8-2013

# The Relationship among Ankle Function, Functional Capacity, and Body Composition to Balance in Geriatric Populations

Joseph Robert Chaney
*University of Arkansas, Fayetteville*

The Relationship among Ankle Function, Functional Capacity, and Body Composition to Balance in Geriatric Populations

The Relationship among Ankle Function, Functional Capacity, and Body Composition to Balance in Geriatric Populations

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Kinesiology

by

Joseph R. Chaney
University of Central Arkansas
Bachelor of Science in Kinesiology, 2011

August 2013
University of Arkansas

This Thesis is approved for recommendation to the Graduate Council.

Dr. Michelle Gray
Thesis Director

Dr. Matthew Ganio
Committee Member

Dr. Inza Fort
Committee Member

Dr. Tyrone Washington
Committee Member

**ABSTRACT**

The primary purpose of this research study was to identify significant relationships among measures of ankle strength, ankle range of motion, body composition, and functional capacity to balance ability in geriatric populations which may potentially assist in identifying older individuals with increased risk of falling. A battery of five test (ankle strength assessments, ankle range of motion , DXA, functional fitness, and balance) were administered to 20 participants (6 males, 14 females, mean age 69.78 ± 3.98) that had indicated to be at least 65 years of age or older and no history of falls within the previous 12 months. Results demonstrated that no significant statistical relationships exist between functional components ($R^2$ = .240, $Part^2$ = .11, $p$ = .358), relative strength ($R^2$ = .240, $Part^2$ = .09, $p$ = .358), range of motion ($R^2$ = .240, $Part^2$ = .00, $p$ = .358) and body composition ($R^2$ = .240, $Part^2$ = .07, $p$ = .358) as each relates to balance. Additionally, the data failed to demonstrate any significant relationship of relative ankle strength ($R^2$ = .19, $Part^2$ = .08, $p$ = .221) and ankle range of motion ($R^2$ = .10, $Part^2$ = .08, $p$ = .221) as compared to functional capacity. Although the data failed to demonstrate statistical significance or strong correlations, the individual components effect on balance may be more appropriately observed when combined with more complex indicators of fall risk such as gait analysis or biomechanical measures in dynamic balance conditions.

## Table of Contents

# Chapter I

## Introduction

With the rapid growth of older generations (persons over the age of 65), there is also an increase in age-associated chronic disease and other health concerns which exhibit an apparent need for research associated with risk prevention within this age group. Within the $20^{th}$ century, the geriatric population (65+ years) has increased from 3.1 million to over 35 million, with projections expecting to double by 2030. This rapid growth gives rise to the perceptible need of health promotion and risk prevention among this population to increase functional capacity and independence while decreasing medical and economic burden within society (He, Sengupta, Velkoff, & DeBarros, 2005). Previous research estimated that around 250,000 hip fractures occur each year in older populations (with hospitalization for women exceeding men) which indicates the apparent importance of risk prevention for falls (Desai, Zhang, & Hennessy, 1995). Falls present very serious and costly problems among elderly populations which can lead to progressive loss of function and independence (Sturnieks, George, & Lord, 2009). With falls and instability-related accidents contributing to a majority of bone fractures and loss of independence among older populations, the area of balance and stability is becoming increasingly critical to study. Research has demonstrated that approximately 25% of individuals at age 70 have experienced a balance related fall, as occurrence increasing to 35% at the age of 75. Older individuals are also 50% more likely to experience additional falls following the first incident (Tinetti & Speechly, 1989). Although some falls can be result of a single cause, it is thought that falls typically occur as result of several combined factors. This suggests that if one factor attributed to poor balance function can be improved; the prevalence of subsequent falls may be decreased (Mecagni, Smith, Roberts, & O'Sullivan, 2000).

To assist with risk prevention and rehabilitation fields, it is important to better understand various factors that can reduce risks associated with deficiencies in functional capacity as geriatric population numbers continue to increase. Balance is defined the process that maintains the center of gravity within the structure's support base and requires constant adjustment through muscle activation and joint repositioning (Greve, Alonso, Carolina, Bordini, & Camanbo, 2007). Several musculoskeletal and nervous system diseases can affect the ability to maintain balance. Previous research related to lower limb stability has indicated the importance of synergistic muscle group strength and range of motion, particularly in populations with lower limb impairments, balance issues, and obesity.

Functional capacity is another area of particular importance due to the capacity to estimate an individual's level of independence and determine their capability and proficiency to which they can perform tasks of daily living (Gardner, Robertson, & Campbell, 2000). However, little research has been conducted to establish a relationship between functional capacity, ankle agonist/antagonist muscle strength, joint range of motion, and body composition as each relates to balance in geriatric populations. There is an apparent need to determine if a relationship exists between each of these factors and balance to aid in risk prevention among older populations. Growing research in the field helps to provide information to determine the effectiveness of public health efforts in preventing foreseeable risks associated with morbidity and mortality (Desaiet et al., 1995). Research has also demonstrated that individuals ages 20-70 will experience a 20-40% reduction in lower limb strength; however various strength training can improve strength capacity and enhance stability in older individuals (Larsson, 1974). More recent research determined in older men and women, annual lower limb strength losses are typically experienced at 1-2% and 3.5% respectively, on an annual basis (Skelton, Grieg, Davies, &Young, 1994).

Balance and stability are known to typically deteriorate as aging progresses; however, both elements have been shown to be receptive to training. Currently, there is no defined consensus to determine the most critical components of balance training due to the complexity of motor function (Wolfson et al, 1996). In observing research related to balance and stability function, numerous study designs have been conducted as well as a variety of measured variables such as numerous stability training programs, sensory deprivation, various subject populations, body compositions, and previous injuries have been utilized. Although conflicting research has observed that training independent factors related to balance may be beneficial towards fall prevention in the elderly, the incorporation of multiple factors simultaneously such as group exercise or performing cognitive and physical tasks simultaneously during dynamic movements may be favorable to reduce fall risks and enhance balance ability (Wu, 2002).

Promotion of exercise can decrease the occurrence of sedentary related ailments such as sarcopenia which can further exacerbate existing chronic conditions and increase the prevalence of chronic illness. Recent research has also demonstrates that resistance training can combat weakness and frailty and further detrimental effects, as well as enhance balance, stability, and coordination skills among older populations (Segun & Nelson, 2003). Lower limb strength has been associated with decreased occurrence of falls and stability-related accidents within older populations due to increased postural control and proper body alignment (Samuel, Rowe, Hood, & Nicol, 2011). Muscle deficiencies and imbalances have also contributed to poor reaction to postural sway, increased instability, and impairment of functional capacity among older populations due to poor proprioceptive response (Hurley, Rees, & Newham 1996).

Additional research suggest that balance limitations may also be affected by lack of education of poor health behaviors, poor vision, hip pain, excessive alcohol consumption, and current smoking habits (Satariano, Delorenze, Reed, & Schneider, 1996). Furthermore, research has also demonstrated that the implementation of an exercise regimen performed in conjunction with a fall prevention course was very effective in reducing fall risk among participants (Gardner, et al., 2000). Success of interventions such as gait analysis and stability testing are likely to be optimized by early identification of falls risk, before a serious fall, and before the development of additional problems such as fear of falling and reduced activity levels (Hill, Smith, &Murray, 2000).

Often, falls in elderly populations can also lead to public economic burden due to prolonged hospitalization and rehabilitation, and potential time lost at work (Hamacher, Singh, Van Dieen, Heller, & Taylor, 2011). Risk reduction can assist with improved longevity, higher quality of living, and prolonged independence among older populations. By improving the functional capacity and balance of older individuals, the frequency of falls may also be reduced which can lead to fewer subsequent injuries that often result in serious illness or death (Desai et al., 1995; Cerny, 1998).

**Purpose**

The purpose of this study was to observe the relationship of functional capacity, ankle strength, ankle joint range of motion, and body composition factors as each relates to balance in a geriatric population. The primary aim was to determine how each of these components specifically influences balance which can potentially progress the ability to sustain and increase balance in older populations.

**Hypotheses**

Prior to conducting research, the first hypothesis presumed that participants which demonstrated greater relative ankle strength, more ankle range of motion, increased lean tissue mass, and optimal functional fitness scores will demonstrate greater balance ability as compared to participants with inferior scores. Data from each of these measures was used to determine whether a significant relationship exists among each factor and balance scores.

The second hypothesis anticipated that participants that demonstrated a high measure of relative strength and optimal ankle range of motion would demonstrate better scores on each of the functional fitness tests. This was assumed due to increased strength and range of motion at the ankle being potentially indicative of lower limb mobility in elder populations. Participants that score lower in ankle strength and range of motion measures may also exhibit poor balance scores as result of poor motor control or inability to efficiently adjust postural stance in unstable conditions.

The third hypothesis assumed that participants yielding decreased amounts of fat-free mass (lean tissue) would demonstrate poor balance scores as compared to participants that exhibited more optimal body composition measures. Several factors associated with decreased muscle mass can include decreased strength, diminished functional ability, and inability to rapidly adapt to rapidly changing stimuli (particularly unstable surfaces. Other complications may occur through the increased amount of fat mass which is typically observed in conjunction with the loss of lean tissue mass in elder populations.

Data collection and analysis further determined if each of the independent factors being measured within the study were significantly related to balance. Although each component was objectively measured, it was be determined that a combination of several factors may be the most appropriate means to improving balance ability in older populations. Through measuring each of these components that are related to balance (functional capacity, ankle strength, ankle joint range of motion, and body composition), this research helped to better determine how each factor specifically relates to balance and if supplementing current training and rehabilitation programs can lead to a reduction of falls to further promote safety and risk prevention among geriatric populations.

**Assumptions**

In conducting this research, it was assumed that all participants performed each of the assessments within the study including the modified Senior Fitness Test (SFT) and modified stair protocol, ankle strength test, range of motion test, DXA, and balance protocol to the best of their individual ability while maintaining personal boundaries of safety. It is also assumed that each participant can properly perform and complete each test related to the study due to the non-invasive nature of each assessment.

**Definition of Terms**

1. <u>Ankle Strength</u>- The amount of rotational ankle force provided by each subject during both plantar and dorsiflexion within the sagittal plane (measured in N/M of torque/body weight).
2. <u>Balance</u>- The ability of the body to remain in an upright position within a base of support, while minimizing postural sway.
3. <u>Body Composition</u>-The amount of body fat reported per individual (measured in kg).
4. <u>Fat-Free Mass</u>- The total amount of body mass that excludes the measure of body fat

5. Functional Capacity- The measure of a subject to demonstrate a series of standardized tests at the best of their capability to determine their functional ability involving everyday tasks.
6. Geriatric Populations- Age $\geq$ 65 years for subjects participating within this study.
7. Postural Sway- The amount of body movement which deviates the body's center of mass from the center of gravity in any direction within an upright position.
8. Range of Motion- The amount of movement within (measured in degrees) to which a body segment rotates around a fixed axis or joint.

**Significance of Study**

The significance of this study is to determine if significant relationships exist between factors related to balance (functional capacity, ankle strength, range of motion, and body composition) to balance in older populations. Any significance demonstrated within the study may indicate physiological areas to promote conditioning and rehabilitation to preserve and promote balance ability to further reduce the risk of falls among the elderly.

## Chapter II

## Literature Review

Currently, research discussing lower limb strength and balance is limited to varying populations and examine a variety of training and rehabilitation methods to enhance lower limb strength to promote balance. With progressing age, poor balance and stability occur as result of loss in muscle strength and poor coordination; however research has demonstrated that rehabilitation and strength training can enhance factors associated with improved balance (Buchner, et al., 1996). Decreased balance ability, particularly in older populations, has been associated with the increased frequency in falls and related incidents (Day, et al., 2002). Combined factors such as muscle atrophy and decreased joint flexibility (particularly in lower limbs) can lead to impaired motor control, delayed movement response, and overall impaired functional capacity (Tinetti & Speechly, 1989). In determining the relationship of each of the factors to balance, various training and rehabilitation programs can be supplemented or enhanced to promote balance ability and functional capacity.

Specifically, strength has been determined to be a major factor in balance and decreased frequency of falls in older populations, especially in individuals that have previously experienced a fall or instability related accident. Research has also determined other impairments such as delayed response to postural changes and slowed gait patterns can attribute to poor balance and frequency of falls (Fukagawa, Wolfson, Judge, Whipple, & King, 1995). Other research demonstrates that older populations with type II diabetes may be at even greater risk of balance impairments due to factors associated with peripheral neuropathy, thus, more susceptible to falls. However, training programs that focused on lower limb strengthening, proprioception, and reaction time in populations with type II diabetes indicated balance improvements (Morrison, Colberg, Mariano, Parson, & Vinik, 2010). Individuals who had also previously experienced a fall demonstrated declines in functional measures such as balance, gait, and activities of daily living (Chu, Chiu, & Chi, 2005). Thus, research suggests that intervention through resistance training may help to improve balance and stability which can lead to decreased risk of falls particularly in elderly populations.

Several tests can be performed to determine the abilities and risks associated decreased muscle strength and elasticity, as well as functional capacity in older populations. Several protocols through the Biodex dynamometer system can isolate biomechanical joint structures and precisely measure force production within a given joint to determine if muscle strength or range of motion deficiencies exist among different individuals. In addition to a self-reported assessment of functional capacity, it is important to also utilize a physical component that can quantitatively measure capacity. A physical assessment can be utilized from a battery of testing methods, but the assessment should also be validated using a cross-sectional study design to accurately assess functional ability of the individual, accurately categorize functional capacity, indicate functional changes over time, and as means of relevant information to the clinician (Guralnik, Branch, Cummings, & Curb, 1988). Validated measures of functional ability provide accurate estimates of physical capabilities to which professionals can appropriately develop training and rehabilitation programs (Skelton, Grieg, Davies & Young, 1994).

**Functional Measures**

Recent research has demonstrated that older individuals that participate in at least 20-30 minutes of physical activity most days of the week demonstrate greater functional ability as compared to those that are only active throughout the day or are inactive (Brach et al., 2004). When selecting a specific protocol or test to evaluate functional capacity, appropriateness of the measure, practical aspects of test administration, and psychometric properties should each be considered carefully to determine reliability and validity of the assessment (Van Swearingen & Brach, 2001).

The Senior Fitness Test (SFT) is a validated assessment used to determine functional capacity among older adults. This test is conducted over a series of six components which includes the 8-Foot Up-and-Go test, 30 second seated-to-standing test, both arm (shoulder joint) and hamstring (hip joint) flexibility measures, upper body strength assessment, and a 6 minute walk test to determine aerobic capacity. Modified versions of this test have also been performed to measure specific components within the assessment (Rikli & Jones, 2001).

The 8-Foot-Up-and-Go Test (TUG) is a common measure that is used to assess functional mobility, particularly among elder populations. Participants begin in a seated position in a chair and are timed to stand up and walk over a distance of 8 feet, turn, and return to the seated position. Shumway-Cook, Brauer, and Woollacott (2000) demonstrated that using the TUG functional assessment, individuals that experienced have difficulty performing the test in conjunction with a cognitive or mental objective were more susceptible to falls. This research demonstrates that decreased coordination during complex dynamic movements, combined with simultaneously performing activities of daily living, could decrease balance and stability and increase risks of falls in elderly populations (Shumway, et al., 2000).

Functional mobility is also commonly measured using the Seated-to-Standing (STS) measure which replicates the dynamics of sitting and moving into a fully upright position. The

Seated-to-Standing test is a common measure of functional capacity in older adults; however, research has determined that factors such as stability, mobility, and psychological status are key components associated with the measure (Whitney et al., 2005). It is important to note that performance (Lord, Murry, Chapman, Munro, & Tiedemann, 2001) examined validation of this measure and determined that a variety of issues including visual contrast sensitivity, lower limb proprioception, peripheral tactile sensitivity, reaction time involving a foot-press response, sway with eyes open on a foam rubber mat, body weight, anxiety, knee flexion, and ankle dorsiflexion strength were significant and independent predictors of STS. This test is also considered a practical alternative to determine functional mobility among the elderly as compared to manual muscle testing or other instrumented options as the STS functional capacity test may be a better predictor of functional ability when used in conjunction with other measures such as the TUG test, seated to standing assessment, or other balance measures (Richard, 1995).

The Short Physical Performance Battery (SPPB) is another common lower limb functional capacity test that can quantify functional ability. This tool has also been used to assist in identifying potential elevated falling-risk individuals that performed poorly on the test (Volpato et al., 2010). This test observes balance through standing while isolating each leg independently over a 10 second period and observes functional dynamic components including both walking (timed over a distance of 4 meters) and a seated-to-standing assessment in which a series of repetitions are performed and recorded. The SPPB has been used on a variety of studies in which functional capacity is being measured, particularly in older populations and balance impaired individuals (Pahor, 2006).

Other research has observed the effects of dual-task training in older adults. Dual-task training can effectively measure functional capacity by observing the ability to perform a task in conjunction with a physical component (such as walking) that is common in daily living. Particularly, a series of tasks were performed by older individuals while simultaneously performing one of several functional training tests including the Chair Stand Test, Functional Reach Test, Timed Up and Go Test, and Trail Making Test. Each of these tests when performed in concurrence with a cognitive or physical objective. Dual-task training is applicable in assessing functional ability and better understanding deficiencies associated with poor functional status. Results indicated that postural control was significantly improved following the dual-task training program which suggests that training and performing various tasks simultaneously could potentially improve balance and stability, particularly in elder populations (Hiyamizu, Morioka, Shomoto, & Shimada, 2010).

**Activities of Daily Living (ADL).** In previous research, ADLs can be assessed using a self-reported questionnaire. The Stanford Health Assessment Questionnaire (HAQ) was developed using a series of 20 ADLs to which individuals indicate the degree of difficulty for each task, as well as need for help and the use of assistive devices. Any change in difficulty among tasks can be assessed to more completely portray the functional capacity in performing ADLs. Modified versions of the questionnaire (mHAQ) have also been utilized to observe more specific tasks related to a particular area of interest (Pincus, Summey, Soraci, Wallston, & Hummon, 2005). Evaluation of the ADL questionnaires can provide helpful insight to personal functional ability as well as identify previous injuries which may challenge daily routines among elderly populations.

**Cognitive function.** Several studies have observed the relationship between performing cognitive tasks while observing postural sway for individuals in a standing position. Research suggests that simple cognitive tasks can significantly impact balance, especially in older populations in which stability is impaired (Shumway-Cook et al., 1997). Cognitive tasks performed during balance assessments have included visual perceptual matching, sentence completion, and basic mathematical equations as participants are simultaneously conducting a series of balance assessments. Speed and accuracy of verbal responses related to the cognitive component are often quantified for comparison between study participants (Condron & Hill, 2002).

**Muscle Strength**

In recent years, research has determined that a variety of strength training methods could be beneficial in older populations due to the increase in frailty, chronic disease, and sarcopenia. Current research demonstrates that only 12% of older individuals participate in muscle-strengthening activities regularly at least twice per week (Nelson et al., 2007). When performed regularly, strength conditioning can enhance and preserve bone density, functional independence, and vitality, as well as reduce the risk of osteoporosis, type 2 diabetes, heart disease, and other chronic conditions that can affect balance. Through implementation of resistance training, muscle regeneration and strength levels can help to slow muscle atrophy even as aging occurs, and prevent additional complications associated with progressive muscle deterioration that can significantly affect balance among older individuals (Metter, Talbot, Schrager, & Conwit, 2002). It is important promote and develop resistance training programs into regular exercise and rehabilitation routines to prevent further muscle deterioration and maintain strength levels within elder populations.

Loss of muscle strength has also indicated poorer functionality as well as inferior quality of living, which demonstrates that preservation of strength and functionality can be a major component of cognitive health and functional capacity (Samuel et al., 2011). Much of the previous research suggests a variety of strength training programs ranging from controlled laboratory muscle group isolation, to home-based programs can prove effective in regressing muscle atrophy, with key emphasis on determining the most appropriate training approach per individual (Segun & Nelson, 2003). It is important to determine the most appropriate and effective training methods sustain strength levels, particularly in older individuals to ensure that functional ability can be maintained. A suitable training or rehabilitation program that enhances lower extremity stability and strengthening can minimize the potential for additional health complications as result of falls among older populations (Morrison et al., 2010).

In older adults, research has demonstrated that deliberate contraction of specific muscle groups (particularly plantar and dorsiflexor muscles) does have a tendency to decrease with age (Obata, Akai, Nakazawa, & Ohtsuki, 2010). Increased fatigue and decreased torque production were also associated observed n older muscles (age >70 years) during dynamic exercise (Dalton, Power, Vandervoort, & Rice, 2010). When observing factors of aging on muscle contractions, several differences have been ascertained between younger and older males. Following a series of isometric and dynamic strength protocols, older males (age >70 years) demonstrated a 26% drop in maximal voluntary contraction (MVC) torque, and 38% decrease in overall peak power as compared to young participants (age 20-30 years). The study indicated that older populations experience greater and more rapid fatigue during fast dynamic movements at unconstrained velocity and could be a potential area of improvement to increase overall muscle response as it relates to balance (Dalton et al., 2010). Although results found in this particular study demonstrate significant decrease in torque and peak power measurements among the age groups, it is important to note the task-dependent nature of the activity can affect the fatigability. These studies further demonstrate the need for continued resistance training, particularly muscular endurance is necessary to preserve strength and prevent conditions associated with muscle loss in older populations.

Research also establishes that low muscle strength is associated with mortality, presumably due to sarcopenia and low physical activity. To date, sarcopenia (age-related muscle loss) has been shown to deteriorate muscle fiber composition, contractility, innervation, increase fatigue, and decrease metabolism; however, little has been observed with this condition as it relates to tasks of daily living. Additional research also suggest the link that reduced muscle mass as it relates to sarcopenia can be detrimental to bone health due to the lack of mechanical forces placed on the skeletal system thus preventing the stimulation of bone formation (Dutta, 1997). Although Metter and colleagues (2002) determined muscle mass preservation and physical activity participation were important to decrease the impact of sarcopenia on mortality, these factors did not fully account for balance impairments, strength losses, and muscle atrophy among older populations.

Several protocols and programs have been developed to support and maintain muscle function in order to enhance balance. Some of these strength training protocols include isolation of specific muscle groups. Research has demonstrated that sarcopenia has become a recurring problem in older populations as rapid muscle atrophy combined with loss of muscular function contribute to poor balance and stability, particularly in older populations (Cruz-Jentoft et al., 2010). As sarcopenia and other conditions continue to reduce functional capacity, it is apparent for resistance training to be implemented in a weekly training routine. Some research has observed the effects of endurance training such as resistance training (muscular) and cycle protocols (cardiovascular) to improve balance only to determine that the short-term regimens did not have a restorative effect on balance, gait, or overall health status, but did suggest the chronic training programs could lead to a reduction of overall falling rates in older populations due to improved coordination and enhanced awareness of body position (Buchner et al., 1996). The implementation of a muscular or cardiovascular endurance protocol may further progress motor coordination and promote slow-twitch fiber development to decrease fatigability in elder populations.

The promotion of fall prevention has also been observed through the implementation of group exercise training to increase balance and stability among older adults. In a study conducted by Barnett, Smith, Lord, Williams, & Baumand (2002), individuals that were identified to be at higher risk of falls and were randomly assigned to either a group exercise intervention program or control group. The exercise intervention group included subjects that participated in a total of 23 structured group exercise classes in conjunction with a series of home based exercises over a one-year period. Following the conclusion of the study, participants in the exercise program intervention scored higher during the re-test demonstrated significant improvements in postural sway with eyes open and closed and coordinated stability as compared to control group participants that did not participate in regular physical activity. The study suggests that community and home based group exercise programs may promote enhanced balance and stability among other groups to further reduce the risk among falls among older individuals (Barnett et al., 2002).

Tai Chi has also shown to be an effective method of training, particularly in older populations, due to training utilizing combined factors of muscle strengthening, breathing techniques, and involved coordination which showed significant potential towards improving overall balance ability as well as reduction of risks associated with instability related conditions in older populations (Wu, 2002). Research has demonstrated that techniques such as Tai Chi can also be beneficial to build and maintain strength, especially in older populations. Short term strength training to improve dynamic balance, stability control, and narrow-stance stability occurred over a three month period, three times per week at 45 minutes per session. Participants all showed improvement through this training program, and were able to maintain all balance and stability gains through the utilization of a Tai Chi protocol performed once a week for 60 minute sessions (Wolfsonet et al., 1996). In analyzing several approaches to improving balance factors in geriatric populations, Wu (2002) determined that isolated variable training such as resistance training, balance training, and feedback training which each can enhance a specific area related to balance, but results were inconclusive between various studies. Although each of these specific factors can be improved independently with specific training, it may be advantageous to incorporate all of the factors together using Tai Chi or similar regimen (Wu, 2002).

Additional research has observed a group exercise intervention over a period of 12 months that utilized a series of exercises that focused on leg strength, lower limb stability, balance, and coordination through a series of repetition exercises. During the classes, participants could modify each exercise according to personal abilities which allowed for personalization of training and promoted long-term adherence to the program which is critical to ensuring long-term health and functional ability. Participants showed significant improvements in postural sway and coordinated stability, however, results did not demonstrate significant strength or reaction-time changes between the intervention and control groups. The study also found that subjects within the exercise intervention group reported a 40% decrease in the number of falls within the 12 month trial period. The study suggests that the class atmosphere in conjunction with the utilization of coordination skills during the classes could be useful in promoting exercise adherence as well as developing lower limb stability and balance to prevent falls in geriatric populations (Barnett et al., 2002).

Alternative means of resistance training that utilize various balance methods have also demonstrated to be effective in enhancing balance ability. When observing the isolated effects of balance training using techniques such as rolling boards, trampolines, and rubber balls compared to traditional strength training, strength gains were similar between both groups. The study determined that balance training is efficient in developing muscle strength as well as equalization of muscular imbalances following balance training (Heitkamp, Horstmann, Mayer, Weller, & Dickhuth, 2001).

Research related to muscle function and balance determined that older individuals recorded greater activity of slower twitch muscle groups (tibialis anterior and soleus muscles) to compensate for balance as compared to younger participants. This demonstrates that older subjects decrease body sway by activating a contraction strategy of postural control around the ankle joint, and may not be efficient with smaller muscle groups to compensation for balance discrepancies as compared to younger populations (Melzer, Benjuya, & Kaplanski, 2001). This suggests that older adults may benefit from training of both slow and fast twitch muscle groups to maintain and effectively improve balance ability and postural response in unstable conditions.

**Range of Motion**

Range of motion, particularly in lower limb joints, has demonstrated to have a direct impact on impaired balance and stability among older populations. Prince, Corriveau, Hébert, & Winter (1997) stated the importance of identifying diagnostic measures by which can be reliable predictors of fall-prone elderly individuals and to improve programs that can promote balance improvements and stability. One major factor determined through this research was the reduction of lower limb range of motion, particularly with the ankle joint, which altered gait and kinematic patterns among the elderly, causing a greater occurrence of falls and instable conditions (Prince et al., 1997).

With combined factors of muscle atrophy and decreased proprioceptive function, joint flexibility and muscle elasticity can contribute to poor stability and poor functional capacity. Muscle atrophy and poor flexibility can also lead to reduced efficacy of rehabilitation which can decrease the probability of full recovery or improvement of balance related factors (Hurley, 1997). Additionally, research has demonstrated that several static and slow-dynamic stretches, often performed following exercise, can be beneficial to promote muscle elasticity and increase joint range of motion to help maintain postural balance and decrease the risk of falls in older populations (Feland, Myrer, Schulthies, Fellingham, & Measom, 2001).

Previous research examining ankle range of motion has been observed in community-dwelling elderly women. Balance ability was measured using the Functional Reach Test (FRT) and the Tinetti Performance-Oriented Mobility Assessment (POMA). Goniometry measurements were used to determine bilateral ankle active-assistive range of motion (AAROM) and passive range of motion for participants. Research determined that a correlation exists among ankle range of motion and balance ability, but further examination was required to determine if increasing range of motion demonstrated an improvement on balance (Mecagni et al., 2000).

Although differences exist between falling rates among different genders and various age groups, little information has been observed among biomechanical factors, such as range of motion. The connection between ankle range of motion and balance can be attributed to muscle elasticity as well as the ability to recover and regain balance following a forward fall. Research has demonstrated that diminished ankle range of motion in conjunction with muscle atrophy can affect balance and diminish fall recovery, especially among older women (Gardner et al., 2000).

**Body Composition**

Increased body composition (Body Mass Index >30 $kg/m^2$) has been shown to increase functional limitations in older adults, to a greater extent in women as compared to men. Individuals with increased BMI measurements reported functional limitations for both men and women even in the absence of sarcopenia which may indicate that increased body fat composition is significant determinant of functional capacity (Davidson, Ford, Cogswell, & Diets, 2002). Gallagher and colleagues (2000) researched the prevalence of sarcopenia conditions among elder populations are often more progressive in individuals with increased body fat percentages as compared to those with more lean body composition (Gallagher et al, 2000). Other research demonstrates that increased body fat may lead to biomechanical difficulties, particularly poor muscular responses and loss of stability mechanisms, especially in geriatric populations (Greve et al., 2007). The complications as result of these combined factors can advance the probability for falls and lead to an increase in overall health risk among older adults.

Research has also demonstrated that an increase in Body Mass Index (BMI) is correlated with increased postural instability, especially when combined with a lack of physical activity or decreased muscle mass. Although BMI is not a parameter of body composition, it can be inferred that increases in fatty tissue can lead to problems with postural balance across all populations

(Greve et al., 2007). Self-reported physical activity levels indicated by older populations (>60 years) over a 10 year period determined that fat free mass decreased around 2% in males (loss of muscle) and fat mass was increased 7.5% over the decade for both men and women. The research indicated that although fat mass increases in both males and females over the 10 year period, female fat gain was attributed to age whereas males saw increases as result of decreased physical activity. Results of the study suggest that increases in physical activity could reduce, or slow the rate at which fat mass accumulates in older populations, thus increasing vitality and longevity and further promoting factors associated with improved balance (Hughes et al., 2002).

**Balance**

Balance among the elderly has become an increasingly popular area of interest due to the significance of stability issues and prevalence of falls among the elderly. Although balance ability can be assessed though a variety of factors such as vestibular function, visual acuity, proprioception, muscular and biomechanical alignment, and breathing, the main cause of poor balance and falls among the elderly is a combination of multiple factors (Heitkamp et al., 2001). Research suggests that improvement on even one factor related to balance ability may significantly reduce the risk for falls or subsequent accidents related to instability and prolong independence among the elderly (Rose, Jones, & Lucchese, 2002).

Balance can be measured using a variety of techniques and assessment tools, however, the use of clinical and research tools such as the Biodex Balance System (BSS) or force plate systems will provide greater information and tailored protocols to better identify specific variables being measured. The Biodex Balance System is a common instrument used in clinical application to observe and quantifiably measure balance ability. This assessment tool has been utilized in many clinical and research settings due to the variety of applications and automated protocols which can test a variety of balance and stability factors with a high degree of accuracy. Platform stability levels can be adjusted to alter the difficulty for a specific population being tested or protocol being performed. Often, protocols with the BSS assess balance over a timed period (typically 20-30 seconds) as the machine can vary resistance and range in difficulty as the protocol progresses (Cachupe, Shifflett, Kahanov, & Wughalter, 2001). Protocols can be performed using semi-tandem or single-leg foot positions to better isolate balance dynamics being measured. Stability index scores have been shown to have the greatest reliability among various tests and trials (Schmitz, & Arnold, 1998).

Force plates are often used in clinical and research application to determine balance capabilities. Typically, force plate instrumentation measures factors such as center of pressure (COP) and center of mass (COM). The difference between these variables (COP-COM) can be calculated to determine postural sway control mechanisms and has shown to be highly effective at measuring balance among elder populations (Lafond, Duarte, & Prince, 2004).

Although several means of assessing balance ability and fall risk are used in clinical applications, it is imperative to note the complexity of balance. In identifying individuals with an increased fall risk, it is critical to observe multiple components of balance to determine fall risk prevalence. Through observation of multiple mechanisms, variables that contribute to decreased balance can be more effectively identified and more efficiently improved.

# Chapter III

## Methodology

### Participants

In conducting this cross-sectional study, a total of 23 participants (7 males, 16 females) ages ≥65 (69.18 ±11.31) years participated in the study. Each subject was measured all variables within the study (functional capacity, ankle strength, ankle joint range of motion, and body composition). Subjects for this research project were community-dwelling older adults in the Northwest Arkansas area and were selected on a voluntary basis. Subjects choosing to participate demonstrated the ability to properly and safely perform each of the assessments associated with the study. Selection for participants included age greater than or equal to 65 years of age, ability to safely perform each assessment, and could not have current significant injury that could affect the proper demonstration of each test associated with the study. Participant selection was not biased toward current functional ability, sex, previous history of falls (greater than 12 months), or indication of previous injury to ensure the data collected were applicable to comparable populations.

### Testing Environment

All physical testing was performed within the Human Performance Lab located in the Health, Physical Education, and Recreation (HPER) building on the campus of University of Arkansas. Each of the test administrators were properly trained to safely conduct testing protocols and were certified in CPR/AED training. Automated External Defibulators (AED) and emergency action plans were also available on site in the event of a medical emergency during testing.

## Pre-Testing Procedures

Subjects selected to perform the study completed an Informed Consent form to inform participants of inherent risks associated with the study. Participants were also required to complete and submit a modified Health History Questionnaire (HHQ) form that indicated current risk to perform exercise as well as notify testing instructors of any previous injuries that may affect testing results. All forms were completed prior to testing to ensure each participant was physically able to safely complete the testing procedures prior to the start of the research assessments. Subjects were then weighed and height was measured via a Detecto (Webb City, MO) physician's scale to ensure accuracy throughout the extent of the assessment.

Testing administrators demonstrated how each of the assessments was to be performed to ensure proper form and accurate measurements within each section. Participants then performed each test as outlined by specific protocol requirements for each assessment.

## Functional Capacity

Testing subjects performed a modified Senior Fitness Test (SFT) which included two of the six components commonly used in the SFT including the 8-Foot Timed Up-and Go test and 30 second seated-to-standing test. A stair-climb was also implemented among the functional capacity assessment due to the specificity of coordinated lower limb function as well as the recruitment and utilization of the musculature surrounding the ankle joint.

The 8-Foot Up-and-Go test was executed by participants using a chair and a marker that determines approximately 8 feet in front of the chair. Participants were instructed to begin in a seated position and move to a fully upright position and progress towards a designated marker, turn, and return back to the chair and into a seated position. A practice trial was performed prior to the actual test, and the measures included two trials per participant. Times were recorded and used to quantifiably estimate functional mobility for each subject. The seated-to-standing test was be performed by participants using the same chair from the previous test as they were instructed to begin in a fully seated and relaxed position and were asked to move into a fully upright position then back to a seated position over a series of repetitions within a 30 second period. Measurement for these assessments required minimal equipment and were performed using a non-arm chair and a stopwatch as the test administer counted the number of repetitions each participant completed (starting from a seated position, to full standing, and back to seated with arms crossed across chest) within a 30 second time period. Repetitions were recorded and used to obtain an estimate of functional capacity for each subject.

A modified stair-climb test was used to measure functional mobility for each participant. The stair-test protocol was performed on a series of nine steps located within the HPER building. Participants were instructed to begin at the bottom of the stairs in a semi-tandem foot position, as the test administrator requested that participants do not use the aid of the hand rail unless it was absolutely necessary to prevent an eminent fall. This helped to ensure the data collected were a direct measure of the lower limb functional mobility and not include additional support during the test. A verbal countdown was also used prior to the start of each trial to eliminate any anticipatory start to the test. Each subject was then instructed to climb each of the nine stairs, as quickly and safely as possible, until they had reached the landing at the top to which their time was stopped and recorded. Each subject performed two trials for this test as assessment times were compared between all study participants. A combination of these three assessments provided an accurate measure of functional capacity which was used to determine if functional capacity among the elderly is related to balance performance.

## Ankle Strength

Ankle strength was assessed using the Biodex System 3 isokinetic dynamometer (Shirley, NY) via an isokinetic bilateral protocol (concentric plantar flexion/concentric dorsiflexion). Measurements for height and weight were entered into the Biodex protocol for accurate assessment during each trial for each participant. The Biodex isokinetic dynamometer system, has demonstrated accuracy and efficiency in measuring range of motion and various muscle factors (such as peak torque production, average work production, and fatigue index) through the isolation of specific muscle groups which provides consistent and quantifiable data for comparisons among a variety of studies (Arnold & Schmitz, 1998). The bilateral protocol was performed for three trials of 60 degrees/second, 180 degrees/second, and 240 degrees/second (both plantar and dorsiflexion measurements). Each trial (three trials per leg) was performed over a series of 10 repetitions to accurately determine average torque (TQ) production to body weight (BW) between legs. Relative strength (TQ/BW) assessments demonstrated the force producing ability for each foot which was translated into postural response during static and dynamic balance conditions.

## Ankle Range of Motion

Range of motion was determined through an assessment of plantar and dorsiflexion at the lateral malleolus of the both the right and left fibula, through the frontal anatomical axis. Range of motion measurements were determined using a goniometer (two measurements at each ankle, with $\leq 5$ degrees difference), and measure the maximal range of movement (in degrees) for both the right and left ankles.

## Body Composition

The use of the General Electric (West Milwaukee, WI) Dual-Energy X-ray Absorptiometry (DXA) system provided non-invasive, accurate, and efficient method to obtain several bone density and body composition measures for each participant. Body composition including body fat percentage (% fat), fat-free mass (lean), fat mass (FM), and bone mineral content (BMC) were obtained using the DXA body scanner. DXA scans omit a radiation level equivalent to 1/10 of a standard x-ray, which provided reduced risk and minimal radiation exposure.

## Balance Assessment

Balance assessments were performed using the Biodex Balance System SD (Shirly, New York). The test was performed using the "fall risk" assessment protocol due to the ability to select factors such as height and age which allows the system to automatically compare results to standardized data among various age groups, including the elder population. Participants were instructed to stand on the balance platform as the system prompted participants of specific foot positions according their center of pressure. Upon completion of the pre-test setup, subjects completed a practice trial to become familiar to the unstable balance platform, as participants were then instructed to not use the support rails (unless the risk of a fall is eminent) to ensure data collection measured each individual's balancing ability without the assistance of supportive aid. Platform resistance became progressively more unstable as each individual trial progressed (20 seconds per trial with 10 second rest periods between trials). A series of three trials was performed by each participant as the protocol compiled the results for comparison among standardized results of various age groups and determines an average balance score which was compared to other scores within similar age categories. Overall Stability Index (SI) was determined using the Biodex SD system via the system formula:

$$(DI)^2 = \sqrt{\sum(0-X)^2 + \sum(0-Y)^2} \div number\ of\ samples$$

Anterior/Posterior stability index demonstrated the variance in platform displacement in degrees from the level starting position which was determined using: $(DI)y = \sqrt{\sum(0-Y)^2} \div number\ of\ samples$. Medial/Lateral stability index demonstrated the various in platform displacement in the frontal plane as determined by the formula: $(DI)x = \sqrt{\sum(0-X)^2} \div number\ of\ samples$. Standard deviation of each measure indicated the amount of variability between trials which was determined by the formula: $\frac{\sum}{n}\ \sqrt{(Xn + \overline{X}}\ ^2 \div number\ of\ samples$.

**Statistical Analysis**

Statistical significance was set at $\alpha \leq .05$ level and all results are reported as means ± sd. SPSS statistical software (Armonk, New York) was used to analyze data. Balance was determined to be the dependent variable. Multiple regression analysis employed measures of body composition measures (FFM and body fat percentage), ankle strength (plantar and dorsiflexion), functional ability tests (Seated-to-standing (STS), up-and-go test (U&G), and stair climb test (SCT)) as the independent variables. Body Composition measures (FFM) were measured in kilograms (kg), functional measures (U&G and SCT tests) were measured in seconds, range of motion was measured in degrees, and strength ability was measured in torque/body weight ratio to account for relative strength production between participants. Correlations within the data excluded participants 5, 17, and 21 due to being significant outliers within the data set. These observations were omitted because results indicated to be outside of the normal population. The omission of these outliers indicated an adjusted sample size for the data set (*n* = 20).

A correlation was performed on each of the relative ankle strength measures and determined that dorsiflexion measures at 60º, 180º, and 240º were most related to balance among the six strength measures. The 180º dorsiflexion measure was determined to be the relative strength component in the correlation to balance portion of the statistical analysis because this figure was most strongly correlated to balance (*Pearson Correlation* = -.182). A correlation also was performed on the functional fitness components and determined that the 30 STS measure was most related to balance among the battery of functional tests (*Pearson Correlation* = .279) and was used to represent the functional component in the correlation to balance portion of the statistical analysis. Range of motion measures were averaged between both the right and left ankles for each participant and correlated to balance. The FFM measurement data was unaltered prior to the correlation analysis.

The initial research hypothesis examined if a relationship existed between ankle strength, ankle range of motion, functional ability, or body composition to balance ability. Balance testing measures included both males (*n* = 6) and females (*n* = 14) which met at least the minimal criteria (age ≥65, no falls in previous 12 months) for participation in the study (69.78 ± 3.98). Body strength was measured using the Biodex Isokinetic Dynamometer (Shirly, NY) and functional measures (excluding the stair-climb measure) were performed as outlined for functional ability field testing guidelines in accordance with the Senior Fitness Test Manual (Rikle & Jones, 2001). In observing the data collected, observations 5, 17, and 21 demonstrated to be outliers within the data set and were omitted from statistical analysis to increase the likelihood for significant relationships among each of the factors measured.

The sample size of this research study may also contribute to the absence of statistical significance. Measures of functional capacity (STS, SCT, and U&G) were compared within a correlation to balance as the 30 second seated-to-standing measure demonstrated the greatest correlation to balance, therefore it was the component used to indicate functional capacity in the multiple regression analysis performed in the data. This measure indicated a stronger correlation to balance as compared to other functional components because it was the only functional test which was performed in a static foot position, similar to the balance assessment. In addition, each of the relative strength measures (60º PF TQ/BW, 60º DF TQ/BW, 180º PF TQ/BW, 180º DF TQ/BW, 240º PF TQ/BW, and 240º DF TQ/BW) were compared in a correlation as the 180º DF TQ/BW demonstrated the greatest correlation to balance and was also used in the multiple regression analysis. This use of the 180º DF TQ/BW measure of relative ankle strength measure demonstrated the highest correlation to balance due to the similar strength means used to compensate in rapid shifting body posture in stable balance conditions. Statistical analyses were conducted with the outliers 5, 17, and 21 omitted to optimize any chance for statistical significance among the compared measures within the data set.

# Chapter IV

## Results

In analyzing all measured components (relative ankle strength, ankle range of motion, body composition, and functional capacity) the data did not demonstrate significant statistical relationships to balance in the data set. Relative ankle strength measures and ankle range of motion measures failed to demonstrate a strong correlation which indicates that increased ankle strength (TQ/BW DF 180º) and range of motion (ROM) do not translate into enhanced balance ability.  Additionally, results indicated that body composition (FFM) was not highly correlated to balance. This suggests that individuals with decreased lean tissue mass do not demonstrate lesser balance ability as compared to individuals with increased fat free mass. No significant differences were indicated between each of the observed measures as compared to balance between genders.

### Gender Differences

An independent sample t-test was also performed to determine d if statistical significance between genders existed among each of the measured factors and balance within the data set. Results for measured variables to balance for males and females are located in Table 1. Balance, functional capacity, ROM, and relative ankle strength measures were not different between genders. FFM was significantly higher in males ($p$ = .000). Based on the results, all data were analyzed as one group.

The independent sample t-test for each measure indicated t-values and significance for each variable as compared between genders (Table 1). Balance score ($t$ = .878, $p$ = .392), STS (*t* = .090, *p* = .930), ROM (*t* = .410, *p* = .687), DXA FFM (*t* = 7.342, *p* = .000), and TQ/BW DF 180º (*t* = 1.226, *p* = .236).

**Hypothesis One**

The primary purpose for this research project was to determine the relationship between the measured factors (relative ankle strength, ankle range of motion, body composition, and functional capacity) as they relate to balance. A multiple regression statistical analysis was performed on each of the tested factors as each relates to balance to determine the amount of variance accounted for by knowing relative ankle strength ROM, FFM, and functional capacity (Figures 1-4). Regression analysis indicated that the four predictor variables accounted for 24% of the variance in balance (*p* = .36). In each of the independent variables, it was apparent that functional capacity (STS), and relative ankle strength had the largest unique contributors accounting for 11% and 9.9% respectively.

**Hypothesis Two**

The second hypothesis observed measures of relative ankle strength (TQ/BW DF 180º) and greater ankle range of motion (ROM) would demonstrate better scores in functional capacity (STS). A multiple regression statistical measure was performed with relative ankle strength and ROM components as each relates to functional capacity. Multiple regression analysis revealed that in knowing relative strength and ROM, 19% of the variance of balance was accounted for (*p* = .18). No significance was demonstrated between relative ankle strength and ankle range of motion measures as compared to functional capacity (Table 2).

**Hypothesis Three**

The third hypothesis determined the relationship between the body composition (FFM) measures to balance. Body composition (FFM) demonstrated no correlation to balance ($r = .27$, $p = .25$). No significant relationship was demonstrated between FFM and balance.

# Chapter V

## Discussion

The primary aim of this research project was to determine if statistical relationship exists between ankle function, ankle range of motion, functional capacity, and body composition in geriatric populations. Although data collected throughout the study (relative ankle strength, range of motion, and functional ability) failed to demonstrate a significant relationship to balance this could be result of several factors. First, inclusion criteria for subject participation were fairly minimal. This may possibly suggest that the population group for the study varied greatly in previous injury, aptitude in performing each assessment, strength ability, and body composition which could lead to a larger range in result figures as compared to a more selective test group. Second, testing measures that were conducted (specifically relative strength measures) can demonstrate a dramatic range in difference due to participant capability, motivation, or factors related to fatigue. This may have demonstrated no change in correlation to balance ability scores even if participant criteria had been more selective. Third, it is important to note that balance is a complex and dynamic component which can be difficult to measure solely through the observed measures within this study. Factors in this study may have a greater impact on balance ability when measured in conjunction to previous influences demonstrated to be major contributors to balance such as proprioception, vestibular function, visual acuity, body orientation, and musculoskeletal alignment (Hill, Smith, & Murray, 2000).

Although results for the study failed to demonstrate any strong correlations or significant statistical relationships between ankle strength, ankle range of motion, functional fitness, and body composition measures to balance ability, it is important to note that each of the observed factors may still contribute to balance when combined with other aspects. For example, Fukagawa and colleagues (1995) demonstrated that lower limb strength plays a key role in balance when simultaneously observing ankle and knee strength and gait patterns to predict the occurrence of falls in older populations. Other research demonstrated that although resistance training and dynamic balance retraining decrease the occurrence of falls in elderly populations, the factors independently were not correlated as predictors of balance ability (Gardner et al., 2000). Hamacher et al., (2011) presented the importance of analyzing dynamic stability and gait variability via biomechanical measures to better identify individuals at greater risk of falling. This research identified that although lower limb strength was a component of stability, the combined factors that contribute to gait (leg swing time, stride time, stance time, and acceleration at the ankle) were better predictors of fall risks in older populations (Hamacher et al. 2011).

While the present study failed to demonstrate significance among ankle strength, range of motion, functional ability, or body composition to balance, it is critical to note the nature of the balance assessment that was conducted was performed in a static position with minimal kinetic movement in the lower extremity. This may indicate that performance of ankle strength or other lower body joint locations (hip and knee) are not the best single indicators of static balance ability, but may contribute to a greater degree in assessment of dynamic balance conditions. Previous research also indicated that although single leg balance and other factors could indicate injurious falling, each of the isolated variables measured were not significant predictors of balance due to the diverse factors related to falling (Vellas et al, 1997).

It is also important to note that the present study excluded participants that had not experienced falls within the previous 12 months which prompted a limitation to the study. This limiting factor may have failed to demonstrate significance among each of the measured components to balance due to the subject population not demonstrating deficiencies in ankle strength, range of motion, or functional ability as compared to subjects with increased risk of falling or previous indication of falls. In future research, it is important to include participants who have indicated previous falls or are at increased risk of falling to obtain a sample that may indicate decreased balance ability and greater risk of falling. Future research observing the significance of balance ability in elderly populations involved subjects that had previously indicated a balance related fall prior to participation in the study may demonstrate significant relationships between measured variables to balance ability.

## Conclusion

Although minimal significance in the correlations was established between the measured variables and balance in the study, it is important to understand the complexity and the many factors that contribute to balance ability. Previous research has demonstrated significance among similar variables as they relate to identifying persons of increased fall risk in the elderly, but little research has demonstrated a considerable relationship between single components such as ankle strength, body composition, joint range of motion, or functional capability as each relate to balance ability. However, each of the components being measured in this study should be viewed as contributors to stability, gait pattern, and compound kinetic movements which have been proven to be indicators of fall risk in older populations.

To continue progression of research related to balance in older adults, further observation of relationships between resistance training interventions and dynamic balance ability may be beneficial. Additional research may also observe connections between individuals with decreased lean tissue mass (FFM) and functional capacity. In comprehending the effect specific variables to balance ability, new ideas may emerge which can further enhance current exercise and rehabilitation programs that benefit functional capacity training and reduce fall risks within older populations.

With the conclusion of this research project, it is important to continue the promotion of strength training, enhancement of flexibility, improving body composition, and boosting functional ability to continue to promote healthy living and longevity in older populations. The improvement of each of these components will help to preserve lean muscle mass and bone density levels and enhance the standard of living for the rapidly increasing geriatric population.

Table 1

*Gender Differences in Balance, ROM, Ankle Strength, FFM, and Functional Capacity*

| | Means ± sd (males) | Means ± sd (females) | *t* | *p* |
|---|---|---|---|---|
| Balance Score | 4.27 ± 1.85 | 3.47 ± 1.85 | .878 | .392 |
| Relative Ankle Strength | 31.29 ± 7.22 | 27.10 ± 6.91 | 1.23 | .236 |
| Ankle ROM | 66.33 ± 6.22 | 64.75 ± 8.48 | .410 | .687 |
| Body Composition (kg) | 55.73 ± 5.37 | 38.80 ± 4.45 | 7.34 | .000* |
| Functional Capacity | 20.83 ± 4.96 | 20.64 ± 4.11 | .090 | .930 |

*Note.* *$p \leq .05$, indicates significant relationship, kg = kilograms, ROM = Range of Motion, FFM = Fat Free Mass, sd = Standard Deviation. $n = 20$.

Table 2

*Combined Gender ROM, Ankle Strength, FFM, and Functional Capacity to Balance*

| | Means ± sd | *t* | *p* | *Part*$^2$ |
|---|---|---|---|---|
| Relative Ankle Strength | 28.36 ± 7.09 | -1.40 | .182 | .10 |
| Ankle ROM | 65.23 ± 7.74 | 0.02 | .984 | .00 |
| Body Composition (kg) | 43.87 ± 9.19 | 1.22 | .243 | .07 |
| Functional Capacity | 20.83 ± 4.96 | 1.47 | .163 | .11 |

*Note.* *$p \leq .05$ indicates significant relationship, $r = .240$, kg = kilograms, ROM = Range of Motion, FFM = Fat Free Mass, sd = Standard Deviation. $n = 20$. No significant relationship was observed between measured factors and balance.

Table 3

*Relative Ankle Strength and Ankle ROM to Functional Capacity*

| | Means ± sd | Functional Capacity | *t* | *p* | *Part*$^2$ |
|---|---|---|---|---|---|
| Relative Strength | 28.36 ± 7.09 | .329 | 1.27 | .221 | .08 |
| Ankle ROM | 65.22 ± 7.74 | .329 | 1.27 | .221 | .08 |

*Note.* $*p \leq .05$ indicates significant relationship, ROM = Range of Motion, sd = Standard Deviation. $n = 20$. No significant relationship was observed between measured factors and balance.

Table 4

*Correlations of Measured Demographic Variables*

| | Bal Score | Wt | Ht | Sex | Age |
|---|---|---|---|---|---|
| Balance Score | 1.000 | 0.514 | 0.550 | -0.203 | -0.094 |
| Weight (lbs) | 0.504 | 1.000 | 0.764 | -0.523 | -0.207 |
| Height (in) | 0.550 | 0.764 | 1.000 | -0.616 | -0.109 |
| Sex | -0.203 | -0.523 | -0.616 | 1.000 | -0.210 |
| Age | -0.094 | -0.207 | -0.109 | -0.210 | 1.000 |

*Note.* *$p \leq .05$ indicates significant relationship, Wt = weight, Ht = height, lbs = pounds, in = inches, sd = Standard Deviation. $n = 20$. No significant relationship was observed between demographic factors and balance.

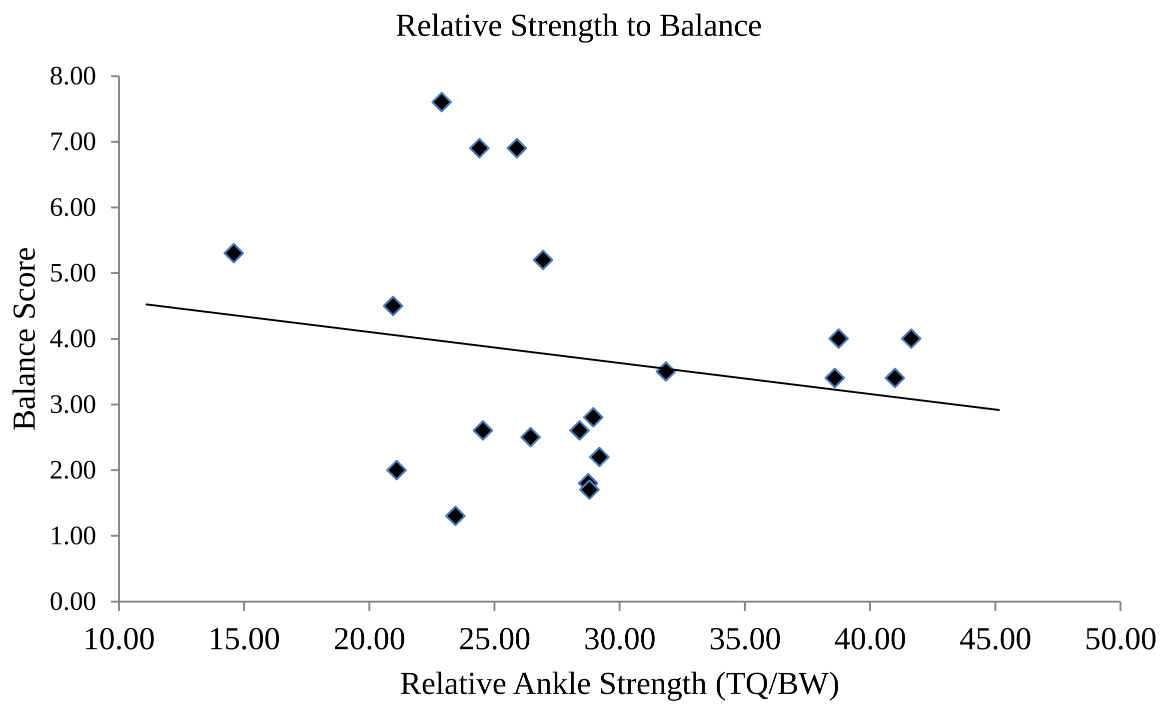


Figure 1

*Relative Strength (TQ/BW) to Balance Score*

*Note*. TQ/BW = Torque/Body Weight, Mean = 28.36 ± 7.09, $t$ = -1.40, $Part^2$ = .10, $R^2$ = .240, $p$ = .182. Figure illustrates linear regression of Relative Strength variable to Balance. ($n$ = 20).

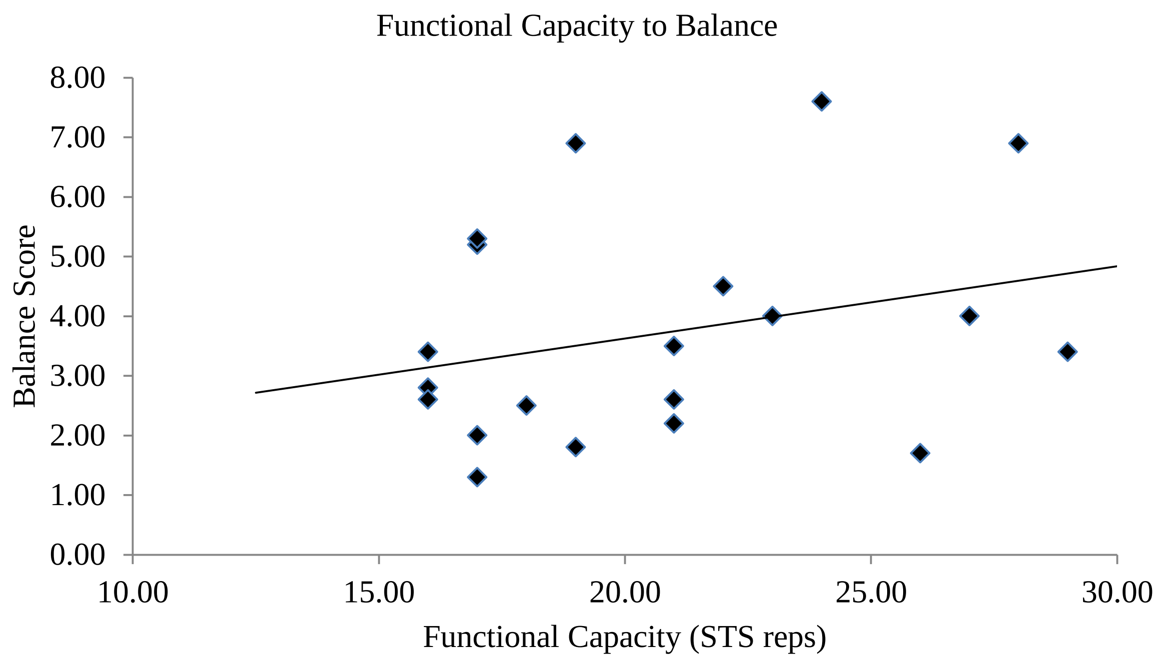


Figure 2

*Functional Capacity (STS repetitions) to Balance*

*Note.* STS = Seated-to-Standing, Mean = 20.70 ± 4.24, $t = 1.47$, $Part^2 = .10$, $R^2 = .11$, $p = .163$. Figure illustrates linear regression of Functional Capacity variable to Balance. ($n = 20$).

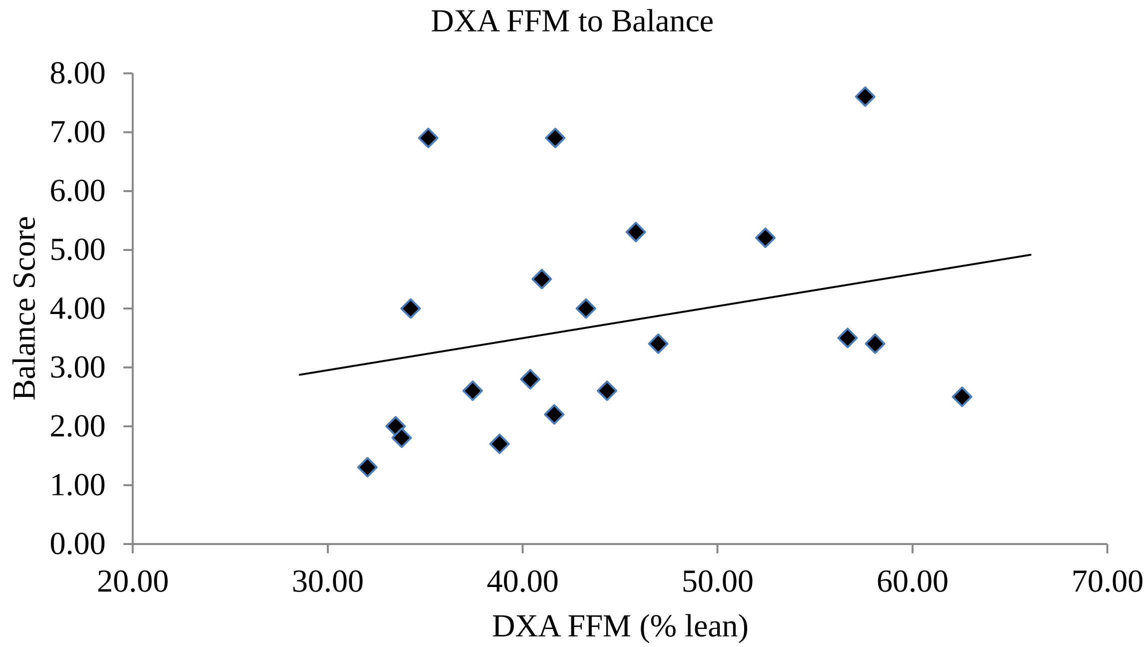


Figure 3

*Body Composition (Fat Free Mass) to Balance*

*Note*. FFM = Fat Free Mass, Mean = 43.87 ± 9.19, $t$ = 1.22, $Part^2$ = .07, $R^2$ = .240, $p$ = .243. Figure illustrates linear regression of Body Composition variable to Balance. ($n$ = 20).

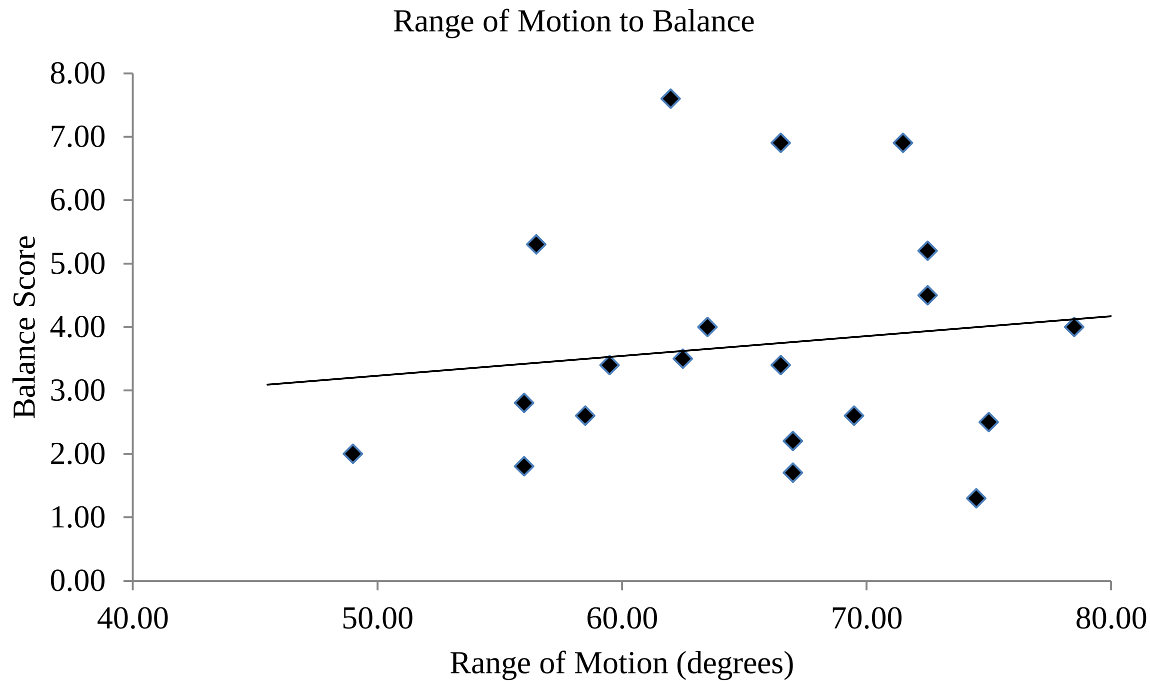


Figure 4

*Ankle Range of Motion (degrees) to Balance*

*Note.* STS = Seated-to-Standing, Mean = 65.23 ± 7.74, $t$ = .02, $Part^2$ = .00, $R^2$ = .240, $p$ = .984. Figure illustrates linear regression of Range of Motion variable to Balance. ($n$ = 20).

## References


Arnold, B. L. & Schmitz, R. J. (1998). Examination of balance measures produced by the Biodex stability system. *Journal of Athletic Training*, *33*(4), 323-327.

Atkinson, H. H., Rosano, C., Simonsick, E. M., Williamson, J. D., Davis, C., Ambrosius, W. T., … Kritchevsky, S. B. (2006). Cognitive function, gait speed declince, and comorbidities: The health, aging, and body composition study. *The Journals of Gerontology*, *62*(8), 844-850.

Barnett, A., Smith, B., Lord, S.R., Williams, M., & Baumand, A. (2002). Community-based group exercise improves balance and reduces falls in at-risk older people: A randomised controlled trial. *Journal of Age and Aging*, *32*(4), 407-414.

Brach, J. S., Simonsick, E. M., Kritchevsky, S., Yaffe, K., Newman, A. B. & The Health, Aging and Body Composition Study Research Group (2004). The association between physical function and lifestyle activity and exercise in the health, aging and body composition study. *Journal of the American Geriatrics Society*, *52*(4), 502–509.

Buchner, D. M., Cress, M. E., de Lateur, B. J., Esselman, P. C., Margherita, A. J., Price, R., & Wagner, E. H. (1996). The effect of strength and endurance training on gait, balance, fall risk, and health services use in community-living older adults. *The Journals of Gerontology*, *52*, M218-M224.

Cachupe, W. J., Shifflett, B., Kahanov, L., &Wughalter, E. H. (2001). Reliability of Biodex balance system measures. *Measurement in Physical Education and Exercise Science*, *5*(2), 97-108.

Cerny, K., Blanks, R., Mohamed, O., Schwab, D., Robinson, B., Russo, B., & Zizz, C. (1998).The effect of a multidimensional exercise program on strength, range of motion, balance and gait in the well elderly. *Gate and Posture*, *7*(2), 185-186.

Chu, L. W., Chi, I., & Chiu, A. Y. (2005). Incidence and predictors of falls in the Chinese elderly. *Ann Acad Med Singapore*, *34*(1), 60-72.

Condron, J. E. & Hill, K. E. (2002).Reliability and validity of a dual-task force platform assessment of balance performance: Effect of age, balance impairment, and cognitive task. *Journal of the American Geriatrics Society*, *50*(1), 157-162.

Cruz-Jentoft, A. J., Baeyens, J. P., Bauer, J. M., Boirie, Y., Cederhold, T., Landi, F., … Zamboni, M. (2010). Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. *Age and Aging*, *39*(4), 412-423.

Dalton, B. H., Power, G. A., Vandervoort, A. A., & Rice, C., L. (2010). Power loss is greater in old men than young men during fast plantar flexion contractions. *Journal of Applied Physiology*, *109*(5), 1441-1447.

Davidson, K. K., Ford, E. S., Cogswell, M. E. & Diets, W. H. (2002). Percentages of body fat and body mass index are associated with mobility limitations in people aged 70 and older. *Journals of the American Geriatric Society*, *50*(11), 1802-1809.

Day, L., Fildes, B., Gordon, I., Fitzharris, M., Flamer, H., & Lord, S. (2002). Randomised factorial trial of falls prevention among older people living in their own homes.*British Medical Journal*, *325*(7356), 128.

Desai, M. M., Zhang, P., & Hennessy, C. H. (1995).Surveillance for morbidity and mortality among older adults – United States, 1995-1996.*Center for Disease Control, 48*(SS08), 7-25.

Dutta, C. (1997). Significance of sarcopenia in the elderly. *The Journal of Nutrition, 127*(5), 9925-9935.

Feland, J. B., Myrer, J. W., Schulthies, S. S., Fellingham, G. W., & Measom, G. W. (2001). The effect of duration of stretching of the hamstring muscle group for increasing range of motion in people aged 65 years or older. *Physical Therapy, 81*(5), 1110-1117.

Fukagawa, N. K., Wolfson, L., Judge, J., Whipple, R., & King, M. (1995). Strength is a major factor in balance, gait, and the occurrence of falls. *The Journals of Gerontology, 50*A, 64-67.

Gallagher, D., Ruts, E., Visser, M., Heshka, S., Baumgartner, R. N., Wang, J., … Heymsfield, S. B. (2000). Weight stability masks sarcopenia in elderly men and women. *American Journal of Physiology-Endocrinology And Metabolism*, *279*(2), E366-E375.

Gardner, M. M., Robertson, M. C., & Campbell, A. J. (2000). Exercise in preventing falls and fall related injuries in older people: A review of randomized control trials. *British Journal of Sports Medicine, 34*, 7-17.

Greve, J., Alonso, A., Carolina, A., Bordini, P. G., & Camanbo, G. L. (2007) Correlation between body mass index and postural balance. *Journal of Clinical Science, 62*(6), 717-720.

Guralnik, J. M., Branch, L.G., Cummings, S.R., & Curb, J. D. (1988). Physical performance measures in aging research. *The Journal of Gerontology, 44*(5), 141-146.

Hamacher, D., Singh, N. B., Van Dieen, J. H., Heller, M. O., & Taylor, W.R. (2011). Kinematic measures for assessing gait stability in elderly individuals: A systematic review. *The Journal of the Royal Society, 8*, 1682-1698.

He, W., Sengupta, M., Velkoff, V. A., & DeBarros, K. A. (2005). 65+ in the United States: Current population report. *US Census Bureau. Washington, DC: US Government Printing Office*.

Heitkamp, H.C., Horstmann, T., Mayer, F., Weller, J., & Dickhuth, H. (2001). Gain in strength and muscular balance after balance training. *International Journal of Sports Medicine, 22*(4), 285-290.

Hill, K., Smith, R. &Murray, K. (2000). An analysis of research on preventing falls and falls injury in older people: Community, residential and hospital settings. Report to the Commonwealth Department of Health and Aged Care. *Canberra, Australia: Commonwealth Department of Health and Aged Care.*

Hiyamizu, M., Morioka, S., Shomoto, K., & Tomoaki, S. (2010). Effects of dual task balance training on dual task performance in elderly people: A randomized controlled trial. *Clinical Rehabilitation, 26*(1).

Holmbäck, A. M., & Lexell, J. (2007). Reproducibility of isokinetic ankle dorsiflexor strength and fatigue measurements in healthy older subjects. *Isokinetics and Exercise Science, 15*(4), 263-270.

Hughes, V. A., Frontera, W. R., Roubenoff, R., Evans, W. J., & Singh, M. A. (2002). Longitudinal changes in body composition in older men and women: Role of body weight change and physical activity**.** *The American Journal of Clinical Nutrition, 76*(2), 473-481.

Hurley, M. V. (1997). The effects of joint damage on muscle function, proprioception and rehabilitation. *Manual Therapy, 2*(1), 11-17.

Hurley, M. V., Rees, J., & Newham, D. J. (1996).Quadriceps function, proprioceptive acuity and functional performance in healthy young, middle-aged and elderly subjects. *Age and Aging, 27*(1), 55-62.

Kim, K. E., Jang, S. N., Lim, S., Park, Y. J., Paik, N. J., Kim, K. W., … Lim, J. Y. (2011). Relationship between muscle mass and physical performance: is it the same in older adults with weak muscle strength?. *Age and Aging, 41*(6).

Lafond, D., Duarte, M., & Prince, F. (2004).Comparison of three methods to estimate the center of mass during balance assessment. Journal of Biomechanics, *37*(9), 1421-1426.

Larsson, L. (1974). Aging in mammalian skeletal muscles. *The Aging Motor System*. Praeger Pusblishing, New York, 60-96.

Lord, S. R., Murry, S. M., Chapman, K., Munro, B., & Tiedemann, A. (2002). Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people. *Journal of Gerontology, Biological Science and Medical Science, 57*(8), 539-543.

Mecagni, C., Smith, J. P., Roberts, K. E., & O'Sullivan, S. B. (2000). Balance and ankle range of motion in community-dwelling women aged 64 to 87 years: A correlational study. *Journal of the American Physical Therapy Association*, *80*(10), 1004-1011.

Melzer, I., Benjuva, N., & Kaplanski, J. (2001). Age-related changes of postural control: Effect of cognitive tasks. *Journals of Gerontology, 47,* 189-194.

Melzer, I., Benjuya, N., Kaplanski, J., & Alexander, N. (2009).Association between ankle muscle strength and limit of stability in older adults.*Age and ageing*, *38*(1), 119-123.

Metter, J. E., Talbot, L. A., Schrager, M., & Conwit, R. (2002).Skeletal muscle strength as a predictor of all-cause mortality in healthy men. *The Journals of Gerontology*, *57*(10), 359-365.

Morrison, S., Colberg, S. R., Mariano, M., Parson, H. K., & Vinik, A. I. (2010). Balance training reduces falls risk in older individuals with type 2 diabetes. *Journal of Diabetes Care, 33*(4), 748-750.

Nelson, M. E., Rejeski, W. J., Blair, S. N., Duncan, P. W., Judge, J. O., King, A. C., … Castaneda-Sceppa, C. (2007). Physical activity and public health in older adults: Recommendation from the American College of Sports Medicine and the American Heart Association. *Physical Activity and Public Health for Older Adults, 39*(8), 1435-1445.

Obata, H., Kawashima, N., Akai, M., Nakazawa, K., & Ohtsuki, T. (2010). Age-related changes of the stretch reflex excitability in human ankle muscles. *Journal of Electromyography and Kinesiology*, *20*(1), 55-60.

Ortman, J. M., & Guarneri, C. E. (2009). United States population projections: 2000 to 2050. United States Census Bureau.

Pahor, M. (2006). Effects of a physical activity intervention on measures of physical performance: Results of the Lifestyle Interventions and Independence for Elders Pilot (LIFE-P) Study. *The Journals of Gerontology, 61*(11), 1157-1165.

Pincus, T., Summey, J. A., Soraci, S. A., Wallston, K. A., & Hummon, N. P. (2005). Assessment of patient satisfaction in activities of daily living using a modified stanford health assessment questionnaire. *Arthritis and Rheumatism, 26*(11), 1346-1353.

Prince, F., Corriveau, H., Hébert, R., &Winter, D. A. (1997). Gait in the elderly. *Gait & Posture*, *5*(2), 128-135.

Richard, W. B. (1995). Sit-to-stand test for measuring performance of lower extremity muscles. *Perceptual and Motor Skills, 80*(1), 163-166.

Rikli, R. E., & Jones, C. J. (2001). *Senior fitness test manual* (Vol. 1). Human Kinetics, Champaign, IL.

Rose, D. J., Jones, C. J., & Lucchese, N. (2002). Predicting the probability of falls in community-residing older adults using the 8-foot up-and-go: A new measure of functional mobility. *Journal of Aging and Physical Activity*, *10*(4), 466-475.

Samuel, D., Rowe, P., Hood, V., & Nicol, A. (2011). The relationships between muscle strength, biomechanical functional moments and health-related quality of life in non-elite older adults. *Age and Aging, 41*(2), 224-230.

Satariano, W. A., Delorenze, G. N., Reed, D., & Schneider, E. L. (1996). Imbalance in an older population: An epidemiological analysis. *Journal of Aging and Health, 8*(3),334-358.

Segun, R. & Nelson, M. E. (2003).The benefits of strength training for older adults. *American Journal of Preventative Medicine, 25*(3), 141-149.

Schmitz, R., & Arnold, B. (1998).Intertester and intratester reliability of a dynamic balance protocol using the Biodex Stability System. *Journal of Sport Rehabilitation, 7,* 95-101.

Shumway-Cook, A., Brauer, S., & Woollacott, M. (2000). Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go Test. *Journal of the American Physical Therapy Association, 80*(9), 896-903.

Shumway-Cook, A., Woolacott, M., Kerns, K. A., & Baldwin, M. (1997).The effects of two types of cognitive tasks on postural stability in older adults with and without a history of falls. *The Journals of Gerontology, 52*(4), 232-240.

Skelton, D. A., Grieg, C. A., Davies, J. M., & Young, A. (1994). Strength, power, and related functional ability of healthy people aged 65-89 years. *Journal of Age and Aging*, *23*(5), 371-377.

Sturnieks, D. L., George, R., & S. R. Lord. (2009). Balance disorders in the elderly. *Clinical Neurophysiology, 38*(6), 467-478.

Tinetti, M. E., & Speechly, M. (1989).Prevention of falls among the elderly. *The New England Journal of Medicine, 320*, 1055-1059.

Van Swearingen, J. M., & Brach, J. S. (2001).Making geriatric assessment work: Selecting useful measures. *Journal of the American Physical Therapy Association, 81*(6), 1233-1252.

Vellas, B. J., Wayne, S. J., Romero, L., Baumgartner, R. N., Rubenstein, L. Z., & Garry, P. J. (1997). One-leg balance is an important predictor of injurious falls in older persons. *Journal of the American Geriatrics Society*, *45*(6), 735.

Volpatol, S., Cavalieril, M., Sioulisl, F., Guerra, G., Maraldi, C., Zuliani, G., … Guralnik, J. M. (2010).Predictive value of the Short Physical Performance Battery following hospitalization in older patients. *The Journals of Gerontology, 66A*, 1.89-96.

Whitney, S. L., Wrisley, D. M., Marchetti, G. F., Gee, M. A., Redfern, M. S., & Furman, J. M. (2005). Clinical measurement of sit-to-stand performance in people with balance disorders: Validity of data for the Five-Times-Sit-to-Stand Test. *Physical Therapy, 85*(10), 1034-1045.

Wing Chu, L., Chiu, A. Y., & Chi, I. (2006).Impact of falls on the balance, gait, and activities of daily living functioning and community-dwelling Chinese older adults. *The Journals of Gerontology, 61*(4), 399-404.

Woicik, L. A., Thelen, D. G., & Schultz, A. B. (2001). Age and gender differences in peak lower extremity joint torques and ranges of motion used during single-step balance recovery from a forward fall. *Journal of Biomechanics, 34*(1), 67-73.

Wolfson, L., Whipple, R., Derby, C., Judge, J., King, M., Amerman, P., … & Smyers, D. (1996). Balance and strength training in older adults: Intervention gains and Tai Chi maintenance. *Journal of the American Geriatrics Society, 44*(5), 498-506.

Wu, G. (2002). Evaluation of the effectiveness of tai chi for improving balance and preventing falls in the older population—A review. *Journal of the American Geriatric Society, 50*(4), 746-754.

# Appendix

UNIVERSITY OF ARKANSAS

*Office of Research Compliance*
*Institutional Review Board*

February 14, 2013

MEMORANDUM

| | |
|---|---|
| TO: | Joseph Chaney<br>Michelle Gray |
| FROM: | Ro Windwalker<br>IRB Coordinator |
| RE: | New Protocol Approval |
| IRB Protocol #: | 13-02-461 |
| Protocol Title: | *The Relationship between Various Factors that Contribute to Balance in Geriatric Populations* |
| Review Type: | ☐ EXEMPT ☐ EXPEDITED ☒ FULL IRB |
| Approved Project Period: | Start Date: 02/14/2013 Expiration Date: 02/07/2014 |

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

**This protocol has been approved for 40 participants.** If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

The IRB determined and documented that the risk is no greater than minimal and this protocol may be reviewed under expedited review procedure for future continuing reviews.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or irb@uark.edu.

210 Administration Building • 1 University of Arkansas • Fayetteville, AR 72701
Voice (479) 575-2208 • Fax (479) 575-3846 • Email irb@uark.edu