THE ASSOCIATION OF OBESITY AND MUSCLE STRENGTH
AND POWER WITH THE ABILITY TO RECOVER BALANCE
FROM A FORWARD LEANING POSITION

BY

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DEDICATION

This thesis is dedicated to Jamie, my soon to be wife, for everything you do for me every day to make my life better. Your love and support mean more to me than I can express and I thank you for everything you have sacrificed for me.

This thesis is also dedicated to my parents, Lis and Knud. Thank you for making everything I have accomplished possible. Without your ongoing and unquestionable support and inspiration, I would not have had these amazing opportunities which have paved the way for what is to be an incredible career and a happy life. You have both instilled in me a strong work ethic and ability to think for myself and I thank you for everything you have done and continue to do.
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ABSTRACT

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THE ASSOCIATION OF OBESITY AND MUSCLE STRENGTH AND POWER WITH THE ABILITY TO RECOVER BALANCE FROM A FORWARD LEANING POSITION

Thesis under the direction of Anthony P. Marsh, Ph.D., Department of Health and Exercise Science.

This study measured the ability of older adults to recover balance when released from a forward leaning position. This forward leaning assessment was used as a surrogate for a balance recovery from a fall. The maximal body lean angle from which the subject could recover their balance was referred to as LeanMax. The primary aim was to assess the effects of obesity on LeanMax in a group of older adults (mean age = 70.6 ± 4.6 yrs). The second aim was to determine whether lower limb muscle strength or power were associated with the LeanMax. Ten obese subjects (mean BMI = 33.3 ± 2.6 kg·m⁻², 4 female) and 6 non-obese subjects (mean BMI = 25.1 ± 2.0 kg·m⁻², 3 female) were recruited. Each subject completed the forward lean assessment as well lower limb muscle strength (1 repetition maximum – 1RM) and power tests (peak power against a resistance of 70% 1RM) using Keiser Pneumatic Leg Extension and Leg Press machines.

There was no significant difference (p = .422) in LeanMax between the non-obese (mean = 15.4 ± 4.4°) and obese subjects (17.2 ± 4.2°). When mass was added to the non-obese subjects to simulate obesity, there was a trend (p = .062) for LeanMax to be reduced. There was also a trend (p = .062) for the simulated obese group to have a lower LeanMax (12.1 ± 4.5°) than the obese subjects (17.1 ± 3.7°) to whom they were equated for BMI and gender.

Lower limb muscle strength (r = .575, p = .020) and power (r = .548, p = .028) were both significantly correlated with LeanMax when measured using the Leg Press machine. The number of minutes spent doing physical activity of a moderate or greater intensity (≥3 METs) was also positively associated with LeanMax (r = .577, p = .019).

In summary, obesity was not associated with reduced ability to recover balance from a forward leaning position but additional mass in itself showed a trend to reduce LeanMax. Based on our findings, weight loss is not indicated for improving balance recovery, however, physical activities of a moderate or greater intensity and particularly those that promote lower limb strength and balance should be promoted in older populations.
REVIEW OF THE LITERATURE

An Aging Population Susceptible to Falls

The population of adults aged over 65 in the United States is increasing dramatically. Estimates suggest that between 2010 and 2030 this population will grow from 39 to 71 million to represent almost 20% of the US population. A fall may be defined as an unexpected event in which an individual comes to rest on the ground, floor or lower level. Falls are a major medical problem for older adults as this population has a higher prevalence of falls and a greater susceptibility to morbidity and mortality resulting from a fall.

Also increasingly prevalent in the older population is obesity. More than 32% of men and women aged over 60 yrs are clinically obese as characterized by a body mass index greater than 30kg·m\(^{-2}\). A number of studies have suggested that obesity may impair balance or be a risk factor for falls in older adults.

When a trip or slip occurs, balance is perturbed and must be regained through rapid movement of the lower limbs. While strength is fundamental to producing forceful contractions, velocity of the contraction must also be high so that balance can be regained rapidly. It has been suggested that under these circumstances, muscle power may be more important than muscle strength for regaining balance. Muscle strength and muscle power have both been shown to be associated with functional capacity and are known to deteriorate with age. Muscle power has been shown to decline at an earlier age and faster rate than muscle strength in both upper and lower limb muscles. The combination of age, obesity and reduced muscle power increase the risk of a slip or trip.
and impair physical function related to balance recovery thereby contributing to the growing incidence of injurious falls.

Falls are a Public Health Problem for Older Adults

Falls pose a major health risk for the older population with more than one third of community dwelling adults over 65 falling at least once a year\(^4\), \(^5\), \(^1\). Of greater consequence than the high incidence of falls alone is the combination of incidence and susceptibility to injury. Falls are the leading cause of death from unintentional injury\(^4\) and the most common cause of non-fatal unintentional injuries and hospital admissions of adults aged over 65 yrs\(^6\). In 2006, the Center for Disease Control (CDC) reported that 16,650 adults over 65 yrs died in the United States as a result of a fall\(^3\). With the population aging and chronic disease becoming more prevalent, the incidence of fall related mortality has increased significantly. Since 1999, the CDC reported a 54% increase in the incidence rate of fall related mortality in adults over 65 yrs reaching 44.68 deaths per 100,000 people in 2006\(^3\). Risk of fall related mortality increases significantly with age especially in those over the age of 75 yrs\(^1\). In 2006, individuals aged 65-69 yrs suffered from 9.51 fall related deaths per 100,000 people\(^3\). In contrast, those aged 75-79 and greater than 85 yrs had a 3.5 and 16 fold greater fall related mortality rate respectively. Falls amongst the elderly are associated with substantial medical costs. In 2000, direct medical costs totaled $179 million for fatal falls and $19 billion for non-fatal falls\(^1\).\(^11\)

In 2008 more than 2.1 million people aged 65 and older (>5% of this population) were treated for unintentional non-fatal fall related injuries and 503,391 were
hospitalized. The risk of falls and unintentional fall related injury increases greatly with age. In 2008, the incidence rate of fall related injuries for adults aged 65-69 yrs was 2,829 per 100,000 while the rate for adults aged over 85 yrs is more than four times this – 12,145 per 100,000.

The combination of chronic diseases such as osteoporosis and impaired physiological functions such as reaction time and balance increases the risk of a fall occurring and makes even a mild fall more hazardous. Approximately 5-10% of falls result in serious injury such as hip fractures, fractures of another bone, joint dislocation, subdural hematoma, serious soft tissue injury, or head injury. Traumatic brain injuries and injuries to the lower extremities are the most common and costly injuries accounting for 78% of fall related mortalities. Falls are responsible for about 90% of more than 300,000 hip fractures that occur each year, an injury which often results in long-term functional impairment. Magaziner et al. found that 12 months post fracture, new dependency in physical and instrumental activities of daily living for those previously independent ranged from about 20% for putting pants on to almost 90% for climbing 5 stairs. Between 15% and 25% of adults aged over 65 yrs suffering hip fractures remain in nursing homes for at least 12 months and 20% of older adults who suffer a hip fracture die within one year. Those who fall and sustain a hip fracture have been shown to have a mortality rate of 20-30% within a year of the fracture.

Traumatic Brain Injuries (TBI’s) are potentially one of the most disabling injuries and can result in long-term cognitive, behavioral and emotional complications. Falls are the leading cause of TBI’s accounting for 52% in adults aged over 65 yrs. Of falls that result in mortality, TBI’s are reported to account for 46% of such falls.
1995 and 2001, the average annual number of TBI’s for adults aged over 65 yrs was 155,283 which resulted in 83,000 emergency room visits, 60,000 hospitalizations, and 12,283 deaths\textsuperscript{64}. After children aged 0-4 yrs, adults aged over 75 yrs have the highest rate of fall related TBI’s (359.8 per 100,000)\textsuperscript{64}.

Recovery from injury is often delayed in the elderly resulting in further deconditioning which augments their falls risk\textsuperscript{102}. In the month following hospital discharge the risk of a fall increases and is also elevated during acute illness and exacerbation of chronic disease\textsuperscript{75,76}. Falling can also result in subsequent fear of falling causing older adults to become less active, more deconditioned and more susceptible to fall related injuries\textsuperscript{121}. A meta-analysis by Scheffer et al found that the three main risk factors for fear of falls were having had a fall, being female, and old age\textsuperscript{106}. They also reported that fear of falls resulted in a decline in physical activity and mental performance, as well as an increased risk of future falls and reduced health related quality of life.

**Causes of Falls and Subsequent Injury and Death**

Sattin aptly describes falls as a syndrome representing symptoms and signs of disordered function in a disordered environment\textsuperscript{105}. An underlying cardiac or musculoskeletal disease may be the cause of a fall. Likewise, a fall may lead to an event such as a fracture or traumatic brain injury. The cause of most falls are likely multifactorial. Some may have an unexplained etiology whereas that of others may be obvious e.g. syncope, seizure, stroke. Furthermore, falls may be explained by intrinsic problems with the individual and/or extrinsic or environmental factors. A number of risk
factors that increase the incidence of falls in the elderly and worsen the outcome have been identified.

Age has been shown to be a risk factor for fall related injuries\textsuperscript{3, 5, 6, 102}. This can be explained by the physiologic changes in the neuromuscular and musculoskeletal system that are common in the elderly. These changes lead to or are a result of osteoporosis, arthritis, decreased muscle strength, decreased muscle mass, decreased joint flexibility, decreased collagen elasticity and strength, and general pain and discomfort\textsuperscript{105}. This combination of factors increases the risk of slips or trips, reduces the bodies potential to be able to absorb forces inflicted by a slip, trip or fall, and likely leads to further deconditioning of the individual.

Osteoporosis increases the risk of bone fracture resulting from a fall by reducing the density of bone and thereby its resistance to a force. Given that osteoporosis is more prevalent in older women, more women are reported to suffer from fall related fractures, particularly of the hip\textsuperscript{51}.

Problems with gait and balance are frequently associated with falls risk. Older adults tend to display a more hazardous gait than younger individuals. With age, there is greater step timing variability and declines in postural control, body orienting reflexes, muscle strength, muscle power, and height of stepping which combined increases the risk of slips and trips and reduces ability to recover balance\textsuperscript{86, 87, 102}. Gait and balance abnormalities are related to age and may be affected by chronic diseases, vision, mental status and medication use.

By impairing sensory, cognitive, neurologic, and musculoskeletal function, chronic diseases such as cerebrovascular, cardiovascular, and neurological diseases may
also increase the propensity of an older adult to fall\textsuperscript{105}. Problems with vision affect the sensory feedback an individual requires to adapt to environmental conditions and avoid falls\textsuperscript{57}. Age related vision abnormalities such as cataracts, macular degeneration, and glaucoma should be treated to restore visual function and reduce falls risk. Dementia\textsuperscript{45}, delirium\textsuperscript{109} and depression\textsuperscript{105} increase falls risk. This may be due to increased exposure to hazardous environments which results from confusion, poor judgment, distraction, agitation, and lack of awareness. Sedatives, hypnotics, antidepressants, and benzodiazepines elevate falls risk\textsuperscript{53}. These pharmaceuticals may reduce alertness, affect judgment, compromise neuromuscular function, or cause dizziness and syncope\textsuperscript{126}. Diuretics and antihypertensive medications may act similarly by increasing fatigue, decreasing mental alertness, and causing postural hypotension.

The risk of a fall being injurious depends on the velocity of the fall, the force absorbing capacity of the surface of contact, the protective reaction of the faller, the force the musculoskeletal system can withstand, and the direction and location with which this force is applied to the faller\textsuperscript{105}. By improving the force producing capacity of the muscles and the rapidity with which the force can be applied, older adults may be better able to recover their balance in the event of a slip or a trip.

**Obesity Increases the Risk of Falls**

The World Health Organization defines body mass index (BMI) as body mass in kilograms divided by the square of the height in meters (kg⋅m\textsuperscript{-2}). A normal-BMI ranges from 18.50 - 24.99 kg⋅m\textsuperscript{-2}, a BMI of 25.00 - 29.99 kg⋅m\textsuperscript{-2} is considered overweight, and a BMI \(\geq 30.00\) kg⋅m\textsuperscript{-2} is considered obese. There are several classes of obesity defined
using BMI – Class I (30-34.99 kg·m$^{-2}$), Class II (35.00-29.99 kg·m$^{-2}$) and Class III ($\geq 40.00$ kg·m$^{-2}$). In additional to being a risk factor for chronic conditions such as type II diabetes, coronary artery disease, stroke, hypertension, osteoarthritis, obstructive sleep apnea, and cancer$^1, 63$, evidence suggests that obesity is associated with functional decline and is a risk factor for injury and falls. Lang, et al. found that objective (Short Physical Performance Battery - SPPB) and subjective measures of physical function were inversely correlated with body mass index$^{63}$. Obese older adults were found to be 66% (females) to 99% (males) more likely than normal-BMI older adults to report difficulty in essential activities of daily living (e.g. bathing and clothing) and were 51% more likely to have impaired physical function (a score $\leq 7$ out of 12 on the SPPB).

Matter et al. compared the characteristics of injuries of obese and normal-BMI inpatients$^{82}$. Obese individuals were more likely to suffer from musculoskeletal injuries such as sprains, fractures and dislocations and these injuries were 24% more likely to result from a fall$^{82}$. Fjeldstad et al. found that obese older adults were more likely to report a history of falls and ambulatory stumbling, however, bipedal and unipedal balance (held for a maximum of 60 sec) did not differ significantly between obese and normal-BMI individuals$^{32}$. In contrast to this finding, center of pressure measured postural sway, has repeatedly been shown to be greater in obese subjects$^{54, 85, 107}$, and improves linearly with weight loss$^{115}$. Furthermore, postural sway is greater in obese subjects performing functional reach movements and rapid coordinated movements of the upper limb$^{13, 107}$. Singh et al. compared postural sway over 18 min of quiet standing between normal-BMI subjects and subjects with Class III obesity. The obese group had greater levels of postural sway at the beginning of the test and this increased more rapidly than the
normal-BMI individuals\textsuperscript{107}. These findings are significant because impaired postural control as measured by postural sway has been associated with increased falls risk in older adults\textsuperscript{78}.

Center of pressure measured postural sway has been positively correlated with body mass, BMI, and waist circumference\textsuperscript{35, 61}. These results are attributed to the additional fat mass and greater body segment inertial properties which increase the muscle forces and therefore joint torques necessary to control posture during stance and presumably during more dynamic tasks such as walking\textsuperscript{122}. This is supported by the work of Ledin and Okvist who found that adding weight equal to 20\% of body mass to normal-BMI subjects resulted in increased postural sway and slower sway velocity which indicates a delayed response to changes in posture\textsuperscript{68}. The additional fat mass likely increases the exertion required by muscles to maintain balance and prematurely fatigues muscle, further reducing postural control. If obesity attenuates postural control, it could be argued that obesity may exacerbate age related increases in falls risk. This is purely speculative and further prospective research is warranted to establish a causal link between obesity and the occurrence of falls.

Lower limb muscle strength has been shown to be important for reducing risk of falls\textsuperscript{92}. Absolute knee extensor strength has consistently been found to be higher in obese compared to normal body mass subjects\textsuperscript{55, 56, 90}. However, when applying simple ratio standards to normalize for body mass or lean body mass, obese subjects have reduced relative isometric and isokinetic knee extensor strength\textsuperscript{17, 90, 91}. A more complex allometric approach using knee extensor strength as an exponent of body mass has shown similar reductions in relative knee extensor strength\textsuperscript{56}. Despite the “training effect” and
lower limb muscle hypertrophy that occurs as a result of bearing excess body mass, obesity is characterized by a relative reduction in lower limb strength. Attenuated strength in the obese is thought to be due to lower neuromuscular activation of motor units (possibly due to physical inactivity) and intermuscular fat infiltration which is thought to create a number of metabolic disturbances that promote insulin resistance.

Helbostad, Leirfall, Moe-Nilssen, and Sletvold found that fatiguing the lower limb muscles of healthy older adults caused them to adopt gait characteristics comparable to those of frail adults at risk of falls. After completing chair rises to fatigue, older adults increased step width, medio-lateral trunk acceleration, step length variability, and vertical trunk acceleration variability. Step length variability has previously been found to be predictive of falls risk in older adults. These finding are significant when you consider that obese subjects have greater energy consumption during freely selected gait speed due to excess non-contributory fat mass. Furthermore, the obese have a less efficient gait possibly due to disproportionately heavier limbs than normal-BMI individuals. The gait of obese individuals is characterized by a reduced walking speed resulting from a reduced step length and frequency. Obese subjects also display a longer stance phase duration, a shorter swing phase, and greater double support duration. These characteristics are suggestive of instability and are displayed by populations with known balance disorders due to neurological diseases. The adoption of a slower gait speed and longer double support duration are thought to assist with maintenance of dynamic balance.

Obesity is associated with reduced lower limb muscle strength, poor postural control and aberrant gait mechanics all of which are associated with an increased falls risk.
risk. While these factors are characteristic of many older adults, the literature suggests that they are worsened by obesity. It is reasonable to suggest that the combination of age and obesity exacerbates falls risk factors although no known studies have measured the effects of obesity on balance recovery from a forward leaning position or a simulated trip.

The Role of Muscle Strength and Power in Falls Prevention

Muscle strength is defined as the maximum force a muscle can produce one time. In contrast, muscle power incorporates the velocity of muscle shortening as well as force. Numerous studies have shown that muscle strength declines with age and this is attributed to sarcopenia\textsuperscript{25, 29, 43}. Muscle mass declines by 30-50% between the third and eighth decade of life\textsuperscript{7, 8, 69, 119, 127}. Between 24 and 50 yrs of age muscle mass declines by only 10% becoming accelerated after the fifth decade. A further 40% reduction is reported between the fifth and eighth decades of life\textsuperscript{69}. A recent longitudinal study followed men (initial mean age 65.4 ± 4.2 yrs) for 12 years and with the use of computed tomography found that muscle size decrements occurred at a rate of 1.4% per year\textsuperscript{36}. Structurally, a decline in muscle fiber number is the principle cause of sarcopenia with equal reductions in the number of type I and type II muscle fibers\textsuperscript{25, 69}. While reductions in fiber number are not fiber type specific, Lexell et al. found that at the cellular level, type II fibers loose 26% of their cross sectional area while the size of type I fibers did not differ significantly between those aged 20 to 80 yrs\textsuperscript{69}. Researchers have further demonstrated that type IIB fiber size is reduced more so than type IIA fibers with age\textsuperscript{9, 22}.

In most cases, sarcopenia is accompanied by an equal and often greater loss of muscle strength\textsuperscript{37, 40, 127} and power\textsuperscript{10}. In addition, the quality of the remaining muscle
decreases as indicated by reductions in strength per unit of cross-sectional area and increased fatigability of muscles. The ability of the lower limb muscles to generate sufficient force is a fundamental requirement for maintaining balance and avoiding falls. Wolfson et al. summed the isokinetic strength ($60^\circ\cdot\text{sec}^{-1}$) of muscles about the hip, knee, and ankle joints, expressed this relative to body mass and compared the results to performance on an unstable balance platform and velocity of gait in community dwelling older adults (mean age 80 yrs). Those who lost their balance five or more times had 30% less summed strength and a 10% slower gait velocity compared to those who lost their balance only once. For each Newton-meter•kg⁻¹ increase in strength there was a 20% decrease in the odds ratio for a loss of balance on the unstable platform. La Roche et al., found that a group of older women with a self reported history of falls exhibited 19% lower peak torque when summed across the major muscles of the lower limbed and compared to non-fallers. These studies are cross-sectional and retrospective and therefore do not imply a causal effect of muscle weakness on impaired balance but lend support to the theory that lower limb strength is a requirement for maintaining balance and mobility.

A meta-analysis by Moreland et al. compiled data from 13 studies and found that compared to non-fallers, the odds ratio that fallers had muscle weakness was 1.76 (95% CI = 1.31-2.37) while that for recurrent fallers was higher at 3.06 (95% CI 1.86-5.04). This is strong evidence that lower limb muscle weakness is a risk factor for falls in the elderly. These findings are supported by the American Geriatrics Society which lists muscle weakness as the number one risk factor for falls in older adults (above gait and balance deficits) with a relative risk ratio of 4.4 (95% CI = 1.5-10.3). While muscle
strength is highly modifiable in the older population through the use of progressive strength training\textsuperscript{70} a Cochrane review found that muscle strength training alone does not significantly reduce falls risk in older adults \textsuperscript{38, 99}. Therefore, some researchers have suggested that muscle power may be more relevant to falls prevention than muscle strength.

Muscle power can be determined by the product of the maximal force produced by the muscle and the velocity of muscle shortening while muscle strength is simply the maximal force a muscle can exert. Like strength, muscle power has been shown to decline with age\textsuperscript{79, 81, 98}. Longitudinal data by Metter et al. found that upper body muscle power declines at an earlier age and faster rate than muscle strength\textsuperscript{87}. Similarly, cross sectional data by Izquierdo et al. found that the age related decline in lower limb muscle power was greater than muscle strength and that power was more strongly related to declines in dynamic and isometric balance\textsuperscript{58}.

The loss of power in older adults is not only due to sarcopenia. Fine-wire intramuscular electromyography studies show that individual motor units from senescent muscle have a tendency to fire at a slower rate (10Hz) during maximal voluntary contraction compared to those from younger individuals (40Hz)\textsuperscript{120}. These finding are supported by previous research which found preferential loss of fast twitch motor units and selective denervation of fast twitch fibers in aged muscles of rats\textsuperscript{27}. Isolated muscle fibers from aged muscle also have an attenuated maximal shortening velocity compared to muscle fiber samples from young adults\textsuperscript{62}. Type II fibers from aged muscles have been found to have a reduced release of calcium from the sarcoplasmic reticulum when stimulated electrically\textsuperscript{24}. Combined, these findings suggest that senescent muscle is
characterized by slower rates of activation due to neural, structural, and biochemical factors. The net result is a reduction in not only strength but the velocity at which contractions can be executed and thus reductions in muscle power.

In older adults, loss of lower limb muscle power has been associated with impaired mobility related activities of daily living more so than muscle strength\textsuperscript{10-12, 23, 33, 49, 83, 114}. Bean et al. found that compared to muscle strength, muscle power explained 2-8\% more of the variance in stair climb time, chair stand time, tandem gait velocity, habitual gait velocity, maximal gait velocity and Short Physical Performance Battery scores (Figure. 1)\textsuperscript{11}.

\textbf{Figure 1. Leg Power and Strength as Predictors of Physical Performance}

![Chart showing partial R² values for leg power and leg strength derived from the multivariate regression models. SCT = stair-climb time; CST = chair-stand time; TG = tandem gait; HG = habitual gait; MG = maximal gait; SPPB = Short Physical Performance Battery.]

When comparing isometric and isokinetic (50 and 150°·sec\(^{-1}\)) knee and ankle extensor/flexor strength, power (maximal Watts produced using a Nottingham Leg Extension Power Rig) and bilateral asymmetry of 40 young healthy adults (29.3 ± 0.6 yrs), 44 older non-fallers (75.9 ± 0.6 yrs), and 34 older fallers (76.4 ± 0.8 yrs), Perry et al. stated that “power output showed clear differences between age groups and fall status and appears to be the most relevant measurement of falls risk”\(^9\). Fallers who were defined as having had at least one fall in the last 12 months, had 85% the strength but only 79% the power of non-fallers. Skelton et al used the same muscle power assessment and similar isometric and isokinetic (100°·sec\(^{-1}\)) strength tests on community dwelling, female fallers and non-fallers. There was no significant difference between the two groups for strength except for concentric dorsiflexion strength normalized for body mass. However, fallers were about 24% less powerful for their body mass than non-fallers\(^{10}\). The mean power of the fallers was 1.35W·kg\(^{-1}\) which is less than the functional threshold of 1.5 W·kg\(^{-1}\) suggested as necessary to confidently negotiate a 30cm step. These studies are retrospective and do not infer causality between reduced muscle power and the incidence of falls. Stronger evidence is provided by longitudinal data. Chan et al. followed 5,995 older males (average age 73.7 ± 5.9 yrs) from the Osteoporotic Fractures in Men Study for an average of 4.5 yrs and recorded self reported falls every four months. Men in the lowest quartile of lower limb extension power (maximal Watts produced using a Nottingham Leg Extension Power Rig) were 18% more likely to fall within a four month period compared to those in highest quartile\(^{21}\).

Based on the current research, it is reasonable to postulate that strength is one component of muscular fitness that is important for mobility and recovering balance from
a postural disturbance. Muscle power, which incorporates the speed with which the muscle can shorten, appears to be important with respect to falls resulting from a slip or trip. Velocity of movement may be the limiting factor in falls prevention and measurements of muscle power are more likely to capture this characteristic.

**Balance Recovery from a Forward Leaning Position**

Blake et al. reported that 53% of falls result from trips\(^{14}\). A number of researchers have used a surrogate balance recovery task which measures the ability to regain balance when released from a forward leaning position\(^{42, 71, 72, 116, 123, 124}\). As shown in Figure 2, the subject leans forward and is supported by a lean support cable which is lengthened until the desired lean angle is achieved. The tension in the cable is measured and converted to a percentage of body mass. At a time unknown to the participant, the lean support cable is released. The participant is then required to restore their balance by taking a single step with a designated leg. In order to successfully recover balance from a forward fall, buckling of the knee of the stepping leg after the stepping foot makes contact with the ground must be prevented\(^{41, 97}\).

It is believed that this forward lean assessment requires the same biomechanics necessary to restore balance once it has been perturbed by a slip or a trip. The maximal body lean angle from which an individual can regain their balance is used as a measure of ability to recover balance once a forward fall has been initiated by a slip or a trip. This measure allows for a high degree of experimental control over initial body position, perturbation magnitude, and stepping characteristics.
Figure 2. Forward Lean Assessment

A. Before release from the forward lean. B. Upon completion of the first right foot step. The lean control and safety harness can be seen behind the subject.

The forward lean assessment has repeatedly demonstrated, that older adults, when compared to younger adults, have a reduced capacity to rapidly recover balance when released from a forward leaning posture\(^{71, 72, 116, 123, 124}\). Using a force platform and three-dimensional kinematic data from a motion analysis system, Thelen et al. compared the reaction time of step off (time from cable release to initial vertical force of right foot), weight transfer time (time between reaction time and right foot lift off), step time (time between liftoff and landing of the right foot) and step velocity (step length divided by step time) between old and young males\(^{116}\). Maximal recoverable lean angle was strongly correlated with weight transfer time and step velocity. Wojcik et al. used Thelen et al.’s data in combination with their own to compare young females to older females so that comparisons could be made across age and gender\(^{123}\). Reaction time was
independent of body lean angle, and while the older groups reacted 10-20 msec slower than the younger groups, this was not considered biomechanically significant given that total step time was about 500 msec. While subjects did not increase their reaction speed with increased body lean angle, they were seen to decrease weight transfer time although this was independent of age. Step length also increased at greater angles and at low angles was seen to be about 7% greater for older females compared to young females. Maximal lean angles were considerably greater in the young adults (32.5° vs. 23.9° for young and older males; 30.7° vs. 16.2° for young and older females) and showed a strong inverse correlation with weight transfer time and step time but not reaction time. A strong direct correlation was seen between maximal angle and step velocity. The maximal angle achieved by older females was significantly less than that of younger females and older males while there were no significant gender differences between the younger groups. Also, older females had slower step velocities than both older males and younger females. Wojcik et al. concluded that older females took longer, slower steps than all groups although no definitive explanation is given as to why this age dependent gender difference exists. Thelen et al. concluded that age related differences in maximal lean angle could be attributed to a reduced ability to move the limb rapidly rather than to initiate the step.

In an attempt to elucidate which specific joints had reduced velocity, Madigan and Lloyd investigated whether there were any age related differences in peak joint velocity for the hip, knee and ankle. At a given angle, there were no significant differences in peak joint velocity between old and young subjects. However, at maximal lean angles, peak joint velocities were significantly different. The velocity for older men
at hip flexion, knee flexion and extension, and ankle plantar flexion was significantly lower than that of the younger men. These lower velocities may be a limiting factor in maximal lean angle for older participants.

While the studies by Wojcik et al.\textsuperscript{123} and Thelen et al.\textsuperscript{116} made no measurements during the support phase of balance recovery from a forward leaning position, Madigan and Lloyd\textsuperscript{71} performed a second study where the peak extensor torques were measured during this phase. This was done to further explain the difference in maximal lean angle achieved by a cohort of young (19-23 yrs) and old (65-83 yrs) males. After the first 60ms of heel contact, the hip, knee and ankle joint torques were predominantly extensor (or plantar flexor) and all increased with increasing lean angle regardless of age. However, it was found that the older cohort produced smaller knee extensor torques and there was a trend toward greater hip and ankle extensor (plantar flexor) torques, perhaps reflecting a compensatory mechanism resulting from a reduced ability to produce knee extensor power in the older participants.

Wojcik, et al.\textsuperscript{124} measured isometric and isokinetic (120°·sec\textsuperscript{-1}) strength of the plantar flexors and hip flexors. During recovery from the maximal lean angle, plantar flexion and hip flexion torques were near maximal. Despite this, maximal joint strengths in plantar flexion and hip flexion were poor predictors of performance on this task. It is notable that no measurements were made of knee or hip extensor strength.

To further explore the extent to which lower extremity strength affects balance recovery, Grabiner et al. compared performance on the forward lean assessment to isometric and isokinetic strength of the hip, knee and ankle flexors and extensors. Isokinetic strength was measured concentrically (30°·sec\textsuperscript{-1} and 90°·sec\textsuperscript{-1}) as well as
eccentrically (30°·sec⁻¹). Stepwise multiple regression analysis revealed that maximum isokinetic dorsiflexion strength at 90°·sec⁻¹ explained 29.5% of the variances in maximal recoverable lean angle. The authors postulate that the remaining variance could be explained by factors such as coordination and not simply the ability to create joint moments. Furthermore, the authors measured muscle power with isokinetic assessments at 90°·sec⁻¹. There is a disparity in the literature regarding a definitive measure for muscle power. Assessments at angular velocities of 90°·sec⁻¹ may be insufficient to truly compare to the temporal requirements of this forward lean assessment and may not be a true measure of muscle power.

While performance on the forward lean assessment has been compared to strength of hip, knee, and ankle muscles, to our knowledge no known studies have compared muscle power as measured using a leg extension and leg press machine to performance on this assessment. No comparisons have been made between obese and non-obese populations and no known studies have measured the effects of this assessment on falls efficacy and fear of falls.
Specific Aims and Hypotheses

The US population is aging, becoming more obese, and suffering from sarcopenia which causes a decline in muscle strength and power. Evidence suggests that increases in age and obesity and a decline in muscle power augment falls risk. This study assessed the effects of obesity on the ability of older adults to recover balance from a forward leaning position. Furthermore, this study investigated the importance of muscle power in regaining balance from a forward leaning position.

Specific Aim 1: to determine whether obesity reduces the capacity of older adults to recover balance from a forward leaning position. 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.

Specific Aim 2: to determine whether maximal voluntary strength and power of the lower limb muscles are associated with ability to recover balance from a forward leaning position. Lower limb muscle strength will be measured as the greatest load that can be lifted one time (1RM) using leg extension and leg press machines. Power will be measured as maximal power produced during leg extension and leg press exercises against a load equal to 70% 1RM.

Hypothesis 1: the maximal forward lean angle will be smaller in obese subjects compared to non-obese subjects.

Hypothesis 2: there will be no significant difference in performance on the forward lean assessment between non-obese subjects matched to obese subjects for BMI by the addition of a weighted vest and belt. This hypothesis is based on the notion that
additional mass is what impairs balance in the obese and so when matched for BMI, there should be no difference between the obese and simulated obese groups.

*Hypothesis 3:* both lower limb muscle strength and power will have a positive association with ability to recover from a forward leaning position, however, muscle power will explain more of the variance of balance recovery ability. This hypothesis is based on the notion that balance recovery requires rapid muscle contractions and measures of muscle power are more likely to incorporate this temporal characteristic than measures of strength.
METHODS

Overview of the Design

Six non-obese subjects and ten obese subjects performed a forward lean assessment which measures the maximal forward lean angle from which they could recover their balance using a single step. Non-obese subjects were matched to obese subjects for BMI by wearing a weighted vest to simulate obesity, and the forward lean assessment was repeated. Lower limb muscle strength and muscle power were measured and compared to performance on the forward lean assessment.

Subject Recruitment and Measurement of Characteristics

Subjects were recruited from within Forsyth County, North Carolina. Subjects were recruited as participants who had been involved with previous research studies conducted at Wake Forest University or who had responded to a newsletter that was mailed to them. Six subjects with a BMI of 21-29.99 kg•m⁻² were recruited for the non-obese group and 10 subjects with a BMI of 30-39.99 kg•m⁻² were recruited for the obese group. Those who met initial eligibility criteria (Table I) were scheduled for testing at Wake Forest University (WFU) Health and Exercise Science Human Performance Laboratory. The exclusion criteria were designed to exclude subjects for whom the participation in forward lean assessment may not have been safe.
Table I. Inclusion and Exclusion Criteria

Inclusion Criteria (all of the following)

*Age*: 65-79 yrs

*Activity Status*: sedentary (fewer than 60 minutes of structured, moderate physical activity each week that occurs in no more than 10-minute blocks)

*Body Mass Index (BMI)*: 21 – 29.99 kg·m⁻² for the non-obese group and ≥ 30 kg·m⁻² for the obese group.

*Stability of Residence*: living within a 35 mile radius of WFU for the duration of the study

*Agreeableness*: willing and able to participate in all aspects of the trial

*Consents*: willing to give an informed consent.

Exclusion Criteria (one or more of the following)

*Psychiatric Illness*: bipolar depression or schizophrenia (defined as self-reported treatment for these conditions), currently receiving lithium or neuroleptics

*Severe Symptomatic Heart Disease*: evidence of unstable angina, symptomatic congestive heart failure, or exercise-induced complex ventricular arrhythmias

*Blood Pressure*: a resting blood pressure >160/100 mmHg

*Body Mass Index (BMI)*: <21 kg·m⁻² or ≥40.00 kg·m⁻²

*Severe Systemic Disease*: diagnosis of Parkinson’s disease, chronic liver disease (e.g., cirrhosis, chronic hepatitis), systemic rheumatic condition (e.g., rheumatoid arthritis, psoriatic arthritis, Reiter’s disease, systemic lupus erythematosus), end-stage renal disease or other systemic diseases or abnormal laboratory values that would preclude safe participation in the protocol or jeopardize study completion

*Severe orthopedic impairment*: severe orthopedic impairment that would prevent person from doing the testing

*Fractures/Amputations*: fracture in upper or lower extremity within the last 6 months, upper or lower extremity amputation

*Cancer*: active treatment for cancer other than nonmelanotic skin cancer

*Hearing or Sight Impairments*: significant visual or hearing impairment that cannot be corrected and results in inability to use the telephone or to hear normal conversation

*Cognitive Impairment*: dementia, delirium, or impaired cognitive function as defined by a score on the Folstein Mini-Mental Status Exam <24 (appendix G)

*Participation in Other Trials*: currently participating or planning to participate in another medical intervention study

*Medications*: current use of medications which effect balance

*Alcohol Intake*: consuming more than 21 alcoholic drinks per week or alcoholism

*Functional Limitations*: unable to walk unassisted

*English Literacy*: unable to speak or read English

*Judgment of Clinical Center Staff*: judged to be unsuitable for the trial for any reason by the clinic staff
At Testing Visit 1 (TV1), participants completed an informed consent (appendix A); demographics questionnaire (appendix B), medical history questionnaire (appendix C); and the American Heart Association/American College of Sports Medicine Health/Fitness Facility Pre-participation Screening Questionnaire (appendix D). Self-reported difficulty with activities of daily living was measured 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\textsuperscript{101} and other randomized controlled trials at WFU\textsuperscript{28, 88, 89, 100}. Each question on the PAT-D was scored 1 – 6 and the score reported was the mean score for all 19 responses. Self efficacy in completing activities of daily living without falling and fear of falls were measured using The Falls Efficacy Questionnaire\textsuperscript{118} and The Fear of Falls Questionnaire, respectively (appendix F). Cognitive function was measured using the Folstein Mini-Mental Status Exam\textsuperscript{34} (MMSE - appendix G). Subjects’ reported levels of physical activity from a typical week from the past 4 weeks were measured using the Community Health Activities Model Program for Seniors (CHAMPS) Questionnaire\textsuperscript{113} (appendix H). The number of minutes per week spent doing physical activities with an intensity considered to be moderate or greater (≥3 metabolic equivalents) was recorded. This will be referred to as MOD+ physical activity.

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 with pockets emptied. Height and body mass were used to calculate BMI (body mass (kg) x height (meters)^2).

**Forward Lean Assessment**

The subject was assisted into a Miller full body non-stretch harness (Model/Size 751/UYK, Franklin, PA) which was tethered to the ceiling via a climbing grade safety rope (Figure 3a) and two Black Diamond Freewire Quickdraws (Model BD3810300000ALL1, Salt Lake City, UT). 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/SAF, Franklin, PA) was placed around the waist of the subject at the level of the navel. A lean-control cable (Figure 3b) spanned from the back of the belt to a stable metal pole (Figure 3c) via a Chatillon CSD500 Dynamometer (Largo, FL) - a device used to measure the lean-control cable tension (Figure 3d). The tension was recorded in kilograms (kg) and expressed as a percent of body mass. The lean-control cable was adjusted to be horizontal when under tension. A Scott Archery double-caliper release mechanism (Figure 4c - Model 1001, Clay City, KY) connected the lean-control cable to the dynamometer (Figure 4a), holding it securely until the desired body lean angle was achieved.

The subject was instructed to keep their feet together and flat on the ground, distributing their mass evenly between both feet, keeping their body posture as straight as possible and bending forward at the ankles only. The subjects’ feet were moved closer to or further from the stable metal pole in order to increase or decrease the body lean angle.
respectively. Once in position, the subject was reminded to look straight ahead at a visual target located on the wall on front of them.

**Figure 3. Prerelease from Forward Lean Assessment**

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 angle of forward body lean was measured from the vertical using an electrical inclinometer (Craftsman Digital Torpedo Level, model 48295, Hoffman Estates, IL) which was attached to a 6 foot length of 2 inch by 2 inch timber (Figure. 5 and Figure. 3e). The inclinometer measured angles to the nearest 0.1 degrees. Markers were placed at the level of 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. The starting location of the feet was measured along a tape measure by placing a set square in front of the toes. The location of the feet, the lean-control cable tension (kg), and the subject’s body lean angle were measured within 10 sec of the subject becoming
stable in the forward leaning posture. The subject remained in this position for a maximum of 15 sec. By pulling the hair-touch trigger of the release mechanism (Figure. 4c) the lean-control cable was released causing a forward balance perturbation to be induced.

The release occurred after a random time delay and made very little noise or movement thereby limiting anticipation of release by the subject. Subjects were instructed to regain their balance by taking a single step with their right leg while leaving the left foot in place. Upper extremity movement was constrained prior to release by having the subject fold their arms across their chest. They were instructed that upon release, they could release their arms and use them to assist with balance. Following release, and balance recovery, subjects held the lunge position until the end location of their right and the left feet was measured. Subjects with difficulty balancing in this position were given a chair to hold until the measurements were obtained.

For every trial, the right leg was always the designated stepping leg as it was logistically easier to obtain the various measurements quickly and reliably. Furthermore, Madigan and Lloyd\textsuperscript{72} found there were no significant differences in maximal lean angle achieved when comparing the use of the dominant leg to the non-dominant leg for stepping.

The initial lean angle was 5° and the angle was increased by increments of 2.5° until the participant failed to regain their balance during two consecutive trials at a given angle. If the participant failed to regain their balance twice at a given angle, they were given 1-2 minutes to rest. The angle was then reduced by 1.2-3° (approximately a half increment) and the test was repeated. If the repeated attempt was successful, the angle
was progressively increased by increments of 1.2-3° until the participant again failed to regain their balance. Another 1-2 minutes rest was given and the same angle was repeated. The angle at which two failures occurred was deemed the point of failure. The last angle from which the participant successfully recovered their balance was recorded as the maximum recoverable lean angle (Lean<sub>max</sub>). The criteria for determining a failed trial were adopted from Madigan and Lloyd who have used the forward lean assessment in a number of studies<sup>71, 72</sup>. There were three criteria for determining a failed trial; (1) Taking more than one step with either leg, (2) moving the back leg (left leg) from its starting position by more than 30% of the subject’s height, and (3) falling into the harness or using the harness to regain balance. These criteria provided standardized measures which allowed us to discriminate between subjects who could successfully recover balance using a single step and those who could not.

The obese group did this forward lean assessment once whereas the non-obese group performed the forward lean assessment on two separate occasions at least 48 hours apart to allow for any muscle soreness to subside. We attempted to match non-obese subjects to an obese subject for gender, height within 10cm and when possible age within three years (two matched pairs were 5 and 9 years apart in age respectively). The non-obese subjects had a BMI that was 4 – 10 kg·m<sup>-2</sup> lower than their obese partner. The simulated obese BMI of the non-obese subjects was equated with the actual BMI of obese subjects by adding an adjustable weighted vest and weighted belt. To better distribute the additional mass, 70% of the additional mass was placed in the vest and 30% in the belt. The mass was distributed as evenly as possible throughout the vest and belt. The belt was worn low around the hips to lower the center of gravity but not so low that it
interfered with the subjects’ hip range of motion. The forward lean assessment was
performed exactly as described above while wearing the additional mass. The order of
the forward lean assessment with or without the additional mass was randomized to
control for any learning effect.

At testing visit 2 (testing visit 3 for non-obese subjects (TV2/3)), we assessed the
physical function of the subject using the Short Physical Performance Battery (SPPB, appendix I). The SPPB has been used in the Established Populations for Epidemiologic
Studies of the Elderly (EPESE)\textsuperscript{44}. The SPPB consists of three performance-based tests
that assess lower limb balance, mobility and strength. Each component is scored 0-4 and
the scores are added to give a total score range of 0-12. The result gives an indication of
physical function in older adults.

A history of falling is one of the main risk factors for fear of falls which has been
shown to lead to reductions in physical activity and physical function\textsuperscript{102, 121}. Subjects
were asked to complete the Falls Efficacy Questionnaire and The Fear of Falls
Questionnaire again (appendix F) to determine whether the self efficacy in avoiding falls
and fear of falling changed after completing the forward lean assessment.

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**Lower Limb Strength and Power Testing**

AT TV2/3, subjects had their lower limb muscle strength and power measured
using Keiser pneumatic leg extension (AIR250) and leg press machines (AIR300, Fresno
CA). The machines were calibrated at the start of the study as per the manufacturer
specifications. Both these machines were used bilaterally for both tests. The leg
extension and leg press machines were adjusted so that the hips and knees began at 90° flexion. Subjects performed 5 min of walking or bicycling and a series of lower limb stretches. A warm-up was performed on the leg extension machine at a moderate resistance which allowed 1 set of 4-6 repetitions followed by 1 set of 2-3 repetitions to be completed. Strength was then determined as the most amount of resistance (kg) that could be lifted one time (1 repetition maximum (1RM)). Subjects made repeated attempts to lift progressively heavier loads with 90 sec of rest between efforts. Attempts were made until the subject could not perform the exercise one time with correct form or experienced any pain or requested to stop.

To determine peak power, the resistance was adjusted to 70% of that achieved during 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 sec rest was given after the first effort after which 4 more repetitions were performed, each separated by 30 sec. Callahan et al.\textsuperscript{20} and Marsh et al.\textsuperscript{80} have previously used this protocol with frail, elderly adults and found it to be safe and effective in elucidating the true peak muscle power. At the completion of the five attempts, the highest peak power was recorded in Watts. After completing strength and power testing on the leg extension machine, the above protocol was repeating using the leg press machine.
Statistical Analysis

The distributions of all residual values were checked for normality and outliers using plots and statistical tests using SPSS Version 16.0. Given the small sample size it was difficult to determine whether the distributions were normal, but no transformations of the data were made. Descriptive statistics were used to establish the characteristics of this sample. A series of independent samples T-tests were conducted to determine whether there were any differences between the non-obese and obese groups for age, gender, BMI, falls efficacy, fear of falls, SPPB score, MOD+ physical activity, and lower limb strength (1RM) and power for the leg extension and leg press exercises. Lower limb strength and power were also expressed relative to body mass. Independent samples T-tests were further used to determine differences in relative strength and power between the obese and non-obese groups. We recognize that the small sample size reduced the statistical power and our ability to identify anything but large effect sizes.

The main outcome of interest was the maximal recoverable lean angle ($\text{Lean}_{\text{Max}}$) achieved on the forward lean assessment. Pearson’s correlation coefficients were calculated for entire cohort combined ($n=16$) to determine the association of $\text{Lean}_{\text{Max}}$ with muscle power, strength and BMI. The Fisher-r-z conversion technique was used to determine whether there were any significant differences between correlations that measures of strength and power measures had with $\text{Lean}_{\text{Max}}$. A number of other variables were included in the correlation matrix including age, height, body mass, tensile load in the lean-control cable (kg), tensile load expressed relative to body mass (%), lower limb strength relative to mass, lower limb power relative to mass, PAT-D score, Fear of Falling Questionnaire scores, Falls Efficacy Questionnaire scores, SPPB score, MOD+
physical activity, and the number of prescription medications used. Hierarchical multiple regression analysis was used to compare the power of age, BMI, lower limb muscle power and strength for predicting LeanMax.

To explore the effects of body mass on LeanMax, we used three groups; obese, non-obese and simulated obese. The difference in LeanMax between the non-obese and simulated obese groups was compared using a paired T-test. Two independent samples T-tests were used to determine whether there were any differences between the non-obese and obese groups and between the obese and simulated obese groups.

Dependent samples T-Tests were used to determine whether there were any significant changes in the responses on the Fear of Falls Questionnaire and the Falls Efficacy Questionnaire scores from TV1 to TV2/3. Results for all analyses were considered significant when the P value was less than 0.05.
RESULTS

Participant Characteristics

A total of 16 participants were recruited for this study, 6 non-obese (mean BMI = 25.1 ± 2.0 kg\(\cdot\)m\(^2\), 3 female) and 10 obese (mean BMI = 33.3 kg\(\cdot\)m\(^2\) ± 2.6, 4 female) from within Forsyth County, NC. The mean age of the normal BMI group was 72.2 ± 4.3 yrs and that for the obese group was 69.6 ± 4.8 yrs.

In addition to descriptive data, Table II displays the results from a series of independent samples T-tests used to identify any differences between the non-obese and obese groups. Compared to the non-obese group, the obese group had, on average, a significantly higher body mass (24.9 kg, S.E. = 6.4, p = .002) and BMI (8.2 kg\(\cdot\)m\(^2\), S.E. = 1.2, p < .001). There was a trend towards higher lean-control cable tensions for the obese group (13.0 kg, S.E. = 6.6, p = .070). At TV1, the non-obese group had a mean Falls Efficacy Questionnaire score of 129.2 ± 2.0 (from a possible score of 130 with higher scores indicating greater falls efficacy). This was on average 8.07 (S.E. = 3.7) points higher than the obese group – approaching a statistically significant difference (p = .053). The obese group also had a trend towards greater fear of falls (+3.10, S.E. = 1.5, p = .051). At the visit that followed the forward lean assessment (TV2/3), there were no differences in responses of the Fear of Falls and Falls Efficacy Questionnaires. The obese group produced significantly more power on the leg press machine compared to the non-obese group (-182.6 Watts, S.E. = 72.6, p = .027). There were no other significant differences between the obese and non-obese groups.
# Table II. Descriptive Statistics for Non-Obese and Obese Groups

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* The mean difference is significant at the 0.05 level. † There are two 2 tailed significance values. The top assumes equal variances and the bottom adjusts for variance heterogeneity and is used if Levene’s test has a p < .05. ‡ N = Non-Obese group, O = Obese group.

**Age** = age in years, **Height** = body height in centimeters, **Mass** = body mass in kilograms, **BMI** = Body Mass Index (kg·m⁻²), **Meds** = number of prescription medications.
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* The mean difference is significant at the 0.05 level. † There are two 2-tailed significance values. The top assumes equal variances and the bottom adjusts for variance heterogeneity and is used if Levene’s test has a p < .05. ‡ N = Non-Obese group, O = Obese group.

Lean<sub>max</sub> = maximal recoverable lean angle, Load at Lean<sub>max</sub> = lean-control cable tension at Lean<sub>max</sub>, Relative load = lean-control cable tension at Lean<sub>max</sub> relative to body mass, Falls Efficacy = total score on the Falls Efficacy Questionnaire, Fear of Falls = score on Fear of Falling Questionnaire.
|                          | N  | Mean | Std. Dev | Min | Max | Mean Difference (N – O)† | F     | Sig. (2-tailed) | t    | df  | Sig.  
|--------------------------|----|------|----------|-----|-----|----------------------------|-------|-----------------|------|-----|--------
| **Falls Efficacy 2**     |    |      |          |     |     |                            |       |                 |      |     |        
| (0-130) Non-Obese        | 6  | 126.8| 4.9      | 120.0| 130.0| 5.0 S.E. = 5.3            | 4.146 | .061            | .945 | 14 | .361   
| Obese                    | 10 | 121.8| 12.3     | 96.0 | 130.0|                            |       |                 | 1.148| 12.786| .272   
| Total                    | 16 | 123.7| 10.3     | 96.0 | 130.0|                            |       |                 | .361 |     |        
| **Fear of Falls 2**      |    |      |          |     |     |                            |       |                 |      |     |        
| (0-10) Non-Obese         | 6  | 1.00 | 2.45     | 0.00 | 6.00 | -2.20 S.E. = 1.53         | .764  | .397            | -1.434| 14 | .174   
| Obese                    | 10 | 3.20 | 3.22     | 0.00 | 10.00|                            |       |                 | -1.540| 12.998| .147   
| Total                    | 16 | 2.38 | 3.07     | 0.00 | 10.00|                            |       |                 | .147 |     |        
| **PAT-D Score (1-6)**    |    |      |          |     |     |                            |       |                 |      |     |        
| Non-Obese                | 6  | 1.20 | 0.24     | 1.00 | 1.67 | -0.12 S.E. = 0.15         | .798  | .387            | -.893 | 12.792| .389   
| Obese                    | 10 | 1.32 | 0.31     | 1.00 | 1.94 |                            |       |                 | -.837 |     |        
| Total                    | 16 | 1.28 | 0.28     | 1.00 | 1.94 |                            |       |                 |     |     |        
| **MMSE (0-30)**          |    |      |          |     |     |                            |       |                 |      |     |        
| Non-Obese                | 6  | 29.3 | 1.2      | 27.0 | 30.0 | -0.6 S.E. = 0.5           | 8.326 | .012            | -1.123| 5.412| .309   
| Obese                    | 10 | 29.9 | 0.3      | 29.0 | 30.0 |                            |       |                 |     |     |        
| Total                    | 16 | 29.7 | 0.8      | 27.0 | 30.0 |                            |       |                 |     |     |        
| **MOD+ Physical Activity (min)** |    |      |          |     |     |                            |       |                 |      |     |        
| Non-Obese                | 6  | 170  | 152      | 0    | 420 | -186 S.E. = 143.5         | 5.712 | .031            | -1.292| 12.443| .220   
| Obese                    | 10 | 356  | 409      | 0    | 1170|                            |       |                 |     |     |        
| Total                    | 16 | 286  | 342      | 0    | 1170|                            |       |                 |     |     |        

* The mean difference is significant at the 0.05 level. † There are two 2 tailed significance values. The top assumes equal variances and the bottom adjusts for variance heterogeneity and is used if Levene’s test has a p < .05. ‡ N = Non-Obese group, O = Obese group.

**Falls Efficacy 2** = total score on the Falls Efficacy Questionnaire at TV2/3, **Fear of Falls 2** = score on Fear of Falling Questionnaire at TV2/3, **PAT-D Score** = average score on the Pepper Assessment Tool for Disability Questionnaire, **MMSE** = total score on the Mini Mental State Exam, **MOD+ Physical Activity** = self reported min/week of MOD+ physical activity.
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<th>Max</th>
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<td>191.5</td>
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* The mean difference is significant at the 0.05 level. † There are two 2-tailed significance values. The top assumes equal variances and the bottom adjusts for variance heterogeneity and is used if Levene’s test has a p < .05. ‡ N = Non-Obese group, O = Obese group.

**SPPB** = Short Physical Performance Battery total score, **Extension 1RM** = Leg extension strength, **Press 1RM** = Leg press strength, **Extension power** = Leg extension power, **Press power** = Leg press power.
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<th>Max</th>
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<th>F</th>
<th>Sig.</th>
<th>t</th>
<th>df</th>
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<td>1.57</td>
<td>6.50</td>
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</table>

* The mean difference is significant at the 0.05 level. † There are two 2 tailed significance values. The top assumes equal variances and the bottom adjusts for variance heterogeneity and is used if Levene’s test has a p < .05. ‡ N = Non-Obese group, O = Obese group.

**Relative extension strength** = Leg extension strength relative to body mass (kg lifted • kg body mass⁻¹), **Relative press strength** = leg press strength relative to body mass (kg lifted • kg body mass⁻¹), **Relative extension power** = Leg extension power relative to body mass (Watts • kg body mass⁻¹), **Relative press power** = Leg press power relative to body mass (Watts • kg body mass⁻¹)
Influence of Body Mass Index on Balance Recovery from a Forward Leaning Position

On average, the obese group (n=10) had a LeanMax of 17.2° ± 4.2, whereas the non-obese group (n = 6) angle was 15.4° ± 4.4. The difference between these two groups was not significant (p = .422, Table II).

Recall that the 6 non-obese individuals where matched on BMI to 6 subjects from the obese group. The non-obese subjects had additional mass added to them until their simulated BMI reached that of their obese partner. The non-obese subjects repeated the forward lean assessment and formed a third group which will be referred to as the “simulated obese group”. Figure 6 shows that LeanMax was on average slightly higher for the obese group than the non-obese group, however, like the previous comparisons made between all 10 obese subjects and the 6 non-obese subjects, this difference was not significantly different (p = .496). The simulated obese group had a trend toward poorer performance on the forward lean assessment than both the obese (p = .062) and the non-obese groups (p = .062).
Figure 6. Mean LeanMax<sub>Max</sub> for Matched Pairs in Non-Obese, Obese and Simulated Obese Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>LeanMax&lt;sub&gt;Max&lt;/sub&gt; (°)</th>
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</thead>
<tbody>
<tr>
<td>Non-Obese</td>
<td>15.4 ± 4.4</td>
</tr>
<tr>
<td>Simulated Obese</td>
<td>12.1 ± 4.5</td>
</tr>
<tr>
<td>Obese</td>
<td>17.1 ± 3.7</td>
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</table>
Influence of Muscle Strength and Muscle Power on Balance Recovery

The Pearson’s correlation analysis (Table III) shows that LeanMax had a positive association with absolute lower limb muscle strength and power measured using the leg press machines (Figure 9 and 10), but not the leg extension machine (Figure 7 and 8). Leg press 1RM ($r = .575$, $p = .020$) was correlated to LeanMax as was leg press power ($r = .548$, $p = .028$). The Fisher r-to-z transformation showed that there were no significant differences in the correlation that LeanMax had with leg press strength and power ($z = 0.044$, $p = .516$). When expressed relative to body mass, all measures of lower limb strength and power had significant correlations with LeanMax except for leg extension power. Associations between lean-support cable tension at LeanMax and all measures of absolute and relative leg strength and power had stronger correlations than with LeanMax alone (Table III).
Table III. Pearson's Correlations for Lean\textsubscript{Max}, Descriptives and Measures of Physical Function

| Lean\textsubscript{Max} | Load | Load %BM | BMI | SPPB | Ext 1RM | Ext Power | Press 1RM | Press Power | Ext 1RM Rel | Ext Power Rel | Press 1RM Rel | Press Power Rel |
|-------------------------|------|----------|-----|------|--------|----------|----------|------------|-------------|--------------|--------------|--------------|----------------|
| Lean\textsubscript{Max} | 1.000 |          |     |      |        |          |          |            |             |              |              |              |                |
| Load                    | 0.715** | 1.000 |     |      |        |          |          |            |             |              |              |              |                |
| Load %BM                | 0.849** | 0.862** | 1.000 |      |        |          |          |            |             |              |              |              |                |
| BMI                     | 0.002 | 0.430 | 0.013 | 1.000 |        |          |          |            |             |              |              |              |                |
| SPPB                    | 0.102 | 0.384 | 0.121 | 0.090 | 1.000  |          |          |            |             |              |              |              |                |
| Ext 1RM                 | 0.479 | 0.846** | 0.659** | 0.419 | 0.209 | 1.000    |          |            |             |              |              |              |                |
| Ext Power               | 0.456 | 0.777** | 0.681** | 0.303 | 0.257 | 0.846** | 1.000    |            |             |              |              |              |                |
| Press 1RM               | 0.575* | 0.846** | 0.706** | 0.363 | 0.218 | 0.929** | 0.866** | 1.000      |             |              |              |              |                |
| Press Power             | 0.548* | 0.875** | 0.662** | 0.406 | 0.295 | 0.894** | 0.727** | 0.773** | 1.000      |             |              |              |                |
| Ext 1RM Rel             | 0.548* | 0.841** | 0.785** | 0.151 | 0.229 | 0.937** | 0.860** | 0.918** | 0.823** | 1.000      |             |              |              |                |
| Ext Power Rel           | 0.489 | 0.684** | 0.743** | 0.057 | 0.283 | 0.718** | 0.951** | 0.806** | 0.616* | 0.837** | 1.000      |             |              |                |
| Press 1RM Rel           | 0.638* | 0.677** | 0.773** | 0.018 | 0.228 | 0.729** | 0.790** | 0.889** | 0.577* | 0.875** | 0.852** | 1.000      |             |                |
| Press Power Rel         | 0.619* | 0.784** | 0.770** | 0.096 | 0.363 | 0.766** | 0.704** | 0.704** | 0.913** | 0.836** | 0.720** | 0.692** | 1.000      |                |

* The mean difference is significant at the 0.05 level. ** Correlation is significant at the 0.01 level (2-tailed).

\text{Lean}_{\text{Max}} = \text{maximal recoverable lean angle}, \text{Load} = \text{lean-control cable tension at \text{Lean}_{\text{Max}}}, \text{Load \%BM} = \text{lean-control cable tension at \text{Lean}_{\text{Max}}} \text{ relative to body mass}, \text{SPPB} = \text{Short Physical Performance Battery score}, \text{Ext 1RM} = \text{leg extension strength}, \text{Ext Power} = \text{leg extension power}, \text{Press 1RM} = \text{leg press strength}, \text{Press Power} = \text{leg press power}, \text{Rel} = \text{relative to body mass}. 
Table IV. Pearson’s Correlations for Lean\(_{\text{Max}}\), Descriptives and Psychosocial Measures

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<th>Load %BM</th>
<th>Age</th>
<th>Height</th>
<th>Body Mass</th>
<th>BMI</th>
<th>Meds</th>
<th>MOD+ PA</th>
<th>PAT-D</th>
<th>Efficacy</th>
<th>Fear</th>
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* The mean difference is significant at the 0.05 level. ** Correlation is significant at the 0.01 level (2-tailed).

Lean\(_{\text{Max}}\) = maximal recoverable lean angle, Load = lean-control cable tension at Lean\(_{\text{Max}}\), Load \%BM = lean-control cable tension at Lean\(_{\text{Max}}\) relative to body mass, Meds = number of prescription medications used, MOD+ PA = self reported min/week of MOD+ physical activity, PAT-D = Pepper Assessment Tool for Disability score, Efficacy = Falls Efficacy Questionnaire mean score, Fear = Fear of Falls Questionnaire score.
Figure 7. Association between Leg Extension Strength and LeanMax

\[ r = .479 \quad p = .061 \]

Figure 8. Association between Leg Extension Power and LeanMax

\[ r = .456 \quad p = .076 \]

Figure 9. Association between Leg Press Strength and LeanMax

\[ r = .575 \quad p = .020 \]

Figure 10. Association between Leg Press Power and LeanMax

\[ r = .548 \quad p = .028 \]
A Hierarchical multiple regression analysis was conducted to investigate the predictive power of lower limb muscle power, strength and BMI had on LeanMax while controlling for age. The first block included age and BMI while Leg Press Strength was forced into the second block followed by Leg Press Power in the third. Measures made using the leg press machine were chosen to represent leg strength and power as the measures made using the leg extension machine were not significantly related to LeanMax. The results from this analysis are shown below in Table V - VII. None of the models had overall significance although the addition of Leg Press Strength to the model did produce a significant $R^2$ change of $.375 (p = .019)$. The standardized beta values in model 3 (Table VII) were not significant but were weighted in the predicted direction. Furthermore, the 95% confidence intervals (CI) of the unstandardized beta coefficients were wide with the majority of the intervals in the predicted direction. For example, BMI had a 95% CI of -.826 - .200. Viewing BMI as a continuous variable, this confidence interval suggests that as BMI increases, LeanMax decreases.
### Table V. Multiple Linear Regression Analysis - Model Summary

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<th>Model</th>
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<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
<th>Change Statistics</th>
<th>R Square Change</th>
<th>F Change</th>
<th>df1</th>
<th>df2</th>
<th>Sig. F Change</th>
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</thead>
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<tr>
<td>1</td>
<td>.079(a)</td>
<td>.006</td>
<td>-.147</td>
<td>4.54585</td>
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<td>.006</td>
<td>.040</td>
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<td>.961</td>
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<tr>
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<td>.618(b)</td>
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<td>.227</td>
<td>3.73288</td>
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<td>.375</td>
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<tr>
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<td>.673(c)</td>
<td>.452</td>
<td>.253</td>
<td>3.66827</td>
<td></td>
<td>.071</td>
<td>1.426</td>
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<td>.257</td>
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</table>

a Predictors: (Constant), BMI, Age  
b Predictors: (Constant), BMI, Age, Leg Press Strength  
c Predictors: (Constant), BMI, Age, Leg Press Strength, Leg Press Power  
d Dependent Variable: Maximal forward lean angle degrees

### Table VI. Multiple Linear Regression Analysis – Analysis of Variance

<table>
<thead>
<tr>
<th>Mode</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
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<tbody>
<tr>
<td>1</td>
<td>Regression</td>
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<td>.040</td>
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<td></td>
<td>Residual</td>
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<td>13</td>
<td>20.665</td>
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<td></td>
<td>Total</td>
<td>270.313</td>
<td>15</td>
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<tr>
<td>2</td>
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<td>34.367</td>
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<td>Total</td>
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<td></td>
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</table>

a Predictors: (Constant), BMI, Age  
b Predictors: (Constant), BMI, Age, Leg Press Strength  
c Predictors: (Constant), BMI, Age, Leg Press Strength, Leg Press Power  
d Dependent Variable: Maximal forward lean angle degrees
### Table VII. Multiple Linear Regression Analysis – Coefficients

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>95% Confidence Interval for B</th>
<th>Collinearity Statistics</th>
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<td>B</td>
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*a Dependent Variable: Maximal forward lean angle degrees*
Variables Associated with Balance Recovery from a Forward Leaning Position

$\text{Lean}_{\text{Max}}$ was significantly associated with MOD+ physical activity ($r = .577, p = .019$). However, $\text{Lean}_{\text{Max}}$ was not significantly correlated with scores from the SPPB, PAT-D, the Falls Efficacy Questionnaire or the Fear of Falling Questionnaire for TV1 or TV2/3 (Table III, VI). Height, body mass and BMI were not significantly correlated with $\text{Lean}_{\text{Max}}$, however, height and body mass had strong positive correlations with cable support tension load at $\text{Lean}_{\text{Max}}$ (Table III).

Effect of the Forward Lean Assessment on Falls Efficacy and Fear of Falls

Falls efficacy and fear of falls were not significantly associated with performance on the forward fall assessment, nor did the assessment appear to have any affect on these measures. The Falls Efficacy Questionnaire and Fear of Falls Questionnaire were administered prior to the forward lean assessment at TV1 and again at TV2/3 which was on average 48hrs later. From TV1 to TV2/3, the participants’ scores on the Falls Efficacy Questionnaire did not change significantly ($p = .845$). Responses on the Fear of Falls Questionnaire are scored from 0 - 10. At TV2/3 scores were on average 0.56 (S.E. = 0.29) points lower (less fear) than at TV1, however, this was not a statistically significant change ($p = .07$).
DISCUSSION

Summary of Findings

The main finding from this study were that there were no significant differences in LeanMax between the non-obese and obese groups. When additional mass was added to the non-obese subjects to simulate obesity there was a trend for LeanMax to decrease, that is, subjects did not perform as well with added mass. Leg press strength and leg press power were both strongly associated with LeanMax and there were no significant differences between these two correlations. The relationships were strengthened when lower limb strength and power were expressed relative to body mass.

Influence of Body Mass Index on Balance Recovery

We hypothesized that the obese group would have a lower LeanMax than the non-obese group. This was based on research that has repeatedly shown that obese individuals have impaired balance and postural control, lower physical function, greater difficulty with activities of daily living and are more likely to report a history of falls. This hypothesis was not supported as there was no significant difference in LeanMax between the non-obese and obese groups. There may be a number of explanations for this result.

Obese individuals may get a “training effect” from bearing additional body mass on a daily basis. Obese individuals have been observed to have significantly greater absolute knee extensor strength. This is most likely due to increased thigh muscle
cross-sectional area (CSA) which is positively associated with obesity and knee extensor strength\textsuperscript{39}. These adaptations could be viewed as a positive affect to greater load bearing that results from increased body mass. While hypertrophy of the knee extensors is a typical response to bearing additional body mass, obesity is characterized by reduced lower limb strength when expressed relative to body mass or lean body mass\textsuperscript{17, 90, 91}. Furthermore, there is evidence that both aging and obesity are associated with progressive deterioration of muscle quality; defined as maximal force produced per unit of muscle cross-sectional area (CSA). Goodpaster et al., conducted a large scale (n = 2,627) cross-sectional study which used computed tomography to measure muscle density as a surrogate for muscle fat infiltration\textsuperscript{39}. Lower muscle density values reflected greater lipid content of the muscle. Although the obese subjects had greater mid-thigh muscle CSA, muscle density was negatively associated with BMI, total body fat and maximal isokinetic knee extensor strength (60°·sec\textsuperscript{-1}). Furthermore, muscle density was negatively associated with muscle quality as indicated by reductions in force production relative to the quantity of muscle (CSA).

Arguably, obesity has the capacity to impact lower limb muscle both positively in the form of greater CSA and negatively by reducing the quality of the muscle. A number of the obese subjects used in our study were relatively active. While they were not engaged in any structured physical activity they performed an average of 356 min·week\textsuperscript{-1} (±409) of MOD+ physical activity. It is possible that these levels of MOD+ physical activity in combination with greater total body mass had a positive effect on the function of the lower limb muscles of the obese group. It is also possible that these positive effects outweighed the negative effects that obesity has on 1) muscle quality and 2) the
amount of non-contributory body mass (adipose) that must be decelerated during the forward lean assessment. The positive effects are also evident when comparing muscle power between the two groups. Absolute leg press power was significantly greater in the obese group (Figure 11) compared to the non-obese group, although, when expressed relative to body mass (Figure 12) there was no difference.

It is interesting to note the similarity of the distributions within the two groups for leg press power and MOD+ physical activity (Figure 12 and 13). MOD+ Physical activity had a strong positive relationship with LeanMax (Figure 14). While there was no statistically significant difference between the two groups for MOD+ physical activity there was a select group of obese subjects who were more powerful and performed more MOD+ physical activity. The four most powerful individuals were all obese, performed 345 – 1170min of MOD+ physical activity in a typical week, and scored greater than 10 on the SPPB. More importantly, their LeanMax ranged from 18.75 – 22.5° while the mean for all 16 subjects was only 16.6° ± 4.2. This group may have been higher functioning than the rest of the obese group and most of the non-obese group. This may have resulted in the obese group as a whole performing better on the forward lean assessment than was hypothesized. There were no significant differences between the two groups in any other variables that may have affected LeanMax.

To this point, the discussion has viewed BMI as a dichotomous variable (non-obese or obese). It was hypothesized that an obese BMI would be negatively associated with LeanMax. To assess the effects of BMI on LeanMax when viewed as a continuous variable, we performed a hierarchical multiple linear regression analysis (Table V - VII). BMI was not significantly associated with LeanMax however this could be expected given
the low statistical power of our small sample size. Nonetheless, the 95% CI for the unstandardized beta was -.826 - .200 which suggests that the hypothesis of an inverse relationship between BMI and LeanMax should not be discounted and should be further explored across a wider BMI range in a larger number of subjects.
To further investigate the effects of body mass, the non-obese subjects wore a weighted vest and weighted belt to form the simulated obese group which was compared to the true obese group. It was hypothesized that there would be no significant difference in Lean\textsubscript{Max} between these groups. This hypothesis was not supported. There was a trend for the obese subjects to have a higher Lean\textsubscript{Max} (5.0°, S.E. = 2.37) than the simulated obese group (p = .062).

While there was no significant difference between the non-obese and obese individuals from the matched pairs (p = .496), simulating obesity by adding mass to the non-obese subjects did reduce their Lean\textsubscript{Max} by an average of 3.3° (S.E. = 1.4°). Although this did not reach significance (p = .062), it is clear from Figure 15 that Lean\textsubscript{Max} was reduced in all but one subject when wearing the additional mass. The data suggest that a greater non-contributory mass alone does indeed reduce an older adult’s ability to recover their balance from forward a leaning position. There are several potential explanations for these findings.
Increasing the mass of a person increases the clockwise torque (when viewed from the sagittal plane on the right side) about the ankle which occurs during a forward fall. The hip, knee and ankle joints must rapidly produce extensor torques to counteract this and slow the clockwise movement of the body. From observations of the forward lean assessment, it is clear that balance recovery is limited largely by the speed at which the stepping leg can be brought forward and planted underneath the center of gravity. This observation is supported by Thelen et al., who found stepping velocity was positively correlated with the maximal recoverable lean angle\textsuperscript{116}. Greater clockwise directed torques would increase the angular velocity of the falling body and reduce the time available to plant the stepping foot underneath the center of gravity.
In addition to adequate lower limb muscle strength, power and stepping velocity, coordination of the lower extremity is almost certainly required to successfully recover during the forward lean assessment. The stepping foot must rapidly be placed under the center of gravity and the torso and upper body limbs are also likely to facilitate the balance recovery process by keeping the body’s the center of gravity over the base of support. Given that obesity develops over time it seems likely that the physically active obese individuals have developed motor control patterns that assist in controlling the movement of their body mass. In contrast, the simulated obese individuals who were matched for BMI did not have time to adapt to the greater body mass. They may have been at a disadvantage as a result.

The use of Body Mass Index (BMI) to define the non-obese, obese and simulated obese groups also provides a possible explanation for the lack of differences in LeanMax. BMI provides anthropometric information describing body mass relative to height and is often used as a surrogate for measures of body composition. Individuals classified as obese using this measure may have excessive adipose – a tissue which is non-contributory to productive movement. However, greater levels of muscle mass – a contributory tissue, will also increase BMI. It is possible that the non-obese group had less adipose as well as less muscle. Likewise, it is likely the obese group had greater levels of both adipose as well as muscle which is common in the obese\footnote{39}. Adding mass to a non-obese subject (to form the simulated obese group) to match BMI to an obese subject may have resulted in a decline in the contributory to non-contributory mass ratio in the simulated obese group placing them at a disadvantage.
A more appropriate measure of body composition would be a Dual Energy X-ray Absorptiometry (DEXA) scan or computed tomography (CT) scans from which body fat percentage, lean body mass or muscle cross-sectional area can be determined. This would allow for accurate measurements of contributory (muscle) and non-contributory (adipose) tissues. Non-obese individuals could then be matched to obese individuals by adding only enough weight so the ratio of lean muscle to total body mass (including added weight) is equal to that of the obese subjects. This would equalize the contributory to non-contributory mass ratio and allow for a more valid comparison between the simulated obese and obese subjects.

**Falls Efficacy and Fear of Falling**

There was a trend for the obese group to have lower falls efficacy and greater fear of falls at the first testing visit when compared to the non-obese group. Given that obese individuals are known to have impaired balance and postural control and are at greater risk of falls\(^ {13, 32, 61, 82, 85, 107}\), it could be expected that these individuals were more mindful of their risk and therefore more likely to report some general fear and reduced efficacy for performing activities of daily living without falling.
Influence of Muscle Strength and Muscle Power on Balance Recovery

It was originally hypothesized that lower limb muscle strength and power would both be positively associated with LeanMax. Lower limb strength and power were measured using the leg extension and leg press machines. This hypothesis was only supported when the leg press machine was used to measure lower limb muscle strength and power. Leg press strength ($r = .575$, $p = .020$) and power ($r = .548$, $p = .028$) were both positively correlated with LeanMax. Leg extension strength ($r = .479$, $p = .061$) and power ($r = .456$, $p = .076$) were not significantly correlated with LeanMax. The leg press exercise may better mimic the requirements of the lower limb musculature when the foot strikes the ground during balance recovery from a forward leaning position.

A number of studies have found that measures of strength and power made at isolated joints were not related to balance recovery from a forward leaning position. Wojcik et al. found that maximal strength in plantar flexion and hip flexion were not significantly related to balance recovery from a forward leaning position. Grabiner et al. found that measures of strength and power isolated to the hip, knee and ankle (isokinetic dorsiflexion strength at 90°·sec$^{-1}$ explained 29.5% of the variance) had no significant association with performance on this assessment. We found that knee extension strength and power were not significantly correlated with LeanMax.

In contrast to the knee extension measures, the leg press exercise involves a coordinated and simultaneous contraction of the hip, knee and ankle extensors. When the foot is planted during balance recovery from the forward lean assessment, the hip, knee and ankle extensors are all required to actively decelerate flexion at their respective joints. Furthermore, the leg press exercise is a closed kinetic chain movement while measures of
strength isolated to single joints require movements of the lower limb in an open kinetic chain. When the foot strikes the ground during recovery from a forward leaning position, subsequent movements and contractions occur in a closed kinetic chain where the foot is relatively still and the rest of the limb moves about it. We suggest that the requirements of the leg press machine more closely represents the requirements of foot strike during recovery from a forward leaning position and this explains why this compound exercise is significantly related to LeanMax while strength and power measured using a single joint measurement are not.

Studies which have used a similar measure to determine risk of actual falls provide further evidence that the leg press machine incorporates the demands placed on lower limb muscles during a fall. Chan et al., Perry et al., and Skelton et. al., all used a Nottingham Leg Extension Power Rig which is similar to the press machine used in our study. Perry et al. and Skelton et al. conducted retrospective studies finding those who had fallen were less powerful. Chan et al. used this machine to measure baseline power and found that those in the lowest quartile of power were 18% more likely to suffer a fall at 4.5 year follow-up.

It was also hypothesized that lower limb muscle power would explain more of the variance in LeanMax than lower limb muscle strength. This hypothesis was rejected. Lower limb muscle strength explained 33% of the variance of LeanMax while lower limb muscle power explained 30%. There was no significant difference in the magnitude of the relationship that LeanMax had with either leg press strength or power (z = 0.044, p = .516). Lower limb muscle strength and power were equally important for recovering balance from a forward leaning position.
Impaired lower limb muscle strength\textsuperscript{92, 125} and power have repeatedly been associated with increased falls risk\textsuperscript{21, 66, 98, 108}. While there were no differences in the predictive power of lower limb muscle power over strength, both were positively related to $\text{Lean}_{\text{Max}}$ which is supported by a body of literature that states strength and power are related to the risk of falls.

Our results in combination with previous research indicate that gross lower limb strength as well as power (which incorporates joint velocity) may limit $\text{Lean}_{\text{Max}}$ rather than any single lower limb functional characteristic. Kinematic analyses of the forward lean assessment suggest that step velocity explained the difference between young and old adults\textsuperscript{116}. Madigan and Lloyd observed reduced hip flexion and knee flexion/extension velocities in older adults during the swing phase of balance recovery\textsuperscript{72}. Madigan and Lloyd performed further kinetic analyses of the support phase of balance recovery and found that older adults compensated for reduced knee extensor power by producing greater hip and ankle extensor torques\textsuperscript{71}. A number of studies have also made various measurements of lower limb strength and power and compared these to balance recovery on the forward lean assessment. Despite Madigan and Lloyd’s reports of reduced knee extension power during the forward lean assessment, our findings and those of Grabiner et al.\textsuperscript{42} indicate that knee extensor strength does not appear to be predictive of $\text{Lean}_{\text{Max}}$. Wojcik et al., found that at $\text{Lean}_{\text{Max}}$, plantar flexion and hip flexion torques were near maximal but that isokinetic strength at $120^\circ \cdot \text{sec}^{-1}$ was not predictive of $\text{Lean}_{\text{Max}}$\textsuperscript{124}. While we postulate that gross lower limb strength and power limits $\text{Lean}_{\text{Max}}$, studies by LaRoche et al. and Grabiner et al. indicate that ankle strength and power may contribute more to balance recovery than the other lower limb muscles in isolation\textsuperscript{42, 66}. 
LaRoche et al. reported that ankle flexor/extensor peak torque and rate of torque development were lower in fallers but that these measures made for knee flexion/extension were not. The retrospective nature of this study limits the ability to imply causality. As mentioned, Grabiner et al found that ankle dorsiflexor strength may contribute more to recovering balance than muscles at the hip and ankle, however, like our study, approximately 70% of the variance was left unexplained. The rest of the variance may be accounted for by non-muscular variables.

There are a large number of non-muscular variables which have been associated with increased risk of falls. These include but are not limited to stress, sleep deprivation, vertigo upon rising and the number of prescription medications used (particularly antidepressants, sedatives, psychotropic and anti-seizure medications). Future studies may consider the impact that these variables have on Lean_{Max}. It should be recognized that some of these factors as well as neuromuscular limitations may contribute to the initiation of a fall rather than impaired balance recovery. The forward lean assessment measures only ability to regain balance once it has been perturbed and does not measure ability to avoid perturbation.

It must also be recognized that a number of movements and muscle contractions must occur from initiation of the fall to foot strike. Rapid hip flexion, knee flexion and ankle dorsiflexion are required to clear the leg as it travel above the ground. The nature of the leg press exercise does not reflect these characteristics of the swing phase of balance recovery. Also, the hip and knee extensors must contract eccentrically following foot strike during balance recovery yet we measured leg press strength and power when performing concentric contractions of these muscles. These discrepancies may account
for a loss of predictive value from leg press strength and power. It may be useful to measure isokinetic eccentric strength and power.

**Association of Other Variables with Balance Recovery**

As mentioned earlier, MOD+ physical activity had a strong positive association with LeanMax (Figure 14). While none of the participants were participating in structured physical activity, habitually performing physical activities of daily living of a moderate or greater intensity may be important for maintaining ability to recover balance and reduce the risk of falls.

We found no gender differences for LeanMax (p = .412). This is consistent with the findings of Grabiner et al.\textsuperscript{42} but does not agree with the results of Wojcik et al.\textsuperscript{123,124} who found females performed poorer. It has been reported that females have a higher incidence of fall related injuries than males (70.5\%)\textsuperscript{112}. If performance on the forward lean assessment reflects falls risk, it could be expected that females would on average perform more poorly. However, the higher incidence of fall related injuries may simply be due to higher susceptibility to injury from a fall rather than a higher incidence of falls in itself. Further investigation of gender differences in performance on the forward lean assessment may be necessary.
Direct versus Indirect Measures of Body Lean Angle

Previous studies adopting the forward lean assessment have indirectly measured the body lean angle by extrapolation from the tensile load in the lean support cable load\textsuperscript{71, 72}. In the current study, body lean angle was measured directly using an electronic angle measuring device. We noted that modest changes in body lean angle would, at times, cause unusually large increases in the tensile load in the lean support cable. Furthermore, we observed that the cable tension load at low angles (2.5 – 7.5°) was often equal to those at the modest angles that followed (7.5 - 10°). It is suggested that at low angles, the subjects pulled themselves forward rather than leaning in a relaxed position. These observations suggest that in actual practice there is not a perfect relationship between body lean angle and support cable tension. While increasing the lean angle by increasing the load by 4% body mass\textsuperscript{71, 72} provides a good method of progression, extrapolation of the true body lean angle from cable support tension alone may be inaccurate. Furthermore, direct measurements ensure that the participant is maintaining a consistently straight posture during each trial. It is recommended that future studies report direct measurements of the body lean angle as well as lean support cable tension regardless of the method used to progress the lean angle.
Study limitations

Performance on the forward lean assessment is used as a surrogate for a fall and the biomechanical strategy used to recover balance during this assessment may not be the same as that used when a true fall occurs. Pavol et al. and Brady et al. have produced several studies where the kinematics and kinetics of balance recovery were measured while a true fall was induced using either a concealed mechanical obstacle\(^{95-97}\) or vinyl sheet coated with mineral oil\(^{16}\). While these methods better replicates a true fall, there is no way to progress the magnitude of balance perturbation. Also, these assessments can only be used cross-sectionally. It is unreliable to repeat these assessments once the subject is able to anticipate the obstacle. Although our measure of balance recovery does not completely replicate a fall, our pilot testing indicates that it is a reliable and reproducible measure of ability to recover balance following perturbation.

A limitation to this study is the small sample size which limits statistical power. Future studies should obtain a larger sample of individuals that better represent the population of older adults. We recognize that individuals who volunteer for such research studies are fundamentally different to those who do not which results in an unavoidable sample bias. Furthermore, some of the participants have been involved with previous research studies. Although we used a 6 month wash out period, this was not the first time they have been exposed to a research based exercise intervention. This may have improved their self-efficacy for performance on the various assessments in what could be an intimidating environment for some elderly individuals unaccustomed to physical activity or research settings.
This study attempted to simulate obesity for non-obese subjects by adding a weighted vest and belt. It is acknowledged that the vest and belt used do not distribute weight in the same way it is distributed on a “naturally obese” individual. The vest and belt concentrated the additional mass around the hips and torso whereas true obesity results in a more general distribution of additional mass throughout the body including the limbs.

Previous studies which employed the forward lean assessment\textsuperscript{71, 72, 116} measured the peak tensile load in the safety rope during each trial to identify failed attempts. A trial was considered a failure if more than 18.5\%\textsuperscript{116} or 30\%\textsuperscript{71, 72} body mass was applied to the safety rope. In the current study two research technicians evaluated each trial. One would observe the stepping characteristics of the participant and the other would observe the safety rope. The trial was deemed a failure if it appeared that excessive tension was applied to the safety rope however, no objective measurement of safety rope tension was made. Previous studies also used two force platforms to ensure body mass was evenly distributed between both feet prior to release. While force platforms where not used in the current study, participants were continually reminded to distribute their mass evenly between both feet.
Future directions

The lower limb strength and power tests were conducted on Keiser Pneumatic leg extension and leg press machines only. These machines mostly measure concentric strength and power of the knee and hip extensor muscles. The forward lean assessment consists of sudden hip flexion which precedes the planting of the foot. Strength and power assessment of the hip flexor muscle group may be indicated. Also, the majority of the loading during the forward lean assessment occurs when the foot strikes the ground which requires significant eccentric contractions of the hip and knee extensor muscles. Measurements of eccentric muscle strength may be more strongly correlated to the ability to recover balance from a forward leaning position.

The forward lean assessment has been used by several researchers as a surrogate for a fall\(^42, 71, 72, 116, 123, 124\) however; at present there have been no studies which have assessed the effects of any interventions on subsequent performance. It must be recognized that recovering balance from a forward leaning position requires a complex series of movements during both the swing phase and stance phase. All known studies using this assessment have used a cross-sectional design and have focused on isolated joints, or movements related to either the swing or stance phase of balance recovery. It may be that gross lower limb muscle strength and/or power are necessary to perform this task successfully rather than strength/power of one joint. Future research should consider the effects of strength and power training on recovery from a forward leaning position. Also, this assessment has not yet been validated. Future longitudinal studies may consider using the forward lean assessment to assess a larger group of older adults and monitor subsequent incidence of falls.
Implications and Conclusions

The data presented in this thesis provide limited evidence that obesity reduces an individual’s ability to recover their balance from a forward trip. These findings may be confounded by the use of BMI to define body composition. The use of DEXA may be indicated so that muscle to total body weight ratios can be used to match obese and non-obese subjects. Nonetheless, adding weight to a non-obese individual did attenuate LeanMax indicating that additional mass in itself is disadvantageous.

Gross lower limb muscle strength and power measured using a leg press machine were both positively related to performance on the forward lean assessment. This supports the role of both muscle strength and power in restoring balance from a forward fall. In addition to lower limb strength and power, MOD+ physical activity was also positively related to LeanMax. Both of these findings indicate that a physically active lifestyle and physical activities that promote leg strength and power may be important for falls prevention for older adults. A greater sample size and more sensitive measures of body composition may provide greater insight into the characteristics of individuals likely to fall.

In conclusion, lower limb muscle strength and power of the hip, knee and ankle joints should both be promoted in the older population however, weight loss is not indicated based on these findings.
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 stop.

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 15 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 reimbursement 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) 758-5838.

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: ___________________  Acrosc: ___________________
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 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  □ Paid employee
   □ Friend
   □ Other  Specify:

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

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

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

73
### 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>
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<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>
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<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>
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<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>Yes, No, Don't know</td>
</tr>
<tr>
<td>heart attack occur within the past 6 months?</td>
<td></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>
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<td>blocked or clogged blood vessel in your heart)?</td>
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<td>b. heart failure or congestive heart failure?</td>
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<td>c. heart rhythm problem or irregular heartbeat?</td>
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<td>d. heart conduction problem or heart block?</td>
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<td>e. heart valve problem?</td>
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</tbody>
</table>
5. Has a doctor ever told you that you had 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 to 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

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

<table>
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<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 two or more 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.**

**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-mse.org/pitl/core/template-journal/mse/html/0083c.htm
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>
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2. Walking several blocks?

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<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>
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3. Lifting heavy objects?

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<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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4. Preparing your own meals?

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

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<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>
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</table>
6. Walking one block?

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

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<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>
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8. Moving in and out of a chair?

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<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>
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<th>Usually did not do for other reasons</th>
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9. Managing your money, such as paying bills?

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<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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10. Visiting with relatives or friends?

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<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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</table>

11. Moving in and out of a bed?

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<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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</table>
12. Gripping with your hands?

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<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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13. Using the telephone?

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<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>
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<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

14. Using the toilet including getting on and off of the toilet?

<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>

15. Dressing 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>

16. Getting in and out of a car?

<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>

17. Bathing or showering?

<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>
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<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

FAST 23  
Page 4 of 5
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>
<td>□</td>
<td>□</td>
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</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>
<td>□</td>
<td>□</td>
<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>
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<td>□</td>
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</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>
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<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>
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</tbody>
</table>
## Fear of Falling Questionnaire

The items on this scale are scored from 0 to 10, with 0 meaning "not fearful at all," 5 meaning "somewhat fearful," and 10 meaning "very fearful."

### How fearful are you of falling?

<table>
<thead>
<tr>
<th>Item</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lying front or rear of home</td>
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<tr>
<td>2. Light gardening or hanging out the wash</td>
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<tr>
<td>3. Crossing roads</td>
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<td>4. Using public transportation</td>
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<tr>
<td>5. Simple shopping</td>
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<tr>
<td>6. Light housekeeping</td>
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<tr>
<td>7. Frett and cooking and drinks</td>
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<tr>
<td>8. Walking around inside your house</td>
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</tr>
<tr>
<td>9. Answer the door of elevator</td>
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</tr>
<tr>
<td>10. Get dressed and undressed for all activities without falling</td>
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</tr>
</tbody>
</table>

*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.*
APPENDIX G

Acrostic: ________

I.D #: ________

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 5 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>

<table>
<thead>
<tr>
<th>Place</th>
<th>Response</th>
<th>Correct</th>
<th>Sub-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. What state are we in?</td>
<td>__________</td>
<td>__________</td>
<td></td>
</tr>
<tr>
<td>7. What county are we in?</td>
<td>__________</td>
<td>__________</td>
<td></td>
</tr>
<tr>
<td>8. What city are we in?</td>
<td>__________</td>
<td>__________</td>
<td></td>
</tr>
<tr>
<td>9. What is your 'home' address (facility?)</td>
<td>__________</td>
<td>__________</td>
<td></td>
</tr>
<tr>
<td>10. What is your zip code (what floor do you live on?)</td>
<td>__________</td>
<td>__________</td>
<td></td>
</tr>
</tbody>
</table>

**ORIENTATION TOTAL _____**

### B. REGISTRATION

"Now for the next set of questions, I am going to name 3 objects. When I am finished saying all of them, I am 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"

<table>
<thead>
<tr>
<th>Item</th>
<th>Response</th>
<th>Correct</th>
<th>Sub-total</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Ball</td>
<td>__________</td>
<td>__________</td>
<td></td>
</tr>
<tr>
<td>12. Flag</td>
<td>__________</td>
<td>__________</td>
<td></td>
</tr>
<tr>
<td>13. Tree</td>
<td>__________</td>
<td>__________</td>
<td></td>
</tr>
</tbody>
</table>

**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>(W)</td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>(D)</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 it on floor ________

*Reading*

“Please read the statement on this paper and do what the statement says.”

MMSE doc
Page 2 of 4
**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. Patient closed eyes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29. Patient writes a complete sentence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Copying</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot;Mr./Mrs./Ms. _____ next to the design, please COPY it EXACTLY as it appears.&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30. Patient copies diagram of intersecting pentagons</td>
<td></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

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 #4.)

<table>
<thead>
<tr>
<th>Activity</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>1. Visit with friends or family? (other than those you live with)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2. Go to the senior center?</td>
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</tr>
<tr>
<td>3. Do volunteer work?</td>
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<td></td>
</tr>
<tr>
<td>4. Attend church or take part in church activities?</td>
<td></td>
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<tr>
<td>5. Attend other club or group meetings?</td>
<td></td>
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</tr>
<tr>
<td>6. Use a computer?</td>
<td></td>
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</tr>
<tr>
<td>7. Dance? (such as square, folk, line, ballroom) (do not count aerobic dance here)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>- 4.5 METS; Moderate</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

* Page 1 of 5 *
<table>
<thead>
<tr>
<th>Activity</th>
<th>No</th>
<th>Yes</th>
<th>If yes, how many hours a week?</th>
<th>Less than 1 hour</th>
<th>1-2.5 hours</th>
<th>3-4.5 hours</th>
<th>5-6 hours</th>
<th>7-8 hours</th>
<th>9+ hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>0. Do woodworking, needlework, drawing, or other arts or crafts?</td>
<td></td>
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<tr>
<td>9. Play golf, carrying or pulling your equipment? (count walking time only)</td>
<td></td>
<td></td>
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<tr>
<td>10. Play golf, riding a cart? (count walking time only)</td>
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<tr>
<td>11. Attend a concert, movie, lecture, or sport event?</td>
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<tr>
<td>12. Play cards, bingo, or board games with other people?</td>
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<tr>
<td>13. Shoot pool or billiards?</td>
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<tr>
<td>14. Play singles tennis? (do not count doubles)</td>
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<tr>
<td>15. Play doubles tennis? (do not count singles)</td>
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<tr>
<td>16. Skate? (ice, roller, in-line)</td>
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<tr>
<td>17. Play a musical instrument?</td>
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<tr>
<td>18. Read?</td>
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<tr>
<td>19. Do heavy work around the house? (such as washing windows, cleaning gutters)</td>
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<tr>
<td>20. Do light work around the house? (such as sweeping or vacuuming)</td>
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</tr>
<tr>
<td>Activity</td>
<td>No</td>
<td>Yes</td>
<td>If yes, how many total hours a week did you usually do it?</td>
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<tr>
<td>21. Do heavy gardening? (such as sodding, raking)</td>
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<td>• 4 METS; Moderate</td>
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<td>22. Do light gardening? (such as watering plants)</td>
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<td>• 2.25 METS; Light</td>
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<td>23. Work on your car, truck, lawn mower, or other machinery?</td>
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<tr>
<td>• 3 METS; Moderate</td>
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</tbody>
</table>

*Please note: For the following questions about running and walking, include use of a treadmill.*

<table>
<thead>
<tr>
<th>Activity</th>
<th>No</th>
<th>Yes</th>
<th>If yes, how many total hours a week did you usually do it?</th>
</tr>
</thead>
<tbody>
<tr>
<td>24. Jog or run?</td>
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<tr>
<td>• 7 METS; Moderate</td>
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<tr>
<td>25. Walk uphill or hike uphill? (count only uphill part)</td>
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<td>• 6 METS; Moderate</td>
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<td>26. Walk fast or briskly for exercise? (do not count walking leisurely or uphill)</td>
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<tr>
<td>• 3.5 METS; Moderate</td>
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<tr>
<td>27. Walk to do errands? (such as shop from a store or to take children to school (count walk time only))</td>
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<tr>
<td>• 2.5 METS; light</td>
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<tr>
<td>28. Walk leisurely for exercise or pleasure?</td>
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<tr>
<td>• 2.5 METS; light</td>
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<tr>
<td>29. Ride a bicycle or stationary cycle?</td>
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<tr>
<td>• 4 METS; Moderate</td>
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<tr>
<td>30. Do other aerobic machines such as rowing, or step machines? (do not count treadmill or stationary cycle)</td>
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<tr>
<td>• 5 METS; Moderate</td>
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<tr>
<td>Question</td>
<td>No</td>
<td>Yes</td>
<td>If yes, how many total hours a week did you usually do it?</td>
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<td>-------------------------------------------------------------------------</td>
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<tr>
<td>31. Do water exercises? (do not count other swimming)</td>
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<tr>
<td>• 3 METS; Moderate</td>
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<tr>
<td>32. Swim moderately or fast?</td>
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<tr>
<td>• 3 METS; Moderate</td>
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<tr>
<td>33. Swim relay?</td>
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<tr>
<td>• 3 METS; Moderate</td>
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<td>34. Do stretching or flexibility exercises? (do not count yoga or Tai-chi)</td>
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<tr>
<td>• 2 METS; light</td>
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<tr>
<td>35. Do yoga or Tai-chi?</td>
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<tr>
<td>• 2 METS; light</td>
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<tr>
<td>36. Do aerobics or aerobic dancing?</td>
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<tr>
<td>• 3.5 METS; Moderate</td>
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<tr>
<td>37. 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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<tr>
<td>• 4.5 METS; Moderate</td>
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<tr>
<td>38. Do light strength training? (such as hand-held weights of 5 lbs. or less or elastic bands)</td>
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<tr>
<td>• 3 METS; Moderate</td>
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<tr>
<td>39. Do general conditioning exercises or chair exercises? (do not count strength training)</td>
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<tr>
<td>• 2.5 METS; light</td>
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<tr>
<td>40. Play basketball, soccer, or frisbeeball? (do not count time on sidelines)</td>
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<tr>
<td>• 5 METS; Moderate</td>
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<tr>
<td>Question</td>
<td>Yes</td>
<td>No</td>
<td>If yes, how many hours a week did you usually do it?</td>
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<td>------------------------------------------------------------------------</td>
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<tr>
<td>41. Do other types of physical activity not previously mentioned? (please specify)</td>
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<tr>
<td>42. Do other types of physical activity not previously mentioned? (please specify)</td>
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<tr>
<td>43. Do other types of physical activity not previously mentioned? (please specify)</td>
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</tbody>
</table>

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

Specify:
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 888 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

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SPPB TESTING

PARTICIPANT# _____ _____ ACROSTIC _____ _____ STAFF ID _____

VISIT # _____ DATE: _____ / _____ / _____ (dd/mm/yyyy)

SEMILTANDEM STAND

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 988 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

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 felt unsafe
Score 666 if not attempted because participant refused
SPPB TESTING

PARTICIPANT# __________ ACROSTIC __________ STAFF ID __________

VISIT # __________ DATE: __/__/____ (dd/mm/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)
REFERENCES


64. **Centers for Disease Control and Prevention, National Center for Injury Prevention and Control.** Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations, and Deaths. Atlanta (GA); 2006.


SCHOLASTIC VITA

ERIC CHRISTOPH HAAKONSSEN

Personal Information

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Birth Date: October 10, 1982

Undergraduate Study

2004-2007 University of Wollongong
Wollongong, New South Wales
B.S. Exercise Science and Rehabilitation
Honors Class 1

Graduate Study

2008-2010 Wake Forest University
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M.S. Health and Exercise Science
Advisor: Anthony P. Marsh, Ph.D.
Thesis: The Association of Obesity and Muscle Strength and
Power with the Ability to Recover Balance from a Forward
Leaning Position

Professional Experience

2008–2010 Research Assistant
Wake Forest University
Winston-Salem, North Carolina

2008–2010 Graduate Teaching Assistant, Course Instructor
Wake Forest University
Winston-Salem, North Carolina

2009-2010 Exercise Leader
Intensive Diet and Exercise for Arthritis (IDEA) Study
Wake Forest University
Winston-Salem, North Carolina
2008-2009  Exercise Leader
Healthy Exercise and Lifestyle Programs
Wake Forest University
Winston-Salem, North Carolina

2007-2008  Accredited Exercise Physiologist
Body Dynamics Illawarra
Wollongong, New South Wales

2007-2008  Personal Trainer and Corporate Fitness Leader
Altitude Peak Health and Fitness
Wollongong, New South Wales

Professional Organizations

American College of Sports Medicine, 2009-2010

Australian Association for Exercise and Sports Science, 2007-2008

Certifications

American College of Sports Medicine - Certified Clinical Exercise Specialist

American Heart Association – Basic Life Support

Presentations

Haakonssen, EC, Wrights AP, Rejeski WJ and Marsh AP. A Self-Report Measure of Physical Function in Older Adults Using Computer Animation: The Virtual Short Physical Performance Battery.
  2010 South East American College of Sports Medicine Conference
  Greenville, South Carolina

Haakonssen, EC, Marsh, AP, and Zaccaria, JA. Powertrip: The Influence of Obesity and Muscle Power on the Ability to Recover from a Forward Fall.
  2010 Wake Forest University Graduate School Research Day
  Winston-Salem, North Carolina

  2006 Annual Scientific Meeting of the Australian and New Zealand Association of Clinical Anatomists
  La Trobe University
  Bundoora, Victoria