolus. The subject adjusted their body so that their posture and therefore the markers formed a straight line parallel to the angle measuring device when it was placed at the desired angle (Figure 2). The starting location
of the feet was measured using a tape measure placed along the floor. The location of the feet, the lean-control cable tension and subjects’ forward body lean angle were measured within ten seconds of the subject becoming stable in the lean position. The lean-control cable was released inducing a forward balance perturbation.

![Figure 3: Forward Lean Assessment](image)

The subject is placed in the forward leaning posture prior to being released.

The full body harness is tethered to the ceiling via a safety rope (a). The lean-control cable (b) is attached to a belt and a metal support pole (c) via a dynamometer (d). The body angle is measured by placing the electrical inclinometer (e) parallel to the line connecting the body markers (placed at the left acromion process, greater trochanter and lateral malleolus). The start and end locations of the feet are measured along the tape measures (f).
The release occurred after a brief random time delay and made little sound or movement. The subject could not see the trigger being released and thus could not anticipate the release. Subjects were instructed to regain their balance by taking a single step with their right leg while leaving the left leg in place. It was logistically easier to measure the same leg on each trial and Madigan and colleagues (Madigan & Lloyd, 2005a, 2005b) found there were no significant differences in maximum lean angle when comparing recovery stepping using the dominant versus non-dominant leg. Subjects were allowed to move their arms from a folded position to assist with balance recovery. Following the release and subsequent balance recovery, subjects held their recovered position until the resultant foot location was measured. Subjects with difficulty in maintaining balance in this position were given a chair to hold until measurements could be obtained accurately.

The starting lean angle was five degrees. It was increased in increments of 2.5 degrees until the participant failed to regain their balance in two consecutive trials at a given angle. If the participant failed twice at a given angle, they were given a brief (1-2 minute) rest. The angle was then reduced by 1.25 degrees (half of one increment) and the test was repeated. If this attempt was successful, the angle was increased by increments of 1.25 degrees until the participant failed to regain their balance. After a 1-2 minute rest period, the angle was repeated. The angle at which two failures occurred was deemed the point of failure. The last angle from which the subject could successfully recover their balance was recorded as the maximum recoverable lean angle ($F_{\text{Lean}_{\text{max}}}$).

The criteria for determining a failed trial were adopted from Madigan and colleagues (Madigan & Lloyd, 2005a, 2005b) who have used the forward lean assessment
in multiple studies. There were four criteria used to determine a failed trial: (1) taking more than one step with either leg, (2) moving the left leg from its starting position by more than 30% of the subject’s height, (3) falling into the harness or using the harness to regain balance and (4) when the subject was unable to maintain the forward lean angle position prior to cable release. These criteria provided a standardized discrimination between successful and failed trials.

**Lateral Lean Assessment**

The lateral lean assessment was completed in a similar fashion to the forward lean assessment. The participant turned 90°, standing with both feet together and leaning to their right until the lean-control cable was released. Subjects were placed in the same full body harness which was tethered to the ceiling at a height where the subject could not touch the ground during a failed attempt. The primary difference in setup was the orientation of the lean control cable. This belt was still placed at the level of the naval but the lean control cable was placed in line with the left greater trochanter of the femur. Markers were placed on the sternal notch and umbilicus. The starting lean angle was 2.5 degrees and subject leaned to their right and was increased by 2.5 degrees upon each successful trials. The angle measuring device was placed in front of the subject aligned with the sternal notch, umbilicus and the center point between both feet. The same protocol regarding successful trials was employed.

In between testing visits 1 and 2, subjects received physician clearance to begin exercise at the Wake Forest University Clinical Research Center. At testing visit 2, we assessed physical function of the subject using the SPPB. The SPPB has been used in the Established Populations for Epidemiologic Studies of the Elderly and is recognized as a
reliable measure of physical function (Guralnik et al., 1994). The SPPB consist of three performance based tests (gait speed, chair stands and balance) that assess lower limb balance, mobility and strength. Each of the three components is scored 0-4 and the scores are added to give a total score of 0-12.

Subjects completed The Fear of Falling Questionnaire and the Falls Efficacy Questionnaire (Tinetti et al., 1990) again to determine whether self-efficacy in avoiding falls and fear of falling changed after completing the forward lean assessment.

**Lower Limb Strength and Power Testing**

Lower limb muscle strength and power were measured using Keiser (Fresno, CA) pneumatic leg extension (AIR250) and leg press machines (AIR300). The machines were calibrated at the start of the study as per the manufacturer specifications. Both machines were used bilaterally. Subjects first engaged in a 5 minute aerobic warm up of walking or bicycling and a series of lower limb stretches for the quadriceps, hamstrings, calves and gluteal muscles. The leg extension and leg press machines were adjusted so that the hips and knees were flexed at 90 degrees. A warm up was performed on the leg extension machine at a light to moderate resistance. There were two warm up sets with the first consisting of 4-6 repetitions followed by a 90 second rest and a second of 2-3 repetitions at a slightly higher resistance, respectively. Strength was quantified as the most amount of resistance in kilograms that could be lifted one time (1 repetition maximum – 1RM). Subjects made repeated attempts to lift progressively heavier loads with 90 seconds of rest between efforts. Attempts were made until the subject could not perform the exercise one time with correct form, experienced any pain or discomfort or requested to stop.
To assess peak power, the resistance was adjusted to 70% of the 1RM test. The subject was instructed to perform the same exercise moving through the concentric phase as quickly as possible while controlling the eccentric phase. A 60 second rest was given after the first repetition followed by four more repetitions with a 30 second resting period between each. This protocol was used by Marsh and colleagues (Marsh et al., 2009) with older adults and found to be safe and effective at determining peak muscle power. The highest peak power of the five repetitions was recorded in Watts. After completing the strength and power testing on the leg extension machine, the same protocol was repeated using the leg press machine.

**Resistance Training Intervention**

Subjects were randomized to either a strength training (ST) or power training (PT) intervention. All subjects exercised three times per week (Mondays, Wednesdays and Fridays) for approximately one hour for six weeks (18 sessions total). Both the ST and PT groups completed three sets of resistance training on seven different exercises: leg press, leg extension, leg curl, hip abduction, hip adduction, hip flexion and calf press. The leg press and leg extension were completed on the same pneumatic Keiser machines used in testing. The leg curl, hip abduction, hip adduction and calf press exercises were completed on Nautilus resistance training machines. The hip flexion exercise was completed using ankle weights.

Both groups completed two sets of 8-10 repetitions at 50% of 1RM. During the third set, the subjects were instructed to complete as many repetitions as possible with good form as judged by the interventionist. If the subject completed more than ten repetitions on the third set, their resistance was increased 5-10% for the next session to
overload the muscle and encourage further training adaptations. The PT group was instructed to complete the concentric phase of contraction as fast as possible; whereas the ST group completed the concentric phase in 2-3 seconds. Both groups completed the eccentric phase of contraction in 2-3 seconds. Subjects were instructed to record the number of completed sets and repetitions in a training log (Appendix J). They recorded the number of repetitions for each of three sets at the prescribed resistance as determined by the interventionist. This information was verified and monitored by the interventionist.

Blood pressure was measured and recorded prior to the start of each exercise session. In accordance with the American College of Sports Medicine Guidelines for Exercise Testing and Prescription, exercise was not be performed if systolic blood pressure was greater than 200 mmHg or if diastolic blood pressure was greater than 110 mmHg. Furthermore, exercise was not performed if diastolic blood pressure was abnormally low accompanied by symptoms of dizziness or light-headedness.

**Statistical Analysis**

All variables were examined for normality of distribution and outliers using SPSS version 18.0. The sample size was small and no transformations were completed. Descriptive statistics were calculated to examine the baseline characteristics of the sample. We took note of the small sample size which reduced the statistical power and the ability to detect differences aside from large effects. A series of independent samples t-tests were used to test for any differences between the ST group and PT group at baseline in MMSE, PAT-D 19, FLmax, LLeanmax, leg extension 1RM, leg press 1RM, leg extension peak power, leg press peak power, BMI, age, height, weight and SPPB score.
The primary outcome of interest was change in maximal recoverable lean angle (FLeanmax) achieved on the forward lean assessment following 6 weeks of resistance training. An analysis of co-variance (ANCOVA) was used test the difference between the ST group and PT group using delta scores. We controlled for any baseline differences between the two groups in maximal recoverable lean angle. Additionally, we included age, gender and BMI as covariates. Effect sizes were calculated using Cohen’s d method.

A similar ANCOVA model was repeated for an evaluation of lateral lean max, leg extension 1RM, leg press 1RM, leg extension peak power and leg press peak power. The respective baseline score of each variable of interest was included as a covariate.
RESULTS

Participant Characteristics

A total of 23 participants were recruited for this study. Ten were randomized to the ST group, ten to the PT group and three did not enter the intervention because they did not receive physician clearance or did not wish to engage in exercise following the first testing visit. The ST group consisted of five males and five females with a mean age of 68.1 ± 3.4 years and the PT group consisted of six males and four females with a mean age of 73.4 ± 3.7 years. The mean BMI of the strength group was 30.4 ± 4.1 kg·m⁻² and the mean BMI of the power group was 30.5 ± 4.9 kg·m⁻².

Independent samples t-tests were used to identify any difference between the ST and PT groups at baseline. The ST group was significantly younger than the PT group (p=0.004). There were no other statistically significant differences between the groups at baseline (Tables 2-7).

Box and whiskers plots were completed for leg extension strength, leg press strength, leg extension power, leg press power, FLLeanₘₐₓ and LLLeanₘₐₓ (Appendix K). There was one outlier in leg press strength and one outlier in FLLeanₘₐₓ. However, there was no justifiable reason to exclude them from further analyses.
### Table 2: Descriptive Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Strength (n=10)</th>
<th>Power (n=10)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Age (yrs) *</td>
<td>68.10</td>
<td>3.38</td>
<td>73.40</td>
</tr>
<tr>
<td>Male</td>
<td>50% (5)</td>
<td>60% (6)</td>
<td></td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>30.35</td>
<td>4.14</td>
<td>30.50</td>
</tr>
<tr>
<td>Body Mass (kg)</td>
<td>84.98</td>
<td>11.25</td>
<td>92.44</td>
</tr>
<tr>
<td>Total SPPB score (0-12)</td>
<td>9.80</td>
<td>1.40</td>
<td>9.30</td>
</tr>
</tbody>
</table>

*significant difference

### Table 3: Leaning Task Measurements

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Strength (n=10)</th>
<th>Power (n=10)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Maximal forward lean angle (degrees)</td>
<td>15.50</td>
<td>4.97</td>
<td>15.88</td>
</tr>
<tr>
<td>Maximal forward lean angle cable load (kg)</td>
<td>34.50</td>
<td>14.02</td>
<td>31.58</td>
</tr>
<tr>
<td>Maximal lateral lean angle (degrees)</td>
<td>9.99</td>
<td>2.48</td>
<td>8.50</td>
</tr>
<tr>
<td>Maximal lateral lean angle load (kg)</td>
<td>22.92</td>
<td>5.52</td>
<td>22.11</td>
</tr>
</tbody>
</table>

### Table 4: Self Reported Questionnaire Data

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Strength (n=10)</th>
<th>Power (n=10)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Pepper Assessment Tool For Disability (1-6)</td>
<td>1.29</td>
<td>1.26</td>
<td>0.35</td>
</tr>
<tr>
<td>Falls Efficacy Questionnaire Total Score (0-130)</td>
<td>127.00</td>
<td>4.64</td>
<td>122.5</td>
</tr>
<tr>
<td>Fear of Falling (0-10)</td>
<td>3.30</td>
<td>3.34</td>
<td>2.90</td>
</tr>
<tr>
<td>Total MMSE Score (0-30)</td>
<td>29.40</td>
<td>1.26</td>
<td>29.60</td>
</tr>
<tr>
<td>CHAMPS min spent in moderate activity</td>
<td>294.00</td>
<td>383.94</td>
<td>315.00</td>
</tr>
</tbody>
</table>

*MMSE: Folstein Mini Mental State Examination, CHAMPS: Community Health Activities Model Program for Seniors*
### Table 5: Strength & Power Measurements –Keiser Pneumatic Equipment

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Strength (n=10)</th>
<th>Power (n=10)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Leg extension 1RM (kg)</td>
<td>37.33 21.05</td>
<td>37.38 24.90</td>
<td>0.997</td>
</tr>
<tr>
<td>Leg press 1RM (kg)</td>
<td>144.29 80.34</td>
<td>140.16 57.14</td>
<td>0.896</td>
</tr>
<tr>
<td>Leg extension peak power (W)</td>
<td>303.95 184.19</td>
<td>254.20 182.89</td>
<td>0.552</td>
</tr>
<tr>
<td>Leg press peak power (W)</td>
<td>337.30 146.61</td>
<td>372.85 233.72</td>
<td>0.688</td>
</tr>
<tr>
<td>Leg extension strength relative to body mass (kg/kg)</td>
<td>0.43 0.21</td>
<td>0.41 0.18</td>
<td>0.796</td>
</tr>
<tr>
<td>Leg press strength relative to body mass (kg/kg)</td>
<td>1.67 0.78</td>
<td>1.63 0.44</td>
<td>0.880</td>
</tr>
<tr>
<td>Leg extension power relative to body mass (W/kg)</td>
<td>3.48 1.78</td>
<td>2.72 1.65</td>
<td>0.337</td>
</tr>
<tr>
<td>Leg press power relative to body mass (W/kg)</td>
<td>3.96 1.48</td>
<td>3.93 1.97</td>
<td>0.982</td>
</tr>
</tbody>
</table>

### Table 6: Hip Flexion Strength with Ankle Weights

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Strength (n=10)</th>
<th>Power (n=10)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Hip Flexion 1RM (kg)</td>
<td>2.95 0.79</td>
<td>2.95 0.59</td>
<td>0.476</td>
</tr>
</tbody>
</table>

### Table 7: Weight Stack Equipment Measurements

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Strength (n=10)</th>
<th>Power (n=10)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Hip Abd 1RM (kg)</td>
<td>78.93 16.42</td>
<td>79.83 15.04</td>
<td>0.899</td>
</tr>
<tr>
<td>Hip Add 1RM (kg)</td>
<td>54.66 23.63</td>
<td>53.75 21.91</td>
<td>0.930</td>
</tr>
<tr>
<td>Calf Press 1RM (kg)</td>
<td>108.64 47.36</td>
<td>116.57 40.12</td>
<td>0.691</td>
</tr>
<tr>
<td>Leg Curl 1RM (kg)</td>
<td>42.64 15.70</td>
<td>47.37 17.03</td>
<td>0.536</td>
</tr>
</tbody>
</table>
**Participant Adherence**

Adherence was assessed by the number of sessions attended divided by the number of possible sessions that could be attended (18). For all 15 subjects who completed the intervention adherence was 89% and when stratified by group was 93% for the ST group and 85% for the PT group, respectively (Table 8).

**Table 8: Participant Adherence**

<table>
<thead>
<tr>
<th>Group</th>
<th>Attendance</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST</td>
<td>93%</td>
</tr>
<tr>
<td>PT</td>
<td>85%</td>
</tr>
</tbody>
</table>

**Changes in Muscle Strength Measurement**

In an assessment of unadjusted data, the PT group had a mean increase of 11.97 kg at follow up versus 5.44 kg for the ST group in measures of leg extension 1RM. The PT group had a mean change of 35.15 kg at follow up versus 20.87 kg for the ST group in measures of leg press 1RM (Table 9).

**Table 9: Muscle Strength Raw Scores – means (SD)**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Strength (n=7)</th>
<th>Power (n=8)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Effect Size</td>
<td>Pre</td>
<td>Post</td>
<td>Effect Size</td>
</tr>
<tr>
<td>Leg Extension (kg)</td>
<td>38.95 (25.26)</td>
<td>44.39 (22.70)</td>
<td>0.23</td>
<td>34.81 (27.45)</td>
<td>46.78 (24.89)</td>
<td>0.46</td>
</tr>
<tr>
<td>Leg Press (kg)</td>
<td>152.60 (96.32)</td>
<td>173.47 (72.60)</td>
<td>0.25</td>
<td>141.18 (64.57)</td>
<td>176.33 (68.43)</td>
<td>0.53</td>
</tr>
</tbody>
</table>

There were significant improvements in leg extension strength (p=0.002) and leg press strength (p=0.016) when the ST group and PT group were collapsed and analyzed as one sample (Table 10).
Table 10: ANCOVA of Muscle Strength of Combined Sample – least squares means (SE)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Baseline</th>
<th>Follow-up</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg Extension (kg)</td>
<td>36.74 (4.29)</td>
<td>45.66 (3.35)</td>
<td>0.002</td>
</tr>
<tr>
<td>Leg Press (kg)</td>
<td>146.51 (12.22)</td>
<td>175.00 (9.94)</td>
<td>0.016</td>
</tr>
</tbody>
</table>

Both groups demonstrated improvements in leg press and leg extension muscular strength (Table 11). This model included covariates of age, gender, BMI and baseline score. There was a significantly greater improvement in leg extension strength (13.85 kg versus 3.28 kg) in the PT group (p=0.008). There was no difference in the change in leg press strength between the groups (Table 11).

Table 11: ANCOVA of Muscle Strength – least squares means (SE)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Strength (n=7)</th>
<th>Power (n=8)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Leg Extension Strength</td>
<td>3.28 (2.08)</td>
<td>13.85 (1.92)</td>
<td>0.008</td>
</tr>
<tr>
<td>Change in Leg Press Strength</td>
<td>14.77 (13.90)</td>
<td>40.49 (11.59)</td>
<td>0.257</td>
</tr>
</tbody>
</table>

Changes in Muscle Power Measurement

In unadjusted data, the PT group had a mean increase of 69.94 W at follow up compared to a mean increase of 51.15 W for the ST group in leg extension power. The PT group had a mean increase of 100.0 W compared to a mean increase of 92.07 W for the ST group in leg press power (Table 12).
Table 12: Muscle Power Raw Scores – means (SD)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Strength (n=7)</th>
<th>Power (n=8)</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>Leg Extension (W)</td>
<td>326.71 (216.71)</td>
<td>377.86 (195.37)</td>
<td>0.25</td>
</tr>
<tr>
<td>Leg Press (W)</td>
<td>354.86 (172.78)</td>
<td>446.93 (192.83)</td>
<td>0.50</td>
</tr>
</tbody>
</table>

There were significant improvements in leg extension power (p=0.001) and leg press power (p=0.002) when the ST group and PT group were combined (Table 13).

Table 13: ANCOVA of Muscle Power of Combined Sample – least squares means (SE)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Baseline</th>
<th>Follow-up</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg Extension Power (W)</td>
<td>287.27 (26.1)</td>
<td>348.43 (25.09)</td>
<td>0.001</td>
</tr>
<tr>
<td>Leg Press Power (W)</td>
<td>337.27 (32.84)</td>
<td>433.57 (31.00)</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Covariates in model: age, sex, BMI

There were no significant differences between the ST group and PT group in changes in leg press power (p=0.973) or changes in leg extension power following the intervention (p=0.536) (Table 14).

Table 14: ANCOVA of Muscle Power – least squares means (SE)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Strength (n=7)</th>
<th>Power (n=8)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Leg Extension Power (W)</td>
<td>50.04 (21.65)</td>
<td>70.91 (19.96)</td>
<td>0.536</td>
</tr>
<tr>
<td>Change in Leg Press Power (W)</td>
<td>95.14 (41.45)</td>
<td>97.32 (38.12)</td>
<td>0.973</td>
</tr>
</tbody>
</table>

Covariates in model: age, sex, BMI, peak power at baseline
Influence of Strength or Power Training on Maximal Recoverable Lean Angle

In unadjusted data, the ST group showed a mean increase of 4.1 degrees and the power PT showed a mean increase of 0.6 degrees following the intervention (Table 15).

Table 15: $F_{\text{Lean}_{\text{max}}}$ Raw Scores – means (SD)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Strength (n=7)</th>
<th>Power (n=8)</th>
<th>Effect Size</th>
<th>Strength (n=7)</th>
<th>Power (n=8)</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{\text{Lean}_{\text{max}}}$ (degrees)</td>
<td>15.54 (5.81)</td>
<td>19.64 (5.43)</td>
<td>0.73</td>
<td>15.47 (5.82)</td>
<td>16.09 (4.93)</td>
<td>0.11</td>
</tr>
<tr>
<td>Load at $F_{\text{Lean}_{\text{max}}}$ (kg)</td>
<td>36.11 (16.85)</td>
<td>38.47 (13.96)</td>
<td>0.15</td>
<td>28.30 (12.82)</td>
<td>28.18 (12.32)</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

There was not a significant difference in $F_{\text{Lean}_{\text{max}}}$ between the ST group and PT group. The ST group had an increase of 3.57 degrees compared to 1.09 degrees in the PT group (p=0.422). This model included covariates of age, gender, BMI and baseline score (Table 16).

Table 16: ANCOVA of $F_{\text{Lean}_{\text{max}}}$ – least squares means (SE)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Strength (n=7)</th>
<th>Power (n=8)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in $F_{\text{Lean}_{\text{max}}}$ (degrees)</td>
<td>3.57 (1.92)</td>
<td>1.09 (1.77)</td>
<td>0.422</td>
</tr>
</tbody>
</table>

Covariates in model: age, sex, BMI, forward $F_{\text{Lean}_{\text{max}}}$ at baseline
Figure 4: Individual Change in Forward FLean_{max}
Influence of Strength and Power Training on LLean$_{\text{max}}$

In unadjusted data, the PT group showed a mean increase of 2.81 degrees and the ST group showed a mean increase of 1.98 degrees following the intervention (Table 17).

Table 17: Lateral LLean$_{\text{max}}$ Raw Scores – means (SD)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Strength (n=7)</th>
<th>Power (n=8)</th>
<th>Effect Size</th>
<th>Pre</th>
<th>Post</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLean$_{\text{max}}$ (degrees)</td>
<td>10.70 (2.46)</td>
<td>12.68 (2.64)</td>
<td>0.77</td>
<td>7.66</td>
<td>10.47</td>
<td>0.69</td>
</tr>
<tr>
<td>Load at LLean$_{\text{max}}$ (kg)</td>
<td>24.97 (5.12)</td>
<td>28.67 (5.97)</td>
<td>0.67</td>
<td>20.91</td>
<td>21.11</td>
<td>0.03</td>
</tr>
</tbody>
</table>

There were no significant differences in the change in LLean$_{\text{max}}$ between the ST group and the PT group. The PT group increased 2.82 degrees compared to 1.98 degrees in the ST group (p=0.587). This model included covariates of age, gender, BMI and baseline score (Table 18).

Table 18: ANCOVA of LLean$_{\text{max}}$ – least square means (SE)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Strength (n=7)</th>
<th>Power (n=8)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Lateral Lean$_{\text{max}}$ (degrees)</td>
<td>1.98 (0.98)</td>
<td>2.82 (0.90)</td>
<td>0.587</td>
</tr>
</tbody>
</table>

Covariates in model: age, sex, BMI, LLean$_{\text{max}}$ at baseline
Figure 5: Individual Change in $\text{LLean}_{\text{max}}$
**Other Analyses**

Additional analyses were completed to compare $F_{\text{Lean}_{\text{max}}}$ with age and gender. We also completed an analysis of the percent improvement in leg extension strength, leg press strength, leg extension power and leg press power. Last, we computed the raw score means of the total number of trials to reach maximum recoverable forward and lateral lean angle.

There was a trend for better performance in young compared to old participants ($p=0.173$, Table 19).

**Table 19: Correlation Between Age and $F_{\text{Lean}_{\text{max}}}$**

<table>
<thead>
<tr>
<th>Measures</th>
<th>Pearson Correlation</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age and $F_{\text{Lean}_{\text{max}}}$</td>
<td>-0.29</td>
<td>0.173</td>
</tr>
</tbody>
</table>

There was a trend for greater improvement in males compared to females ($p=0.130$, Table 20).

**Table 20: Independent Samples T-test of Gender**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean (SD)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male (n=12)</td>
<td>Female (n=11)</td>
</tr>
<tr>
<td>$F_{\text{Lean}_{\text{max}}}$ (degrees)</td>
<td>16.77 (4.44)</td>
<td>13.06 (6.69)</td>
</tr>
</tbody>
</table>

In unadjusted data, the ST group improved 18.9%, 20.2%, 24.3% and 32.5% in leg extension strength, leg press strength, leg extension power and leg press power, respectively (Table 21). The PT group improved 25.3%, 25.8%, 26.9% and 13.1% in leg extension strength, leg press strength, leg extension power and leg press power, respectively (Table 21).
Table 21: Raw Score Percent Change of Muscle Strength and Power

<table>
<thead>
<tr>
<th>Measure</th>
<th>ST Group (n=7)</th>
<th>PT Group (n=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leg Extension Strength</td>
<td>18.9%</td>
<td>25.3%</td>
</tr>
<tr>
<td>Leg Press Strength</td>
<td>20.2%</td>
<td>25.8%</td>
</tr>
<tr>
<td>Leg Extension Power</td>
<td>24.3%</td>
<td>26.9%</td>
</tr>
<tr>
<td>Leg Press Power</td>
<td>32.5%</td>
<td>13.1%</td>
</tr>
</tbody>
</table>

In adjusted data, subjects completed 9.9 trials at baseline and 10.3 trials at follow up in the forward leaning task. Subjects completed 7.1 trials at baseline and 8.3 trials at follow up in the lateral leaning task.

Table 22: Number of Leaning Trials

<table>
<thead>
<tr>
<th>Measure</th>
<th>Baseline (n=15)</th>
<th>Follow up (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLean_{max} (degrees)</td>
<td>9.9</td>
<td>10.3</td>
</tr>
<tr>
<td>LLean_{max} (degrees)</td>
<td>7.1</td>
<td>8.3</td>
</tr>
</tbody>
</table>
DISCUSSION

Summary of Findings

The main result from this study was there were no significant differences between the ST group and PT group in measurements of FLean_max following six weeks of resistance training. Also, there were no significant differences between the ST group and PT group in measurements of LLean_max following the six week resistance training intervention. The PT group showed greater improvements in leg extension strength compared to the ST group. Leg extension power and leg press power increased following the intervention in the PT group and there were trends towards improvement in the ST group; however changes in peak power in leg extension and leg press were not different between the ST group and PT group.

This study also provided some evidence for the use of ST and PT protocols with older adults. However, our sample was highly functional and the same protocol may not be appropriate for older adults with a lower level of physical function. Older adults were able to complete the forward and lateral leaning tasks and it was reasonable to test our subjects before and after an intervention. However, it was challenging for older adults to maintain static leaning postures near their maximum leaning angle.

Influence of Resistance Training on Maximal Recoverable Lean Angle

Our main outcome was maximal recoverable lean angle in the forward leaning task following six weeks of resistance training (FLean_max). We hypothesized that the PT group would show a greater improvement in FLean_max after six weeks of resistance training compared to the ST group. This was based on a large body of literature that suggests that muscle power may be more influential than muscle strength in tasks were
velocity of movement is crucial (Bean et al., 2003; Grabiner et al., 2005; Hanson et al., 2009; Henwood et al., 2008; Herman et al., 2005; Marsh et al., 2009; Orr et al., 2006). Contrary to our hypothesis, there were no significant differences between the ST group and PT group in FLean_{max} following the resistance training intervention (p=0.422). There were also no significant differences between groups following the intervention in Lateral FLean_{max} (p=0.587). There are a variety of explanations for these results.

There were no significant differences in FLean_{max} between the ST group and PT group following the intervention. However, a Cohen’s d (Cohen, 1988) of 0.73 in the raw score of FLean_{max} in the ST group from baseline to follow up suggests that ST provided a greater effect than PT. Our hypothesis for future research would not change since there were no significant differences between groups in muscle power improvement. The Cohen’s d (Cohen, 1988) for leg extension power and leg press power from baseline to follow-up did not vary between the ST group and PT group (0.25 vs. 0.38 and 0.50 vs. 0.47, respectively).

The effect sizes observed for in leg extension strength (ST=0.23, PT=0.46) and power (ST=0.25, PT=0.38) and leg press strength (ST=0.25, PT=0.53) and power (ST=0.50, PT=0.47) (Table 8, 10) were small to moderate. A longer intervention leading to greater adaptations in muscle strength and muscle power could positively influence changes in FLean_{max}. This intervention was only six weeks in length and therefore any improvement in FLean_{max} was, in large part, due to a neural component (Hakkinen & Hakkinen, 1995; Hakkinen, Kallinen et al., 1998; Hakkinen, Newton et al., 1998; Keen, Yue, & Enoka, 1994; Moritani & deVries, 1980). Moritani and DeVries (Moritani & deVries, 1980) found that during a 12 week training program, neural factors were the
predominant source of changes in strength during the first 8 weeks. Muscle hypertrophy became the dominant factor for the remaining 4 weeks. Additionally, Hakkinen and Hakkinen (Hakkinen & Hakkinen, 1995) found significant increases in EMG activity during the first 8 weeks of a 12 week resistance training program suggesting neural adaptation in response to training (p<0.05). However, enlargements in muscle cross sectional area were found at 12 weeks (p<0.05). Keen and colleagues (Keen et al., 1994) found that after 12 weeks of resistance training there was an average strength increase of 39% with only a 7% increase in muscle volume. These results suggest that muscle hypertrophy may not occur in the initial stages of strength training; and that improvements in strength are largely attributed to neural adaptations. To compare with Keen et al., our 6 week intervention yielded improvements ranging from 18.9 percent to 25.8 percent (Table 20).

Our intervention consisted of isolated resistance training activities only. Recovering balance from a perturbation requires a dynamic response involving different movement patterns and strategies (Maki & McIlroy, 2006). Thelen and colleagues (Thelen et al., 1997) suggested that recovery in the forward leaning task is largely based on speed of movement, but also stressed the importance of lower extremity coordination. The stepping foot has to rapidly move to the correct position within the base of support under the center of gravity to adequately recover balance in the stepping paradigm. Madigan and Lloyd (Madigan & Lloyd, 2005a) showed in an examination of recovery patterns at the ankle, knee and hip that older adults had a smaller peak power than younger adults. However, older adults had greater peak power than younger adults in some phases of balance recovery. The authors suggested that this may be because of a
change in neuromuscular coordination that occurred due to aging. As the neuromuscular system attempts to mitigate the effects of aging on muscle strength, power and rate of torque development weaker muscle groups might be augmented by other muscle groups that contribute to the same movement such as a concentric contraction of the hip extensors contributing to knee extension (Madigan & Lloyd, 2005a).

Since the PT and ST interventions involved isolated exercises, it may be that the motor control patterns responsible for balance recovery were insufficiently trained. A training program that consists of dynamic movements with a resistance component may be more beneficial than isolated resistance training. Arampatzis and colleagues (Arampatzis, Peper, & Bierhaum, 2011) examined the effects of a dynamic stability training program on the recovery performance of older adults (mean age=66.6 years) on a forward leaning task similar to that used in this thesis. Their study examined the effect of two intervention strategies: dynamic stability training and dynamic stability plus resistance training and also had a control group. After 14 weeks of training, the two experimental groups improved to a similar extent (~35% increase) on their ability to regain balance during simulated forward falls. The authors attribute the improvement to variables related to dynamic stability such as a faster increase in base of support. Adding resistance training to the dynamic stability exercises did not augment the amount of improvement. The main conclusion of the study was that a faster utilization of dynamic stability mechanisms due to improved neuromuscular control results in performance improvements in simulated forward falling.

While muscle power and strength are modifiable (Fielding et al., 2002; Marsh et al., 2009; Orr et al., 2006), it may be that our intervention should have targeted other
variables to improve performance on this forward leaning task. Local improvements in muscle power and strength may not be as important as training the neuromuscular system to respond quickly to a destabilizing perturbation. As stated before, muscle power is the product of muscle strength and velocity, but it is unclear which variable is more important for developing power for balance recovery. Mayson and colleagues (Mayson et al., 2008) performed a cross sectional analysis to assess whether muscle strength or limb velocity was more influential on balance performance in mobility limited elders. They reported that higher leg press velocity had a greater association with balance than muscle strength (Mayson et al., 2008).

**Influence of Resistance Training on Maximal Recoverable Lateral Lean Angle**

To our knowledge, no study has attempted to quantify fall recovery using a leaning task in the lateral direction. Our results showed that LLean\textsubscript{max} was smaller than FLean\textsubscript{max} in the ST group and PT group at baseline and follow up.

The available literature suggests that postural stability in the medio-lateral (M-L) direction may be more sensitive to the effect of aging (Maki et al., 1994; Maki & McIlroy, 2006; Rogers et al., 2001; Rogers & Mille, 2003). In a prospective study of postural balance in the elderly, Maki and colleagues (Maki et al., 1994) found that lateral spontaneous sway was the best single predictor of future falling risk compared to any measure of anterior-posterior (A-P) sway. Greater reductions of balance in the M-L direction compared to the A-P direction may explain why LLean\textsubscript{max} was consistently found to be lower than FLean\textsubscript{max} in our results.
Similar to the forward leaning task, there was no significant difference in LLean\textsubscript{max} between the ST group and PT group following the resistance training intervention. Lateral fall recovery is usually accomplished using protective stepping (Rogers et al., 2001; Rogers & Mille, 2003). Successful recovery is largely dependent on hip abduction and adduction torques (Rogers et al., 2001; Rogers & Mille, 2003). Our intervention had one exercise for hip abduction and one exercise for adduction. These exercises were completed on weight stack machines which isolated this movement. Additional exercises targeting the hip abductors and adductors in a dynamic fashion may produce a greater change in LLean\textsubscript{max} following an intervention.

**Influence of Resistance Training on Leg Strength and Leg Power**

There were significantly greater improvements in leg extension strength in the PT group (p=0.008). A trend towards greater changes leg press strength was observed in the PT group (p=0.140). There were no significant differences between groups in leg extension peak power and leg press peak power (p=0.536 and p=0.973, respectively). However, the small to moderate effect size (Cohen, 1988) for leg extension and leg press power indicates that our intervention was effective. Given that there was no difference between the ST group and PT group in leg extension and leg press power, a traditional strength training protocol may be sufficient to improve measurements of muscle power. However, as stated above, a longer intervention may be needed to determine if there is a benefit of PT over ST in measures of muscle power.

Our results did show trends towards greater improvements in muscle power in leg extension in the PT group. However, the difference in improvement between the two groups may not be meaningful when translated to the forward leaning task. The trend
between the ST and PT group could be related to the protocol used for the PT intervention. Prior research in training for muscle power is conflicting and it is unclear which protocol is best. We tested subjects at a resistance equal to 70% of their one repetition maximum and subjects exercised at 50% of their one repetition maximum. Some research indicates that a lower resistance is best for improving contraction velocity and functional task improvement (Miszko et al., 2003; Orr et al., 2006; Sayers, 2008). Orr and colleagues (Orr et al., 2006) examined improvements in balance index among three different power training groups. Each group exercised at one of three different training loads 80% 1RM, 50% 1RM and 20% of their most recent 1RM, respectively. The greatest improvement in balance index came from the group assigned to 20% 1RM. A potential explanation could be that a lower resistance allows the subject to improve velocity of contraction more so than a higher resistance. With regards to our intervention, a lower resistance setting might be more appropriate to improve contraction velocity. A review by Sayers (Sayers, 2008) stated that peak power occurs at 70% of 1RM. However, the author also stated that contraction velocity is at its highest at lower external resistance levels near 40% of 1RM. Cuoco and colleagues (Cuoco et al., 2004) found that muscle power developed at higher velocities with lower resistance (40% 1RM) explained more of the variability in function than muscle performance variables obtained at slower contraction velocities with higher maximal strength.

Although the groups did not show any significant differences in the change in leg press power and change in leg extension power, when combined, they did show significant improvements (p=0.002 and p=0.001, respectively) following the resistance training intervention (Table 13). This suggests that our training intervention did have an
effect but the PT intervention was not effective in eliciting a greater muscle power improvement than the ST intervention.

**Limitations and Potential Confounders**

This study has several limitations. Firstly, the forward leaning task may not accurately mimic the same biomechanical requirements needed to recover balance. However, the task was designed to give the researcher a high degree of experimental control while quantifying the ability to recover balance from a perturbation with a novel yet safe procedure. $F_{\text{Lean max}}$ showed trends to be greater in younger versus older adults ($p=0.173$) and greater in males than females ($p=0.130$) which is in accordance with other outcomes and prior research (Madigan & Lloyd, 2005a, 2005b; Wojcik et al., 1999, 2001) related to falls (Tables 20 & 21).

Second, the nature of the leaning tasks does not allow us to examine fall recovery as a dynamic action. The starting position is static and may not reflect a typical falling scenario. Third, our criteria for a successful attempt does not allow for more than one step during balance recovery. Clearly balance recovery following a trip may involve multiple steps. We had two common patterns of recovery that led to failure. First, if the subject required multiple steps with the right or left foot to recover their balance or if the harness caught the subject where a true fall would normally occur. There is some research that suggests older adults take slower and smaller steps during balance recovery (Hsiao-Wecksler & Robinovitch, 2007; Luchies, Alexander, Schultz, & Ashton-Miller, 1994). Older adults have greater difficulty recovering balance with a single step (Luchies et al., 1994). However, due to safety concerns, we did not allow a multiple step recovery. Next, given the novelty of the forward leaning task, there is a learning effect from
repeating the task. There is no way to discern improvement from the intervention and improvement from repeating the task a second time. However, our study had only two visits separated by six weeks and only 10 trials were completed at each of these visits. It is difficult to suggest that a strategy was adapted to improve performance between visits. Next, our study was not influenced by a ceiling effect. Past research reported maximal forward lean angles of 17 degrees for old females (Wojcik et al., 1999) and 24 degrees for old males (Thelen et al., 1997) and our subjects did not reach these values.

With regards to the study design, a larger sample is needed to increase the statistical power to state with confidence if there are any differences between the groups for our primary outcome of FLean_max. The small to moderate effect sizes (Cohen, 1988) observed suggest that increasing the sample size might increase the statistical power enough to observe a significant difference. Our training intervention was 6 weeks in duration. Some research indicates that it is possible to achieve a significant improvement in muscle strength and power in this amount of time (de Vos et al., 2005; Miszko et al., 2003). De Vos and colleagues (de Vos et al., 2005) reported that an 8 week power training intervention improved peak muscle power by 14-15%. However, this is a limitation in that any physiological adaptation that occurs is mainly neuromuscular. Greater improvements in muscle strength and power would likely result due to morphologic adaptation. A longer intervention would be required to encourage a morphological adaptation to occur as a result of resistance training. Fielding and colleagues (Fielding et al., 2002) reported a 97% improvement in leg press peak muscle power in older women following a 16 week power training intervention. Similarly, Marsh and colleagues (Marsh et al., 2009) showed that power training led to a two-fold greater
increase than strength training in knee extension (+34.4% versus 19.9%) and leg press (41.4% versus 22.3%) following a 12 week resistance training intervention. In the present study muscle power improvements ranged from 13.1% to 32.5% (Table 21). Prior research suggests that a longer intervention would help to distinguish the suspected advantages of PT over ST in improving muscle power.

Finally, the ST group had a mean age 5.3 years younger than the PT group (p=0.004). Muscle power declines at a rate of 3-4% per year (Petrella, Kim, Tuggle, Hall, & Bamman, 2005) and the difference between the groups could represent a 15-20% difference in age related muscle power declines. The PT group could be starting at a reduced baseline level of muscle power compared to the ST group. Also, the sample had a mean BMI of 30.5 kg·m⁻² and this may not be reflective of the general population. Obese older adults show greater postural sway and a greater prevalence of falls and trips (Fjeldstad et al., 2008; Singh et al., 2009). Last, the sample was high functioning (SPPB<sub>ST</sub>=9.8, SPPB<sub>PT</sub>=9.3) and did not report a past history of falling. A sample that targets individuals with a history of falling or at an elevated risk for falling may yield different results.
FUTURE DIRECTIONS

Future research needs to study a larger sample over a longer intervention duration. Furthermore, studies need to address different power training intensities to determine which is most efficacious for improving muscle power and balance recovery. Since the change in muscle power did not vary between the ST group and PT group, an intervention where there is greater variability between the groups in muscle power improvement is needed. Additionally, a task to simulate falls that is safe must be developed that allows perturbations to occur in a dynamic setting. This study was designed to improve the ability to recover from a forward leaning position. However, the task was not translated to actual fall occurrences. It is unknown if the prevalence of falls in this sample was reduced as a result of the resistance training intervention. Therefore, an investigation of the subjects fall prevalence following the intervention would also be worthy of study. Next, our subjects did not report a history of falling or exhibit a higher risk for falling than a normal older adult. It would be of interest to target populations that demonstrate a greater risk for falling or a past history of falls.

The primary outcome of our study was maximal recoverable forward lean angle. Since some research (Maki et al., 1994; Maki & McIlroy, 2006; Rogers et al., 2001; Rogers & Mille, 2003) points to greater reductions in M-L stability, interventions should target specific musculature that controls movement in these directions.

There are other variable associated with falls such as the use of medications, sedatives and sleep deprivation (Agostini, Han, & Tinetti, 2004; Tinetti et al., 1990; Tinetti et al., 1988). Future studies should consider these variables and how they might
influence $F_{\text{Lean}_{\text{max}}}$. Other considerations should include training the patterns of movement with resistance to improve neuromuscular coordination.
IMPLICATIONS AND CONCLUSIONS

Muscle strength and muscle power improved as a result of the resistance training intervention. However, the data presented does not provide evidence that power training was superior to strength training to improve performance on the forward or lateral leaning task. These findings may be confounded by the nature of the forward leaning task. While our hypotheses cannot be confirmed from the results of this study, it is important to note that there were still several positive adaptations that promote the use of resistance training among older adults. Improvements in muscle strength and muscle power are relevant to balance recovery and many other measures of lower extremity physical function. In addition, participants did not exhibit a reduced capacity on the forward leaning task following the intervention. Therefore, our results suggest that resistance training is warranted among older adults to maintain and potentially improve their ability to recover from a forward trip. Further research with a larger sample and longer ST and PT intervention is needed to determine if PT is in fact superior to ST to improve one’s ability to recover from a forward leaning position.
APPENDIX

APPENDIX A

WAKE FOREST UNIVERSITY
INFORMED CONSENT

Powertrip Pilot Study
The influence of obesity and resistance training on the ability to recover from two leaning postures using a single step.

INVESTIGATORS:
Anthony Marsh, PhD
Health and Exercise Science
Wake Forest University

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. Your participation is voluntary. Please take your time to read the following information, and ask the study staff to explain anything that you do not understand or may be concerned about. You may also discuss the study with your friends and family. You are being asked to participate because you are in a specific body mass index range, aged 65-79 years, recently completed other randomized control trials, and/or have indicated a willingness to be contacted for testing or research.

Why Is This Study Being Done?
The purpose of this research study is twofold. First, we wish to measure the effect of obesity in older adults on the recovery of balance when challenged by a forward and sideways leaning task. Second, we wish to examine the effects of two different 6 week weight lifting exercise programs on the recovery of balance from a leaning position.

How Many People Will Take Part in the Study?
There will be 16 participants in this study.

What Is Involved in the Study?
To begin, you will be asked to attend a screening and assessment session at the Department of Health and Exercise Science Human Performance laboratory. You will be asked to complete a number of questionnaires to provide us with information regarding your health history, your background, and daily activities.

There are times that some questionnaires reveal medical problems that you may not have been aware of. Do you request that we alert you to this information and send important medical findings from your study tests/exams to your personal physician? Yes_______ No_______. If your answer is yes to this question, and we do find any evidence of medical problems, we will ask you for your physician's name and contact information at that time.
We will measure your height, weight, and waist circumference. We will measure your physical function using a brief assessment which measures your ability to stand from the seated position, to balance, and to walk 8 feet.

Finally we will measure your ability to recover your balance from a leaning position. You will be placed in a safety harness attached to the ceiling which will prevent you from coming into contact with the floor. A support cable will be attached to a belt you will wear so we can control your leaning position. The other end of the cable will be secured to a stable structure. You will be asked to slowly lean forward until your body is at the desired angle. Within 15 seconds but at a time unknown to you, the support cable will be released and you will be required to step forward with your right leg in order to regain your balance without moving your back foot. We will ask you to perform this task at greater lean angles until you are unable to regain your balance with one step. The same task will then be performed with you leaning to your right side. In this task you will step to the side with your right leg to regain your balance. This visit will take about 1.5 hours.

If your body mass index is in the range of 21-25 we will ask you to come back to the lab on another day and repeat these tasks while wearing a weight vest and belt. This visit will last approximately 1 hour.

After about 1 week, you will be assigned, at random, to either a strength training group or a power training group. Random assignment means that the group you are in is chosen at random, similar to flipping a coin, by a special computer program; it is important to remember that neither you nor anyone on our staff may choose your group assignment.

All participants in this study will meet at the Wake Forest University, Health and Exercise Science Department’s Clinical Research Center (CRC) in a group format for 1 hour, three times a week for six weeks with a Certified Clinical Exercise Specialist to undergo a series of exercises using weight machines designed to increase strength and power in the legs.

To complete the study you will be asked to complete the assessments that you did at the beginning of the study within one week of completing the training program. This will include the balance recovery assessments, some questionnaires, height and weight measurements, and a measure of physical function. This visit will last 1.5 hours. Participants with a body mass index of 21-25 will come in for an additional 1 hour visit to repeat the balance recovery assessments wearing the weighted vest.

**How Long Will I Be in the Study?**
If you participate in this study you will be in the study for about 8-10 weeks. The main part of the study is a 6 week exercise program. Prior to and after the intervention we will collect the information outlined above.
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?**

Taking part in this research study may involve providing information that you consider confidential or private. Efforts, such as coding research records, keeping research records secure and allowing only authorized people to have access to research records, will be made to keep your information safe.

With the balance recovery task, there is the risk of injury to the muscles and joints of the leg. These risks will be minimized by the use of a full body harness which will not allow you to fall or make contact with the ground other than with your feet. With both strength and power training, there is the risk of injury to muscles and joints of the leg. These risks will be minimized by using a warm-up prior to exercise and starting out at an intensity or effort that you can handle and gradually increasing that intensity over the 6 week training program. Also, the HES Research Technicians are trained in exercise testing and prescription, and emergency procedures are well established at the CRC if complications should occur.

Finally, to minimize risk we will ask you some questions about your health history and obtain clearance from your physician prior to you engaging in any exercise.

**ARE THERE BENEFITS TO TAKING PART IN THE STUDY?**

If you agree to take part in this study, there may be direct benefit to you. You will be provided with feedback about your physical function measures from your initial and follow-up assessments. This will compare your physical function with average values for people your age which you may show your physician. Participation in the exercise intervention will likely increase strength or power in the legs. This may reduce your risk of falling should your balance be challenged in activities of daily living. We hope the information learned from this study will benefit other people in the future.

**WHAT OTHER CHOICES ARE THERE?**

There are programs, such as health clubs or fitness facilities that offer exercises using weight machines for a monthly fee.

**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?
There will be no financial re-imbursement for your participation in this study.

WHO IS SPONSORING THIS STUDY?
This study is being sponsored by the Department of Health and Exercise Science of Wake Forest University.

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.

WHOM DO I CALL IF I HAVE QUESTIONS OR PROBLEMS?
For questions about the study or in the event of a research-related injury, contact the study investigator, Tony Marsh at (336) 758-4643.

The Institutional Review Board (IRB) is a group of people who review the research to protect your rights. If you have a question about your rights as a research participant, you should contact the Wake Forest University 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 study. I have had a chance to ask questions about being in this study and have those questions answered.

Subject Name (Printed)

Subject Signature                      Date

Person Obtaining Consent               Date
APPENDIX B

Demographics Form

Participant ID: ___________________________ Acrostic: ___________________________
Date: ___________________________

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 □ I do not wish to answer

5. Who lives with you? □ Spouse
   □ Child
   □ 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 Graduates
   □ Other
   Specify: ___________________________
   □ I do not wish to answer

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
   □ I do not wish to answer
APPENDIX C

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

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Has a doctor ever told you that you have diabetes?</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>If you do have diabetes, do you use insulin to control your diabetes?</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>2. Has a doctor ever told you that you have high blood pressure</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>(hypertension)?</td>
<td></td>
</tr>
<tr>
<td>If you do have high blood pressure, do you take medication for your</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>blood pressure?</td>
<td></td>
</tr>
<tr>
<td>3. Has a doctor ever told you that you have had a heart attack?</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>If a doctor has told you that you have had a heart attack, did your</td>
<td></td>
</tr>
<tr>
<td>heart attack occur within the past 6 months?</td>
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<tr>
<td>4. Has a doctor ever told you that you may have any of the following?</td>
<td>Yes, No, Don't know</td>
</tr>
<tr>
<td>a. angina (chest pain, discomfort, pressure or heaviness due to a</td>
<td></td>
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<tr>
<td>blocked or clogged blood vessel in your heart)?</td>
<td></td>
</tr>
<tr>
<td>b. heart failure or congestive heart failure?</td>
<td></td>
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<tr>
<td>c. heart rhythm problem or irregular heartbeat?</td>
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<tr>
<td>d. heart conduction problem or heart block?</td>
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<tr>
<td>e. heart valve problem?</td>
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</table>
5. Has a doctor ever told you that you had a stroke or transient ischemic attack (TIA) or mini-stroke?  
   - Yes  
   - No  
   - Don't know  

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  
   - Yes  
   - No  
   - Don't know  

6. Has a doctor ever told you that you have a blood circulation problem in any of the following areas?  
   - a. in your head or neck?  
     - Yes  
     - No  
     - Don't know  
   - b. in your legs or feet (peripheral vascular disease (PVD) or peripheral arterial disease (PAD))?  
     - Yes  
     - No  
     - Don't know  
   - c. in any other part of your body?  
     - Yes  
     - No  
     - Don't know  

7. Has a doctor ever told you that you have emphysema, chronic bronchitis, chronic obstructive pulmonary disease (COPD), or lung disease?  
   - Yes  
   - No  
   - Don't know  

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?  
   - Yes  
   - No  
   - Don't know  

9. Do you have a vision impairment that cannot be corrected and results in inability drive?  
   - Yes  
   - No  
   - Don't know  

10. Has a doctor ever told you that you have Parkinson's disease?  
    - Yes  
    - No  
    - Don't know  

11. Has a doctor ever told you that you have cancer?  
    - Yes  
    - No  
    - Don't know  

If a doctor told you that you have cancer, were you treated for this within the last 6 months?  
   - Yes  
   - No  
   - Don't know
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?  
a. neck  
- Yes  
- No  
- Don't know  
b. hands  
- Yes  
- No  
- Don't know  
c. feet  
- Yes  
- No  
- Don't know  
d. back  
- Yes  
- No  
- Don't know  
e. shoulders  
- Yes  
- No  
- Don't know  
f. hips  
- Yes  
- No  
- Don't know  
g. knees  
- Yes  
- No  
- Don't know

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
16. 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>
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</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>
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APPENDIX D

AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire

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

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.

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

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 quit within the previous 6 mo.
- Your BP is greater than 140/90.
- You don’t know your BP.
- You take BP 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 more than two of the statements in this section, you should consult your physician or other appropriate healthcare provider before engaging in exercise. You might benefit by using a facility with a professionally qualified exercise staff to guide your exercise program.

If you marked any of the statements in this section, consult your physician or other appropriate healthcare provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

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.


www.acsm-msse.org/pdf/coretemplate-journal/noselimedia/0890c.htm

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APPENDIX E

Functional Performance Inventory

This questionnaire assesses the physical disability of the respondent.

The questionnaire is completed at all data collection intervals and is self-administered. It consists of 23 questions in which respondents are asked to indicate how much difficulty they experienced performing each activity during the past month. Responses are scored on a 6-point scale ranging from “Usually did with no difficulty” to “Usually did not do for other reasons”. There are five subscales: B=Basic; T=transfer; A=ambulation/climbing; UE=upper extremity; and C=complex.

Reference:

Acrostic:   _ _ _ _
ID #:       _ _ _ _
Date:       _ _ / _ _ / _ _

WE WANT TO KNOW HOW WELL YOU CAN TAKE CARE OF YOURSELF AND DO THINGS BY YOURSELF. THESE QUESTIONS WILL ASK ABOUT THINGS THAT MOST PEOPLE DO OR HAVE DONE IN THE PAST. MARK THE BOX UNDER THE PHRASE THAT BEST TELLS HOW YOU WERE ABLE TO DO THE DESCRIBED ACTIVITY IN THE PAST MONTH.

How much difficulty, if any, do you have with each of these activities? Think about the past month. How hard was it to do the activity because of your health?

1. Doing light housework (such as washing dishes, dusting, etc.)?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
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<td>☐</td>
<td>☐</td>
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<td>☐</td>
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</tbody>
</table>

2. Walking several blocks?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

3. Lifting heavy objects?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

4. Preparing your own meals?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

5. Participating in community activities such as religious services, social activities, or volunteer work?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
6. Walking one block?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

7. Lifting or carrying something as heavy as 10 pounds, such as a bag of groceries?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

8. Moving in and out of a chair?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

9. Managing your money, such as paying bills?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
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<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

10. Visiting with relatives or friends?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

11. Moving in and out of a bed?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
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</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>Question</td>
<td>Usually did with no difficulty</td>
<td>Usually did with a little difficulty</td>
<td>Usually did with some difficulty</td>
<td>Usually did with a lot of difficulty</td>
<td>Unable to do</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-------------------------------</td>
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<td>--------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>12. Gripping with your hands?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Using the telephone?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Using the toilet including getting on and off the toilet?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Dressing yourself?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Getting in and out of a car?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. Bathing or showering?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
18. Taking care of a family member?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<td>☐</td>
</tr>
</tbody>
</table>

19. Climbing several flights of stairs?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

20. Raising your arms above your head (to comb your hair or put away groceries)?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
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<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

21. Feeding yourself?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

22. Doing errands, such as grocery shopping or shopping for personal items?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

23. Climbing one flight of stairs?

<table>
<thead>
<tr>
<th>Usually did with no difficulty</th>
<th>Usually did with a little difficulty</th>
<th>Usually did with some difficulty</th>
<th>Usually did with a lot of difficulty</th>
<th>Unable to do</th>
<th>Usually did not do for other reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
### Appendix F

#### Test of Fails Questionnaire

<table>
<thead>
<tr>
<th>Item</th>
<th>10</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) <strong>How confident are you that you could do each of the activities without falling?</strong>&lt;br&gt;Completely confident</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Confident</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fairly confident</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Somewhat confident</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Not very confident</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Very confidence</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Extremely confidence</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Absolutely not confident</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

#### Scale Interpretation

- **10**: Absolutely confident
- **9**: Very confident
- **8**: Somewhat confident
- **7**: Not very confident
- **6**: Not confident
- **5**: Fairly confident
- **4**: Somewhat confident
- **3**: Not very confident
- **2**: Not confident
- **1**: Very confident
- **0**: Absolutely not confident

The items on this scale are scored from 0 to 10, with 0 meaning "not confident at all". Some items may be scored from 0 to 4, with 0 meaning "not confident at all" and 4 meaning "very confident". The items are scored independently. Any responses you do not wish to answer may leave blank.

This survey is designed to assess your physical function and your fear of falling. Please read the questions and answer by choosing the most appropriate answer. Any questions you do not wish to answer may leave blank.
APPENDIX G

Acrostic:  __  __  __  __  __

ID #:  __  __  __

Date:  __/__/____  Visit:  __

Folstein Mini-Mental State Examination

Directions for Interviewer: Read the following statements to the subject. When doing so, be as objective as possible. Do not lead or assist the subject.

"Mr./Mrs./Ms._____, the first set of questions will take about 3 minutes to complete. These questions are about remembering things. Some of the questions are very easy and some are difficult. I just want you to do the best you can."

A. ORIENTATION

<table>
<thead>
<tr>
<th>Time</th>
<th>Response</th>
<th>Correct</th>
<th>Sub-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the year?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. What is the season?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. What is the month?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. What is today's date?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. What day of the week is it?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Place

| 6. What state are we in? |         |         |           |
| 7. What county are we in? |         |         |           |
| 8. What city are we in? |         |         |           |
| 9. What is your 'home' address (facility?) |         |         |           |
| 10. What is your zip code (what floor do you live on?) |         |         |           |

ORIENTATION TOTAL ______

B. REGISTRATION

"Now for the next set of questions, I am going to name 3 objects. When I am finished saying all 3, I'm going to ask you to repeat them. Can you hear me OK? Listen closely. Here we go . . ."

"BALL"  "FLAG"  "TREE"

"Now repeat them back to me"

11. (Ball)  ______  ______

12. (Flag)  ______  ______

13. (Tree)  ______  ______

INSTRUCTIONS FOR SCORING: give 1 point for each correct answer. TOTAL ______

Have patient repeat all 3 items 3 to 10 times, until all 3 can be repeated correctly. Count number of trials needed and record: TRIALS ______

"I want you to remember those objects because I am going to ask you to say them again later."
C. **ATTENTION AND CALCULATION**

“For the next set of questions, I want you to spell the word, WORLD backwards.”

<table>
<thead>
<tr>
<th>Response</th>
<th>Correct</th>
<th>Sub-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.</td>
<td>(D)</td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>(L)</td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>(R)</td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>(O)</td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>(W)</td>
<td></td>
</tr>
</tbody>
</table>

**Scoring:** give 1 point for each letter given in correct order. **ATTENTION TOTAL** ___

D. **RECALL**

“Mr./Mrs./Ms. _____, I had you name 3 objects a short time ago. Can you repeat the names of those objects to me now?”

**Directions to Interviewer:** Give POSITIVE feedback to ANY correct answer.
(Ball, Flag, Tree—any order is OK)

| 19.      |        |           |
| 20.      |        |           |
| 21.      |        |           |

**RECALL TOTAL** ___

E. **LANGUAGE**

“I now have a few more questions.”

22. “What is this called?” (SHOW A PEN) ___ ___

23. “What is this called?” (SHOW A WATCH) ___ ___

24. “I want you to repeat the following sentence after me . . .”

“NO IFS, ANDS, OR BUTS.” ___ ___

*3-Stage Command*

“Mr./Mrs./Ms. _____, take this paper in your right hand (or left, if patient had a stroke, fracture, etc.), fold it in half and put it on the floor.”

**Instructions:** Give one point for each component of the 3 stage command which patient accomplishes.

25. Take paper in right hand ___ ___

26. Fold it in half ___ ___

27. Put in on floor ___ ___

*Reading*

“Please read the statement on this paper and do what the statement says.”
**Instructions:** Give patient piece of paper with instruction, “CLOSE YOUR EYES” on it.

<table>
<thead>
<tr>
<th></th>
<th>Response</th>
<th>Correct</th>
<th>Sub-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>28.</td>
<td>Patient closed eyes</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Writing</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“I want you to write a sentence on the lines below the design. Write down ANY sentence that comes to your mind.”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29.</td>
<td>Patient writes a complete sentence</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Copying</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Mr./Ms. _____ next to the design, please COPY it EXACTLY as it appears.”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.</td>
<td>Patient copies diagram of intersecting pentagons</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SCORING:** all 10 angles must be present and 2 angles from each pentagon must intersect. Ignore tremor and rotation.

**LANGUAGE TOTAL**

**TOTAL SCORE (0-30 points)**

**INTERVIEWER INITIALS:**

**COMMENTS:**
CLOSE YOUR EYES
### APPENDIX H

**POWERTRIP**

<table>
<thead>
<tr>
<th>Participant ID #</th>
<th>Interviewer Code</th>
<th>Date of Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

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**Champs Activities Questionnaire for Older Adults®**

Champs Community Health Activities Model Program for Seniors
Institute for Health & Aging, Center for Healthy and Active Living
University of California San Francisco
Stanford Center for Research in Disease Prevention, Stanford University

Pre-interview instructions for the participant:
I will ask you about various activities that you may have done in the past four weeks; for those activities that you have done, I will also ask you how many times you have done the activity and how many total hours you spent doing the activity. I also may ask you some questions about the activities you report doing to get a better understanding of those activities and to make sure we gather the most accurate information. There are no “right” or “wrong” responses, so please answer each question as honestly and accurately as you can. *Do you have any questions?* (Interviewer Note: If the participant cannot respond or understand the questions, go to question #44.)

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>No</th>
<th>Yes</th>
<th>How many times a week?</th>
<th>If yes, how many total hours a week did you usually do it?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(show response card “Champs 1”)</td>
</tr>
<tr>
<td>In a typical or normal week during the past 4 weeks, did you...</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Visit with friends or family? (other than those you live with)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Go to the senior center?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Do volunteer work?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Attend church or take part in church activities?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Attend other club or group meetings?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Use a computer?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Dance? (such as square, folk, line, ballroom) (do not count aerobic dance here)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>* 4.5 METS; Moderate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
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* Page 1 of 5 *
<table>
<thead>
<tr>
<th>Activity</th>
<th>No</th>
<th>Yes</th>
<th>How many times a week?</th>
<th>Less than 1 hour</th>
<th>1-2.5 hours</th>
<th>3-4 hours</th>
<th>5-6 hours</th>
<th>7-8.5 hours</th>
<th>9 or more hours</th>
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<tr>
<td>0. Do woodworking, needlework, drawing, or other arts or crafts?</td>
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<td>9. Play golf, carrying or pulling your equipment? (count walking time only)</td>
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<td>10. Play golf, riding a cart? (count walking time only)</td>
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<td>11. Attend a concert, movie, lecture, or sporting event?</td>
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<td>12. Play cards, bingo, or board games with other people?</td>
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<td>13. Shoot pool or billiards?</td>
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<td>14. Play singles tennis? (do not count doubles)</td>
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<td>15. Play doubles tennis? (do not count singles)</td>
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<td>16. Skate? (ice, roller, in-line)</td>
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<td>17. Play a musical instrument?</td>
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<td>19. Do heavy work around the house? (such as washing windows, cleaning gutters)</td>
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<td>20. Do light work around the house? (such as sweeping or vacuuming)</td>
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<td></td>
<td>In a typical or normal week during the past 4 weeks, did you...</td>
<td>Yes</td>
<td>If yes, how many total hours a week did you usually do it?</td>
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<td>21.</td>
<td>Do heavy gardening? (such as spading, raking) 4 METS; Moderate</td>
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<td>22.</td>
<td>Do light gardening? (such as watering plants) 2.25 METS; Light</td>
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<td>23.</td>
<td>Work on your car, truck, lawn mower, or other machinery? 3 METS; Moderate</td>
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**Please note:** For the following questions about running and walking, include use of a treadmill.

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<td>24.</td>
<td>Jog or run? 7 METS; Moderate</td>
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<td>25.</td>
<td>Walk uphill or hike uphill? (count only uphill part) 6 METS; Moderate</td>
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<td>26.</td>
<td>Walk fast or briskly for exercise? (do not count walking leisurely or uphill) 3.5 METS; Moderate</td>
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<td>27.</td>
<td>Walk to do errands? (such as to/from a store or to take children to school (count walk time only)) 2.5 METS; light</td>
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<td>28.</td>
<td>Walk leisurely for exercise or pleasure? 2.5 METS; light</td>
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<td>29.</td>
<td>Ride a bicycle or stationary cycle? 4 METS; Moderate</td>
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<td>30.</td>
<td>Do other aerobic machines such as rowing or step machines? (do not count treadmill or stationary cycle) 5 METS; Moderate</td>
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<td>Activity Description</td>
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<td>If yes, how many total hours a week did you usually do it?</td>
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<td>21. Do water exercises? (do not count other swimming)</td>
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<td>22. Swim moderately or fast?</td>
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<td>23. Swim gently?</td>
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<td>* 3 METS; Moderate</td>
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<td>24. Do stretching or flexibility exercises? (do not count yoga or Tai-chi)</td>
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<td>25. Do yoga or Tai-chi?</td>
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<td>26. Do aerobic or aerobic dancing?</td>
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<td>* 3.5 METS; Moderate</td>
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<td>27. Do moderate to heavy strength training? (such as hand-held weights of more than 5 lbs. weight machines or push-ups)</td>
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<td>* 4.5 METS; Moderate</td>
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<td>28. Do light strength training? (such as hand-held weights of 5 lbs. or less or elastic bands)</td>
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<td>* 3 METS; Moderate</td>
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<td>29. Do general conditioning exercises or chair exercises? (do not count strength training)</td>
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<td>* 2.5 METS; light</td>
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<td>30. Play basketball, soccer or racquetball? (do not count time on sidelines)</td>
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<td>* 5 METS; Moderate</td>
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* Page 4 of 5 *
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<th>No</th>
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<th>If yes, how many total hours a week did you usually do it?</th>
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<tr>
<td></td>
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<td>If yes, how many times a week?</td>
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<td>Less than 1 hour</td>
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<td>5-6½ hours</td>
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<td>7 and more hours</td>
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<td>8 or more hours</td>
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</tbody>
</table>

41. Do other types of physical activity not previously mentioned? (please specify)

42. Do other types of physical activity not previously mentioned? (please specify)

43. Do other types of physical activity not previously mentioned? (please specify)

Interviewer Note: Do feel this was a valid interview? Yes No

Specify:

------------------------------------------------------------------

------------------------------------------------------------------

Page 84
APPENDIX I

SPPB TESTING

PARTICIPANT#   ACROSTIC   STAFF ID   

VISIT #   DATE: ___/___/____ (dd/mm/yyyy)

Examiner Note: say to participant

This is a more active part of the exam.
I would like you to try to move your body in different movements.
I will first describe and show each movement. Then I’d like you to try to do it.

___________________________

BALANCE TEST

SIDE-BY-SIDE STAND

Examiner note: Stand next to the participant to help him/her into the side-by-side position. Allow the participant to hold onto your arm to get balance. The say to participant:

I want you to try to stand with your feet together, side-by-side, for 10 seconds. 
foot for about 10 seconds.

Demonstrate the movement. Then say,

You may use your arms, bend your knees, or move your body to maintain your balance, but try not to move your feet. Try to hold this position until I tell you to stop.

Start timing when the participant is read and in position.

Score: ______ = number of seconds held

Score 999 if attempted but participant could not stand unassisted
Score 998 if not attempted because participant could not stand
Score 777 if not attempted because participant felt unsafe
Score 666 if not attempted because participant refused

Was person able to hold balance for 10 seconds?

If yes, CONTINUE WITH SEMI-TANDEM STAND

If no, GO TO 4 METER WALK TEST
SPPB TESTING

PARTICIPANT# __ __ __ ___ ACROSTIC __ __ __ ___ STAFF ID __ __

VISIT # __ ______ DATE: ___ / ___ / ___ (dd/mm/yyyy)

BALANCE TEST

Examiner note: Say to participant:
Now I want you to try to stand with the side of the heel of one foot touching the big toe of the other foot for about 10 seconds.

Demonstrate the movement. Start timing when the participant is ready and in position.

Score: __ __ __ = number of seconds held

- Score 999 if attempted but participant could not stand unassisted
- Score 888 if not attempted because participant could not stand
- Score 777 if not attempted because participant fell unsafe
- Score 666 if not attempted because participant refused

Is the person able to hold balance for 10 seconds?
If yes, CONTINUE WITH FULL TANDEM STAND
If no, GO TO 4 METER WALK TEST

FULL TANDEM STAND

Examiner note: Say to participant:
Now I want you to try to stand with the heel of one foot in front of and touching the toes of the other foot for about 10 seconds.

Demonstrate the movement. Start timing when the participant is ready and in position.

Score: __ __ __ = number of seconds held

- Score 999 if attempted but participant could not stand unassisted
- Score 888 if not attempted because participant could not stand
- Score 777 if not attempted because participant fell unsafe
- Score 666 if not attempted because participant refused
SPPB TESTING

PARTICIPANT# ___ ___ ___ ACROSTIC ___ ___ ___ STAFF ID ___ ___

VISIT # ___ DATE: ___/___/___/____/____/___(dd/mmm/yyyy)

4-METER WALK TEST

Examiner note: Say to participant:
Now we are going to observe how you normally walk.
You may use your cane or other walking aid if you wish.

FIRST WALK:

Examiner note: Show the participant the walking course. Then say.

I want you to walk to the other end of the course at your usual speed,
just as if you were walking down the street to go to the store.

When participant is properly positioned at starting line, say:
Ready, begin.

Score: ___ ___ ___ ___ = number of seconds needed (to the nearest 0.01)

Score 999 if attempted but participant could not walk even with support (cane)
Score 888 if not attempted because participant could not walk
Score 777 if not attempted because participant felt unsafe
Score 666 if not attempted because participant refused

SECOND WALK:

Examiner note: Repeat the test.

Score: ___ ___ ___ ___ = number of seconds needed (to the nearest 0.01)

Score 999 if attempted but participant could not walk even with support (cane)
Score 888 if not attempted because participant could not walk
Score 777 if not attempted because participant felt unsafe
Score 666 if not attempted because participant refused
SPPB TESTING

PARTICIPANT# __ __ __ ___ ACROSTIC __ __ __ ___ STAFF ID ___

VISIT # __ ___ DATE: ___/___/_____ (dd/mmm/yyyy)

CHAIR RISE TEST

SINGLE CHAIR RISE

Examiner note: Say to participant:

The next test measures the strength in your legs.
First, fold your arms across your chest and sit so that your feet are on the floor.
Now, stand up one time keeping your arms folded across your chest and sit down.

Demonstrate the movement and then the participant should perform it.
If the participant is only able to do the test while holding on the chair, the person is not able to
do this test and a NO should be scored.

1. YES – Continue with the

   chair rise test

2. NO – Stop the test.

CHAIR RISE TEST

Examiner note: Now the participant should repeat the chair rise test for five times while keeping
arms folded across chest. When the participant is properly seated, say:
Ready........Stand.
Using a stopwatch, begin timing at the word “Stand.”
Count the number of chair rises out loud as the participant arises each time.
Stop the watch when the participant has straightened up completely in the chair
for the fifth time and all body movement has ceased.

Were all five chair rises completed with arms folded across chest?

1. YES

2. NO (used arms)

3. NO (could not do all 5)

Score: ______________________ = number of seconds (to nearest 0.01)
**APPENDIX J**

**POWERTRIP: Weight Training Record**

**POWER:** push as **quickly as possible** on the way out and count **1, 2, 3** on the way back

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<th>Date — —</th>
<th>Set</th>
<th>Reps</th>
<th>Wt.</th>
<th>Set</th>
<th>Reps</th>
<th>Wt.</th>
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<th>Reps</th>
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<th>Reps</th>
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<tr>
<td>Leg Press S.</td>
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<td>Leg Curl S.</td>
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<td>Hip Abduction S.</td>
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**Set 1:** Do 8-10 reps  **Set 2:** Do 8-10 reps  **Set 3:** Do as many reps as possible with good form

**STRENGTH:** slowly count **1, 2, 3** on the way out and **1, 2, 3** on the way back

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