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Balance and Power in Older Adults With and Without a History of Falls

Stephanie Michelle Gray
University of Arkansas, Fayetteville

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Dr. R. Michelle Gray
Thesis Director

Dr. Matthew Ganio
Committee Member

Dr. Inza Fort
Committee Member

Abstract

The purpose of this study was to observe the differences between power and balance in older adults over the age of 65 with and without falls. A total of 62 community dwelling older adults between the ages of 65 and 92 participated in the study. Two groups consisted of 25 fallers and 37 non-fallers. No statistical differences were found between groups on age, height, weight, or BMI. Testing included the Berg Balance Scale (BBS) to test balance, the Tendo Weightlifting Analyzer (TWA) during a sit-to-stand to test lower body power, and the Physical Activity Scale for the Elderly (PASE) to assess physical activity. Results demonstrate the fallers had significantly lower balance (50.4 ± 6.2; $p = .02$) and average power (325.5 ± 114.3 watts; $p = .01$) when compared to the non-fallers (53.5 ± 3.1; $p = .02$, 420.6 ± 154.9 watts; $p = .01$). Physical activity was significantly correlated to balance ($r = .33$; $p = .01$). Lastly, power and balance were found to be significantly correlated ($r = .43$; $p = .001$). Overall, this study shows fallers have significantly lower power and balance compared to age matched non-fallers. The study also demonstrates balance and power, when measuring power in a way that is associated with activities of daily living, are strongly correlated.

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I. Introduction

The number of older adults is rising rapidly. From the year 2011 and 18 years thereafter, the baby boomer generation will be turning 65 at a rate of 8,000 per day (American Association of Retired People). Americans are living longer than ever. It is predicted by 2030 one in every five Americans will be 65 years or older which results in about 72 million people (National Center for Chronic Disease Prevention and Health Promotion, 2013). With this number on the rise, researchers continue to explore the key to successful aging and increased quality of life. The Consumer Product Safety Commission reported adults over the age of 65 costs the United States over 100 billion dollars every year due to fall-related injuries and deaths (Rutherford, March, & Mills, 2002). Falls are the leading cause of injury-related death in older adults (U.S. Department of Health and Human Services, 2013). Tinetti and Williams (1998) reported the occurrence of annual falls to be 20-30% in individuals over 65 and increasing to 40% in the 75 years and over population. In addition to the increase in risk for falls, older adults also have a greater fear of falling which causes diminished activity (Whipple et al., 1987). Many of these falls are due to a decline in balance seen with age. Obtaining the most effective method for improving balance in the older population is necessary to decrease the number of falls that occur each year.

The aging process is inevitable. Numerous biological changes occur with age including changes in the nervous system, cardiovascular system, muscular strength, muscular power, and body composition (Busse, Maddox, & Buckley, 1985). Among these changes, strength, power, and balance play a key role in maintaining independence in older adults. Limitations in basic mobility tasks such as walking or rising from a chair affect 1 in 4 older adults as well as predicts institutionalization, mortality, and disability (Kramarow, Lenitzner, Rooks, Weeks, & Saydah, 1999; Center for Disease Control and Prevention, 2003). Researchers have established deficits such as muscular isometric and isokinetic strength declining with age are more prominent in the lower extremities in both animals and humans (Aniansson, Sperling, Rundgren, & Lehnberg, 1983). Any functional activity requires force and power generated by the muscles in order for the activity to occur, specifically muscles of the lower extremity (Perry et al., 2007). For example, the ability to climb/descend stairs, standing from a chair, or any unforeseen demands such as hills and uneven surfaces requires strength, power, and balance of the lower extremities. Specifically, performance of dual task situations requires an increased demand for the regulation of balance (Muehlbauer, Besemer, Wehrle, Gollhofer, & Granacher, 2012). Higher levels of postural sway and greater stride-to-stride variability were found while performing a dual task of a 10-meter walk while counting backwards compared to a single task of only walking (Granacher et al., 2011). In accordance with dual tasking, Olsson, Nyberg, and Gustafson (1997), detected that older subjects who stopped walking when talking had significantly increased risk of sustaining a fall within the next 6 months compared to those who continued walking while talking. These results suggest an increase in strength, power, and balance can play a role in improving functionality of the older population.

Living a resilient, disease-free and high functionality state as an individual grows older is considered successful aging (Rowe & Kahn, 1997). Physical activity is known to slow many age-related changes, reduce the onset of multiple diseases and increase longevity (Jacobson, Smith, Fronterhouse, Kline, & Boolani, 2012). Bortz, (1982) suggests a great deal of the functional decline with aging is associated to the lack of regular physical activity and can even be reversed with regular physical activity. Cress et al. (1999) observed the effects of exercise on function in older adults. Participants who participated in exercise had significantly higher

Continuous Scale Physical Functional Performance scores (14%, effect size 0.80) compared to the participants who did not exercise. It is imperative to find the most effective exercise intervention to improve and maintain functional performance of the older population.

Power, defined as the product of force and velocity, differs from strength, which is the ability to generate maximal muscle force in that power takes into account velocity (Bean et al., 2004). Recent studies have found that older adults retain 50% of strength while only retaining 25% of power (Henwood, Rick, & Taaffe, 2008). The measurement of power is beginning to describe more of the discrepancy in mobility function in the older population more so than the past strength measurements. Research has demonstrated muscle power and contraction velocity to have a greater impact on functional performance than muscle strength. Bean et al., (2003) found lack of muscle power to be associated with a 2-to-3 fold greater risk for developing mobility problems in comparison to lack of muscle strength. This is partly be due to the fact that activities of daily living involve the movement of constant loads through a range of motion at variable velocities rather than movement of loads at fixed velocities (McNeil, Vandervoort, & Rice, 2007). There are many methods of power measurement in the older population including pneumatic resistance training equipment, Nottingham Power Rig, or vertical jump on a force platform. More recently, researchers have been exploring the Tendo Weightlifting Analyzer (TWA) for measurements of power. Little research has been done on the TWA and this study is unique in that it will be utilizing the TWA. The literature review will go into further detail on these measurements of power.

Annually, one in three adults over the age of 65 experience a fall (The State of Aging and Health in America, 2013). Defined by Shumway-Cook and Woollacott (2002), postural control is the control of the body's position in space for the purpose of balance and orientation. Declines in balance performance have been seen as early as age 30 which becomes more pronounced after the age of 60 (Era et al., 2006). These declines in balance lead to increased risk of falling as well as increased fear to carry on with normal life. An individual's capability of balancing is coordinated by the complex interaction of various physiologic subsystems (Mayson, Kiely, LaRose, & Bean, 2008). Signals sent to the central nervous system such as visual, vestibular, and somatosensory can adjust body sway and posture by controlling skeletal muscles. Impairments of any component of the postural control system can lead to a decrease in balance (Kaufmann, 1990). The first and most important event in the stabilization of posture is activation of long-loop reflexes at the ankle (Cordo & Nashner, 1982). An increased reliance occurs with age for the ankle to help provide balance and stability (Woollacott, Shumway-Cook, & Nashner, 1986). A combination of the age-related loss of the ability to produce muscle tension along with the diminished sensorimotor conduction can cause significant delays of the adaptive long-loop reflexes of the ankle in response to a balance perturbation (Clarkson, Kroll, & Melchionda, 1981; Sabin, 1982).

Maintaining balance with age not only relies on the central nervous system but on the force of the muscles involved. Daubney and Culham (1999) found the ankle dorsi-flexors to be the best predictor of fall status. Of the 12 muscle groups tested, the ankle dorsi-flexors were the only muscle group predictive of scores on the balance assessments carried out such as the Functional Reach Test (FRT), Berg Balance Scale (BBS), and the Timed Up and Go Test (TUG). Upon providing proprioceptive information, the ankle muscles correct for postural sway by controlling the force put upon the ankle therefore, regulating the body's center of gravity (Kuo & Zajac, 1993; Winter, Patla, & Frank, 1990).

Therefore, discovery of associations between power and balance of the lower extremity could provide some rationale for assessing fall risk and developing fall prevention and rehabilitation programs for the older population (Thomas et al., 2012). This literature review will go into detail on the effects of aging on balance and power and how increased balance and power can reduce the risk of falls in the older population.

A. Purpose of the Study

The purpose of this study was to observe the difference between balance and power in older adults over the age of 65 with and without a history of falls.

B. Research Hypotheses

1) Older adults without a history of falls will have significantly greater power than those with a history of falls.

2) Older adults without a history of falls will have significantly greater balance compared to those with a history of falls.

3) Physical activity level will be significantly correlated to balance and power.

4) Power and balance will be significantly correlated.

C. Limitations

1) There is little information on use of the Tendo Weighlifting Analyzer as a measure of power in older adults.

2) The study sample was limited to two community-centers; which may make the study less generalizable to all community-dwelling older adults.

3) There is not control of exercise before the testing, therefore individuals could be fatigued which may skew the results. However, participants were allowed to rest throughout the test as needed.

4) There are limitations within the Berg Balance Scale as an assistive device cannot be used during the test which may not allow for accurate results for individuals who normally use an assistive device for functional balance.

5) It is possible that identifying fallers through self-report may have missed some individuals who either forgot or would not admit to have had a fall in the last year.

6) The PASE questionnaire is a physical activity assessment of the previous seven days. It is possible the participant did more or less physical activity than normal in the seven days prior to testing, which may give an inaccurate measure of physical activity.

D. Functional Definitions

In order to make clear of specific terminology, consider the following definitions:

1) Tendo Weightlifting Analyzer (TWA) - Measurement of power during a sit-to-stand motion. Average velocity and average power are determined for each sit-to-stand repetition based on body weight in kilograms (Thompson et al., 2010).

2) Berg Balance Scale - Measurement of balance impairments in the older population. The scale includes 14 common functional activities of which each are scored 0 to 4, where 0 indicates an inability to perform the task and 4 indicates the task was performed independently and correctly (Berg, Wood-Dauphinee, Williams, & Maki 1989).

3) Fallers - Considered to have had one or more fall in the previous 12 months with a fall being where part of the body inadvertently met the ground or some lower object.

4) Non-fallers - No fall within the previous 12 months.

5) Older adults - Adults aged 65 years and older.

6) Bioelectrical Impedance Analysis - Allows the measurement of fat free mass and total body

weight in subjects without significant electrolyte and fluid abnormalities. A single frequency is passed between surface electrodes to measure a weighted sum of extra-cellular water and intra-cellular water resistivities (Kyle et al., 2004).

7) Muscular power - The product of force production and the velocity at which the force is produced (Kraemer & Newton, 2000).

8) Physical Activity Scale for the Elderly (PASE) - An activity questionnaire that includes 11 questions on leisure time, household, and work-related activities (Harada, Chiu, King, & Stewart, 2001).

E. Significance of Study

There are 40.4 million adults ages 65 years and older in the United States alone. This number is predicted to increase 36% by 2020 (US Department of Health and Human Services, Administration of Aging, 2011). With this population on the rise, it is critical to understand the most efficient way of staying healthy and active in order to maintain functionality and decrease health care costs. Falls are the leading cause of death among older adults (U.S. Department of Health and Human Services, 2013). Many falls that occur are unexplained and a better understanding of the underlying mechanisms could improve fall prevention. Observing how power and balance correlate in the older population can provide insight to what training interventions are best for fall prevention.

II. Literature Review

A. Introduction

With the baby boomer population increasing at an alarming rate, reducing the number of falls and increasing the ability to perform activities of daily living is crucial. Performance of daily tasks such as climbing a flight of stairs, lifting a grandchild, rising from a chair, or ambulating from place to place demand the use and coordination of muscle power, strength and balance. Research has shown that with age, reductions in muscle power, strength, and balance are inevitable (Miszko et al., 2003). In order to reduce the number of falls and increase functionality of the older population it is necessary to understand the physiological processes that cause declines in power and balance (Reid & Fielding, 2012). First, the review will discuss power and the association to age-related physiological changes, relationship to functional performance, and how power relates to falls. Second, the review will concentrate on balance age-related physiological changes, balance effects on fall rate, and different balance assessments. Last, the relationship between balance and power will be discussed.

B. Power

Researchers are beginning to find the detriment caused by the decline of power with age. Skeletal muscle power which is the product of force and velocity has been shown to decline sooner and more rapidly than muscle strength with age. McNeil et al., (2007) reported significant age-related decreases in explosive force production capacity surpass the decreases seen in maximal strength by two to three times. Strength was found to be relatively well maintained, leaving the lack of velocity production to be responsible for the decrease of power generation. A 25% decrease in power of the dorsi-flexors between the third and seventh decade of life was observed. The reduction doubled in the next two decades leaving individuals in the ninth decade of life to have 60% less power than young men.

i. Age-Related Physiological Changes

Many physiological factors contribute to the age-related reduction in muscle power. Factors such as declines in muscle mass, change in muscle composition, muscle quality, muscle fiber contractile properties and change in neuromuscular function effect the ability to produce power (Aagaard, Suetta, Caserotti, Magnusson, & Kjaer, 2010; Evans & Lexell, 1995). Evans and Lexell (1995) studied the age-related loss of muscle mass and the mechanisms behind aging atrophy. There is a reduction in the number and size of type II muscle fibers with age. Type II muscle fibers are able to generate four times the power output of type I muscle fibers. The loss of type II muscle fibers that occur is consistent with the greater percentage loss of power and speed that is seen with age (Bassey et al., 1992). To further solidify evidence on type II fiber atrophy upon older adults, specifically fallers, Aniansson, Zetterberg, Hedberg, and Henriksson, (1984) biopsied the quadriceps of 52 patients undergoing hip surgery due to fall-related fractures. Results confirmed a disproportionately greater increase in type II fiber atrophy in the fracture patients compared to the control group of a comparable age. Alway and Sui, (2011) speculate the loss of type II muscle fibres is due to nuclear apoptosis and a disruption in neural input. The loss of fast motoneurons causes type II fibers to be denervated, thus there is an increase in slow motor units (Roos, Rice, & Vandervoort, 1997). Reid and Fielding (2011) assessed physiological mechanisms that contribute to power deficits in three populations including healthy middle-aged adults (47 years old), healthy older adults (74 years old), and older adults with mobility limitations (78 years old). Mobility-limited elders had 65% less power in the lower extremities as well as 25% less muscle mass when compared to the healthy older adults. No significant differences in muscle strength were found when muscle strength and muscle power were normalized to muscle cross-sectional area. These results infer that impairments in muscular power seen in mobility-limited older adults compared to healthy older adults are related to the muscle atrophy that occurs with age. Neuromuscular activation, which is defined as the product of muscular force through recruitment and rate-coding of motor units produced by the nervous system affects the power that is able to be produced. Decreases in neuromuscular activation may impact movement velocity and muscle coordination in the older population (Clark et al., 2010; Clark et al., 2011). Clark et al. (2010) observed the relationship between the neuromuscular system and muscle power generation of older adults with mobility limitations, healthy middle-aged adults, and healthy older adults. Mobility-limited older adults showed significant impairments in torque, power, and agonist muscle activation with the largest shortages elicited at the fastest movement velocities when observing the quadriceps and hamstrings musculature during maximal isokinetic dynamometry testing. It was also demonstrated that the mobility-limited older adults had an impaired rate of neuromuscular activity as well as decreased acceleration during dynamic leg extensions when compared to the healthy middle-aged adults and healthy older adults. Similarly, Macaluso et al. (2002) found marked reductions in maximum isometric torque of the knee extensors and flexors in older adults compared to younger adults. Specific tension was significantly lower in the extensors in the older adults compared to the younger adults (93.1 ± 20.1 kN [kilonewton] · m(-2) vs. 112.1 ± 12.3 kN · m(-2), $p < .05$) and in the flexors (100 ± 31 kN · m(-2) vs. 142.7 ± 23.9 kN · m(-2), $p < .01$). These declines were in correspondence with higher levels of antagonist co-activation during knee extension. The decrease of central drive, which is the central nervous system control to the agonist muscle, is associated with smaller number of recruited motor units, decreased firing rate of motor units, as well as impaired motor unit synchronization. The differences of high velocity training, normal strength training, and a non-training group in older adults were observed. An increase in force production and power was seen in the strength training group along with a decrease in movement velocity. On the other hand, the high velocity group significantly increased movement velocity ($p < .05$) (Henwood et al., 2008). High velocity movements such as power training can improve motor-unit firing rate, synchronization of discharge, and levels of muscle activation (Hakkinen, Komi, & Alen, 1985; Sale, 1988). Power training compared to strength training may be the difference in improving functionality in the older population due to the improvement seen in the velocity component.

ii. Relationship of Power to Functional Performance

Due to the physiological changes of aging, power has been shown to be related to functional performance in the elderly. Bean et al. (2003) reported older adults with low muscle power output to have a 2-to-3-fold increased risk of developing functional impairments compared to individuals with low muscle strength. Community-dwelling mobility-limited older adults were observed for the influence of leg power and leg strength on physical performance (Bean et al., 2002). Leg power accounted for 2-8% more of the variance on all measures of physical performance, which included stair-climb time, chair-stand time, tandem gait, habitual gait (walking at a normal comfortable pace), maximal gait (walking as fast as possible), and the Short Physical Performance Battery (SPPB). Bean et al., (2004) carried out an intervention of increased velocity exercise specific to task (InVEST). The program used weighted vests for resistance while performing exercises specific to mobility tasks at the fastest velocity possible. Upon estimating mortality and disability, evidence explains the improvement in the SPPB (2.7 ± 1.2; $p < .0001$) corresponds to a 33% reduction in the probability of death over four years and a 50% reduction in the probability of developing an activity of daily living disability. Bassey et al.

(1992) found leg extensor peak power in frail, institutionalized elders to contribute to chair rise performance, stair climbing, and gait speed. Similarly, Foldvari et al. (2000) studied the relationships between muscle power and strength to functional dependence in 80 elderly community-dwelling women with self-reported disability. Peak muscle power ($r = .47$) was higher than muscle strength ($r = .43$) and aerobic capacity ($r = .40$) in relation to predicting functional status. In comparison to muscle strength, contraction velocity of the leg extensors was associated with gait speed ($p < 0.001$) and the SPPB ($p < 0.02$) in a study on 101 men and women ages 75-90 (Sayers, Guralnik, Thombs, & Fielding, 2005). Similar to previously discussed studies, Miszko et al. (2003) observed the effect of strength training to power training on physical function in the community-dwelling population. In order to measure improvement of physical function, the Continuous Scale Physical Functional Performance test was administered. The power training group was more effective than the strength training group ($p = .033$) with less total work performed than the strength training group. The effect of muscle power-specific training in community-dwelling older adults compared to a non-exercise group was examined. Participants trained twice weekly for 24 weeks. The intervention involved six exercises which were the chest press, supported row, biceps curl, leg press, prone leg curl, and leg extension. The muscle power-specific group performed significantly better than controls at week 8 ($p = .004$; $p < .05$) for the stair climb task and repeated chair rise task (Henwood et al., 2008). Similarly, researchers Bottaro, Machado, Nogueira, Sclaes, and Veloso, (2007) found 10 weeks of high velocity resistance training in sedentary older males to significantly improve functional performance measures after slight improvements in muscle power performance ($p < 0.05$). The power training group improved in the 30-second chair stand test by 43% while the traditional resistance training group only improved 6%. A study conducted by Puthoff and

Nielsen (2007) found lower extremity power to be related to every measure of functional limitation that was assessed as well as to explain the variance found in the functional limitations more so than strength (R^2= .26 to .48). Functional evaluations included the SPPB, the Six-Minute Walk Test (SMWT), and the Late Life Function and Disability Instrument (LLFDI). In addition, Beat et al., (2002) also observed the influence of leg power on functional performance. Leg power was significantly associated with all measures of functional performance and explained between 12% and 45% of the variance (R^2). This literature is highly suggestive that power is related to the functional ability of the older population.

iii. Relationship of Power to Falls

It has been suggested that leg power is important in correcting a perturbation or movement error (Skelton, Kennedy, & Rutherford, 2002). In order to prevent a fall, individuals must have adequate lower limb power in the stabilizing leg in order to counteract the kinetic energy of the unbalanced leg. When a threat to balance occurs, such as a narrowed base of support, perturbation, or loss of vision, a rapid response is needed in order to maintain postural stability. Skelton et al. (2002) observed lower extremity muscle power in fallers compared to non-fallers, ages 65 and older. Results indicate the individuals with a history of falls are 24% less powerful for his or her weight than individuals who did not fall (p = 0.04). The fallers were shown to be less active than non-fallers but were not significantly weaker in any of the strength measurements. Likewise, Whipple et al. (1987) observed the relationship of power in fallers and non-fallers. Peak torque (PT) of non-fallers (= 20.6 newton-meters) was twice the peak torque of fallers (= 10.2 newton-meters). There was also a greater difference in peak torque and power (POW) between the ankle and knee in the fallers (= 15.1 newton-meters, p < .001; = 18.3 newton-meter · radians/second, p < .000). Non-fallers demonstrated ankle torque that was 24.1%

of knee strength, where as the fallers only demonstrated 12% of ankle torque to knee strength. Results confirmed dorsi-flexion power production in the fallers to be 7.5 times less than the non-fallers. The dorsi-flexors are critical to the gait cycle and a decrease in performance has been associated with an increased risk of falls (Kemoun, Thoumie, Boisson, & Guieu, 2002). Strength, power output, and symmetry of leg muscles and the effect of age and history of falling were observed (Perry et al., 2007). When comparing young adults to older fallers and non-fallers, power was significantly higher in the young subjects (269.5 ± 22.6 W) than in the non-fallers (150.7 ± 9.6 W) and fallers (120.3 ± 13.1 W, $P < 0.0001$). Fallers demonstrated 85% of the force of the non-fallers, but only 79% of the power. The relationship of balance to muscle power in healthy older adults was determined (Orr et al., 2004). Results documented muscle power to be significantly lower in fallers than non-fallers ($p = 0.038$). Numerous studies have found power to be associated with functional performance and falls in the elderly.

iv. Power Measurement

Sensitive to age-related losses, power is a more relevant measure than strength in the older population. As power is related to functional performance, it is important to measure power in a way that is most associated with activities of daily living. Due to expense and the need for large sophisticated and immobile equipment, muscle power measurement is rarely used in clinical settings. Lower extremity muscle power measurement can be challenging to assess in individuals with advanced joint problems of the hip or knee or severe mobility problems (Herman et al., 2005). Some options generally used to assess power are pneumatic resistance training equipment, Nottingham Power Rig, vertical jump on a force platform, isokinetic dynamometry, or more recently, the Tendo Weightlifting Analyzer (TWA). Pneumatic resistance training assesses power through a double leg press machine. The seat is adjusted to align the hips and knees in the desired position. Puthoff and Nielsen, (2007) utilized this measurement of power by taking measurements at 40%, 50%, 60%, 70%, 80%, and 90% of measured 1-repetition maximum. This method assesses power across a range of intensities with peak power being the highest power output regardless of the external load at which it was achieved. The pneumatic resistance measurement has demonstrated high reliability and validity for the assessment of lower extremity muscle power in older adults (Bean et al., 2002; Thomas, Fiatarone, & Fielding, 1996; Earles, Judge, & Gunnarsson, 2001). The Nottingham Power Rig [University of Nottingham Mechanical Engineering Unit, UK] is used to assess lower body power. Bassey and Short (1990) determined the Nottingham Power Rig to be the "gold standard," to measure power (Lindemann et al., 2003). Average leg extensor power is calculated from the angular velocity and inertia of a flywheel. Participants are asked to unilaterally depress a foot lever which includes hip and knee extension and ankle plantar-flexion. Although the Nottingham Power Rig is considered the "gold standard" it is expensive and is not able to be taken into the field. The vertical jump assessment of power overcomes the problem of resistance and its adaption to body weight because body weight is included in the measurement. For the older population, the vertical jump is not recommended due to issues of joint stiffness and mobility (Wang, 2008). Isokinetic dynamometry, specifically the Biodex, is an electrically controlled mechanism used in clinical and research settings to measure torque and angular velocity (Drouin, Valovich-McLeod, Shultz, Gansneder, and perrin, 1986). Drouin et al. (1986) found the Biodex to be reliable and valid in determining isometric torque, position, and velocity. The disadvantage of using the Biodex to assess power is the expense of the equipment and the lack of mobility for field testing. Lindemann et al. (2003) measured power during a sit-to-stand transfer. Power was calculated from the vertical ground reaction force of body weight, the difference between height in a sitting and upright position, and the time taken to stand up. The advantage of measuring power of a sit-to-stand transfer is that it is a lower extremity movement that is performed during activities of daily living. In accordance with the Nottingham Power Rig, measurement of power during the rising phase transfer showed good correlation to the isokinetic force and to measurement of power. On the other hand, compared to the Nottingham Power Rig, the sit-to-stand transfer method of power automatically adjusts for body weight because the individual has to lift his or her weight during the movement. This method of measuring power is portable as well as inexpensive. In relation to the sit-to-stand transfer method, the TWA is also able to measure power during a sit-to-stand motion. Power training has been a recent research interest for the older population but little research has been published using the TWA as a measurement of power. In contrast to the sit-to-stand transfer method, the TWA can measure maximal power in multiple joints (Thompson et al., 2010).

C. Balance

Age-related decreases in balance heavily contribute to the increase risk of falling in the older population. Fernie, Gryfe, Holliday, and Llewellyn, (1982) observed individuals over the age of 63 and found participants who fell one or more times in a year had significantly greater postural sway compared to participants who did not fall. Evidence has shown postural sway to be the largest in young children and the older population when measured on a force platform (Hytonen, Pyykko, Aalto, & Starck, 1993). Posture control can be explained as the body's position in space for the purpose of balance and orientation (Shumway-Cook & Woollacott, 2001). Era et al. (2006) found the postural control mechanisms begin to decline at an early age. Balance deficits were apparent between the young (30-39 year olds), middle aged adults (40-49 year olds), and were even more obvious in individuals over the age of 60. Age-related declines in postural control were researched by Lin and Woollacott, (2002). When older adults (mean age 76 years) were compared to younger adults (mean age 25 years) individuals demonstrated slower onset latencies, smaller magnitudes of postural responses, and longer maintenance of postural muscle activation. These changes with age contribute to the age-related loss of balance. Similarly, Tang and Woollacott (1998) observed postural responses to an unexpected forward slip during walking. Older adults presented longer onset latencies, smaller magnitudes, and longer burst durations compared to the young adults. The control of balance demands complex processing and integration of sensory information of which is provided by vision and proprioception, and the vestibular system on a spinal level (Lephart & Fu, 2000). It is important to explore how balance is affected by the physiological changes with age and other variables in order for a change to be made.

i. Age-Related Physiological Changes

Successful proprioception involves different articular, muscular, and cutaneous mechanoreceptors, including muscle spindles, golgi tendon organs, pacinian corpuscles, and free nerve endings (Lephart & Fu, 2000). Older adults have slower onset latencies, smaller magnitudes of postural responses, and longer maintenance of postural muscle activation when responding to a perturbation. It is speculated that the prolonged muscle activation may be a compensatory mechanism to maintain postural stability. Data presented stable older adults (mean age = 73) in response to platform perturbations to not have prolonged muscle activation such as the unstable older adults (mean age = 76) (Lin and Woollacott, 2002). As previously discussed, Tang and Woollacott (1998) also found the active older adults (mean age = 74) had longer onset latencies, smaller magnitudes, and longer burst durations compared to the young adults in response to unexpected forward slips while walking.

As individuals age, morphological changes to the muscle spindles such as increased spindle capsule thickness, and loss of intrafusal and muscular chain fibers occur (Liu, Eriksson, Thornell, & Pedrosa-Domellof, 2005). Muscle spindles contribute to human posture regulation; therefore deterioration of these spindles can affect an individual's balance (Kavounoudias, Gilhodes, Roll, & Roll, 1999). Due to the morphological changes of muscle spindles with aging, afferent input which involves the peripheral nerves that transmit signals to the spinal cord and brain to carry out sensory function is decreased. A decrease in afferent input can affect the control of the muscle length and velocity of contraction. In order to take action quickly to a balance threat, an individual will need adequate muscle length and contraction velocity. In regard to aging effects on golgi tendon organs and the articular receptors, Morisawa (1998) studied the total number of pacinian corpuscles, ruffini receptors, golgi tendon organ receptors, and free nerve endings. It was found that these all decrease with age. Articular receptors are responsible for feedback mechanisms controlling joint movements. With a decrease in the number of articular receptors available, feedback mechanisms are impaired, therefore affecting balance. As a result of aging, the ability to initiate and coordinate rapid effective movements which is integrated in the frontal cortex, basal ganglia, and cerebellum have been shown to be inefficient. These sites are responsible for both gait and balance motor deficits (Sabin, 1982; Wolfson & Katzman, 1983; Sudarsky & Ronthal, 1983; Teravainen & Calne, 1983). Age-related deteriorations contribute to an increasing loss of balance in the older population.

ii. Balance Effects on Fall Rate

Loss of balance due to factors previously mentioned, such as aging effects on the proprioception system, contributes to the increasing fall rate among older adults. Orr et al. (2004) observed relationships of balance to muscle power in older adults. Age contributed 5 to

13% of the variance in dynamic and static balance performance (10 of 15 measures; $p = 0.00$-0.05). Results identified individuals with a fall history to have a lower dynamic balance score ($p = 0.00$-0.05) compared to those without a fall history. The determining factor to whether or not a balance perturbation leads to a fall is the ability or inability to recover balance (Maki & McIlroy, 2006). Unproductive balance strategies put older individuals at a higher risk for falling compared to young adults. Studies have found that older adults tend to initiate stepping at lower levels of instability during an anteroposterior perturbation compared to young adults (Jensen, Brown & Woollacott, 2001; Mille et al., 2003). Not only do older adults initiate the stepping reaction sooner but also have difficulty in executing an effective stepping reaction in that multiple steps are normally taken to recover a perturbation (Wolfson, Whipple, Amerman, & Kleinberg, 1986; Luchies, Alexander, Schultz, & Ashton-Miller, 1994; McIlroy & Maki, 1996). It was found that over 30% of the initial forward or backward stepping reactions in older adults were carried out in order to recover stability (McIlroy & Maki, 1996). Younger adults tend to show a stepping pattern involving a large crossover step in order to recover a perturbation which involves having accurate control of the foot trajectory while older adults often choose a less demanding response of which involves a small medial step. The stepping pattern of older adults to recover from a perturbation is often less effective than that of younger adults which leads to increased risk for falls (Maki, Edmonstone, & McIlroy, 2000). Compared to the young, older adults were more likely to initiate arm movement and grasp safety rails for support. The speed at which these reactions occurred were slower than the young. Researchers have found the ankle muscles to be critical in fall rate (Maki et al., 2000; McIlroy & Maki, 1996; Maki et al., 2001). Studenski, Duncan, and Chandler (1991) reported 10 adults over the age of 60 who had unexplained falls to have weakness of the ankle dorsi-flexors and plantar-flexors compared to the control group of 24 non-fallers. Specifically among those who fell, the tibialis anterior muscle demonstrated prolonged response latency to anterior platform perturbation. On a positive note, balance training has shown to decrease onset latency and enhance reflex activity ($p < .004$) in the prime mover which compensates for the decelerating perturbation impulse (Granacher, Gollhofer, & Strass, 2006).

iii. Balance Assessment

Balance is a complex measurement of which no single comprehensive measure is accessible that tests all aspects of the postural control system. A valid and reliable measure is needed in order to effectively evaluate balance impairment and fall risk. Commonly used tools such as the Berg Balance Scale (BBS), Functional Reach Test (FRT), and the Timed Get Up & Go Test (GUG) measure output of the postural control system. The GUG is a quick measure of basic balance and mobility skill in the elderly. Subjects are asked to rise from a chair, walk 3 meters, turn, and return to the chair while time is measured in seconds (Podsiadlo, & Richardson, 1991; Mathias, Nayak, & Isaacs, 1986). The FRT is designed to measure the limits of stability. Subjects reach forward horizontally as far as possible while maintaining a fixed base of support (Duncan, Weiner, Chandler, & Studenski, 1990). The distance reached is measured. The BBS is developed to measure balance impairments in the elderly as well as individuals with neurological disorders. This test was the measurement of balance for this particular study because it most mimics common activities of daily living and has shown to be associated with fall risk (Shumway-Cook, Baldwin, Polissar, & Gruber, 1997). In relation to the velocity component of power, the BBS presented velocity to be consistently associated with better performance [odds ratio = 14.23 (CI = 1.84-109.72; $p = 0.01$)] (Mayson et al., 2008). The test consists of 14 common functional activities that are scored from a 0 to a 4. A score of 0 indicates an inability to perform the task where as a score of 4 indicates the task was performed independently and correctly. A previous study on 14 subjects aged 65 and over found intraclass correlation coefficients for inter-rater and intra-rater reliability to be r =.98 and r = .99 using the BBS (Berg et al., 1989). The ankle muscle is one of the main muscles involved in maintaining balance (Sorensen, Hollands, & Patla, 2002). Daubney and Culham (1999) examined lower-extremity muscle force and balance performance in older adults. Results revealed that of the 12 muscle groups tested, only the force of the ankle muscles was predictive of scores on balance tests. Results also indicated muscle force values of the ankle dorsi-flexor and subtalar evertor accounted for 58% of the score on the BBS. These results solidify the strength of the BBS to measure different variables that contribute to the maintenance of balance in the older population.

C. Relationship of Balance and Power

While strength has been determined to be an important role in functional performance of the older population, power has been shown to decrease earlier and more rapidly (Aagaard et al., 2010). Power is recently a popular research topic in regards to the elderly population and has shown to correlate to balance and functional performance measures. Mayson et al. (2008) found muscle contraction velocity to be essential in balance performance. Community- dwelling older adults with mobility limitations had higher leg press contraction (at 40% of 1RM) associated with better performance on composite measures of balance that are predictive of falling. Sayers, Bean, Cuoco, LeBrasseur, Jette, and Fielding, (2003) observed the effects of a 16-week, high velocity power training program three times a week in older women. Improvements were seen in dynamic balance (5%) and muscle power scores (97%). Similarly, Orr et al. (2006) carried out a high-velocity training program for 8 to 12 weeks. Data indicated power training at a low intensity (20% of 1RM) to be associated with the greatest improvements in balance performance

(10%). Miszko et al. (2003) found an increase of 21% in balance and coordination after upper and lower body resistance training at 50%-70% 1RM slow contraction velocity for the first 8 weeks, which changed to 40% 1RM for the remaining 8 weeks with the concentric phase being performed at maximum velocity. Bean et al. (2004) studied the effects of increased velocity exercise specific to a task (InVEST) to leg power, balance, and mobility in community-dwelling older women. Subjects wore a weighted vest for resistance while performing fast velocity mobility tasks such as stair climbing, chair stands, and toe raises. Enhancements seen in power corresponded with improvements in balance (InVEST 2.2 ± 2.7 seconds versus control 0.3 ± 5.7 seconds). In relation to the BBS, researchers Jacobson et al. (2012) found a significant improvement in BBS scores ($p < .05$) of 53 older adults after 12 weeks of power training. Participants in the experimental group trained the upper and lower extremities two times a week and increased scores by 33% from pre to post. In contrast to power training improving balance, Granacher, Gruber, Strass, and Gollhofer, (2007) found 12 weeks of balance training to improve maximal and explosive force production ($p < 0.01$) in 40 healthy, elderly men 60-80 years old. In response to a balance perturbation, the time available to recover is less than one second. This critical time period requires a quick, powerful response of the lower extremity to recover balance (Schultz, Ashton-Miller, & Alexander, 1997). It is often assumed that the need for an assisted walking device is due to inadequate balance; however, some researchers suggest it is due to inadequate muscles rather than a lack of balance mechanisms (Bassey et al., 1992). Bassey et al. (1992) found individuals who needed a walking device to have less than half the leg extensor power than those who could walk without any assistance. The age dependent variations of directional sensitivity of balance corrections were observed in three groups (24-34, 34-55, and 60-75 years old). An interaction of age and direction (laterally, forward, and backward) on early balance-correction torques in response to perturbations were observed between 160-260 ms ($p < 0.03$). Torque changes were smaller in amplitude for the elderly and as a result, affected the ability to correct balance (Allum, Carpenter, Honegger, Adkin, & Bloem, 2002). These results are suggestive that maintenance of leg extensor power can help maintain gait speed and improve the quality of life by reducing the prevalence of falls in the elderly population.

Older adults are a unique population and research of balance and power is crucial to maintaining independence. As seen in this literature review, balance and power significantly decline with age and affect one's functional ability, risk of falls, and independence with age. Among these declines, it is important to measure power in a way that mimics a functional task of an older adult such as a sit-to-stand motion. Performing the sit-to-stand motion poses a risk for losing balance and falling whereas measuring power through pneumatic resistance equipment does not. As previously mentioned, little research has been carried out on the TWA specifically during a sit-to-stand motion prior to the present investigation.

III. Methodology

The study was designed to determine the difference between balance and power in men and women over the age of 65 with and without a history of falls. The Physical Activity Scale for the Elderly (PASE) was administered in order to assess physical activity levels. Assessments including power, balance, body weight, height, and body fat percentage were determined. Lower body power was assessed through the TWA during three separate sit-to-stand tasks. Balance was obtained using the Berg Balance Scale which included 14 functional items to assess static and dynamic balance. Body fat percentage was assessed through the bioelectrical impedance analysis. Fall rate was assessed through the number of falls over the past 12 months. Fallers were considered as having one or more falls, where as non-fallers had no history of falls in the past year.

A. Participants and Recruitment

Participants were recruited from the Northwest Arkansas Adult Wellness Center in Rogers, Arkansas. Informational fliers were placed around the center in order to recruit participants. Participants were also recruited by word of mouth. A sign-up sheet was available for designated time slots, which asked for name, e-mail address, and phone number. Based on previous literature which examined power in fallers and non-fallers over the age of 65, a power of 80% sample size was configured to have 32 participants per group (fallers and non-fallers) (Skelton et al., 2002).

B. Screening and Informed Consent

Prior to participation, an informed consent approved by the University of Arkansas Institutional Review Board was read by the participant to inform the individual of all the assessments would be administered as well as the safety hazards associated with the study.

Individuals who signed the informed consent then completed a health history questionnaire which included questions on diagnosis of unstable or unmanaged diseases, neuromuscular or musculoskeletal diseases, age, and medications. The health screening was utilized for inclusion and exclusion criteria. The health screening also assessed fall status. Individuals who had fallen within the previous 12 months were considered a faller. A fall was defined as an event in which the outcome resulted in the individual coming to rest inadvertently on a lower object (Lajoie & Gallagher, 2004). Individuals that had not fallen within the past 12 months were considered a non-faller. Other studies who considered fallers as experiencing one or more falls within the previous 12 months reported a prevalence of 20-40% (Blake, Morgan, & Bendall, 1988; Tinetti, Speechley, & Ginter, 1988).

C. Testing

i. Mini Mental State Examination

Cognitive ability was assessed utilizing the Mini Mental State Examination (MMSE), which includes 11 questions that tests organization, registration, attention and calculation, recall, and language (Kurlowicz & Wallace, 1999). Due to the significant link between decreased cognition and the ability to perform and adapt to exercise, a score of 23 (out of 30) or lower on the MMSE resulted in exclusion of the study because it is indicative of cognitive impairment (Kramer, Erickson, and Colcombe, 2006).

ii. Demographic Measurements

Demographic measurements included body weight, height, and body fat percentage. Shoes and any extraneous weight were removed for the measurement of height (to the nearest 1.0 cm) and weight (to the nearest 0.1 kilogram) on a TANITA WB-3000 scale (Tokyo, Japan). Body fat percentage was assessed through the bioelectrical impedance analysis (BIA). The BIA determines the electrical impedance or opposition to the flow of an electric current through body tissues which can then be used to calculate an estimate of total body water which then can be used to estimate fat-free body mass, and body fat. Jackson, Pollock, Graves, and Mahar (1988), assessed the reliability and validity of the BIA. The BIA, skinfold fat, and hydrostatic methods in this study were all found to be reliable (r = .96-.99) with standard errors ranging from 0.9 to 1.5% fat. Ritchie, Miller, and Wright (2005) found the Tanita foot-to-foot BIA system to be valid in older adults. The BIA measurements were significantly correlated with waist circumference, body mass index, and age (p < .01).

iii. Physical Activity Assessment

Physical activity levels were assessed through the Physical Activity Scale for the Elderly (PASE). This questionnaire assesses participation in housework, home repairs, lawn work, caregiving, work, muscular exercise, endurance exercise, and leisure exercise. The PASE questionnaire has been specifically validated for the older population. Washburn, Smith, Jette, and Janney, (1993) found test-retest reliability over a 2-7 week interval to be .75 (95% CI = 0.69 – 0.80). PASE scores were also found to be positively associated with grip strength (r = .37), static balance (r = .33), and leg strength (r = .25).

iv. Power Measurement

Power was assessed through the TWA during three separate sit-to-stand motions. Specifically measuring power during the sit-to-stand motion mimics a functional task. The sit-to-stand task is part of the Senior Fitness Test and is a valid test used to measure lower body strength and endurance in the older population (Rikli & Jones, 1999). The TWA is a microcomputer system for measuring power and velocity. A strap is placed around the participant's waist of which is attached to the Tendo unit with a nylon cord. The Tendo unit is placed on the floor in a position that will allow the cord to be extended perpendicular to the floor during the sit-to-stand exercise. The average power and velocity during the concentric phase of the sit-to-stand was recorded for each repetition. The TWA has been reported to be reliable (intraclass correlation coefficient [ICC] = .97) for multiple joint maximal muscular power testing (Jennings, Vijoen, Durandt, & Lambert, 2005).

v. Balance Measurement

The Berg Balance Scale is used to assess balance of the older population. The test includes 14 static and dynamic activities related to everyday living. Each activity is scored between 0 and 4 with 0 indicating not able to complete the task and a 4 indicating independently able to complete the task. Tasks include sitting to standing, standing unsupported, sitting unsupported, standing to sitting, transfers, standing with eyes closed, standing with feet together, reaching forward with an outstretched arm, retrieving an object from the floor, turning to look behind, turning 360 degrees, placing an alternate foot on a stool, standing with one foot in front, and standing on one foot. A maximum score of 56 is considered perfect balance (Berg et al., 1989). Studies of various elderly populations (N = 31-101, 60-90 > years of age) have shown high intra-rater and inter-rater reliability (ICC = .98; Berg et al., 1989; Berg et al., 1992). Content validity for the BBS was determined by experts working in geriatric settings. Correlations between BBS scores and other functional measurements in a variety of older adults have been determined such as the Barthel Index (r = .67, N = 31), Timed Up & Go Test (r = -.76, N = 31), and the Tinetti balance subscale (r = .91, N = 31; Berg et al., 1992; Shumway-Cook, Gruber, Baldwin, & Liao, 1997; Bogle-Thorbahn & Newton, 1996; Liston & Brouwer, 1996; Berg et al., 1992).

E. Statistical Analysis

Statistical measures were used for analysis between groups. Data were analyzed using SPSS version 20. Group means + *sd* were reported for balance (BBS) and power (TWA). One-way ANOVA was used to determine any statistical significance between fallers and non-fallers for balance and power. A Pearson Product Moment Correlation was used to determine the relationship between physical activity, balance, and power. Statistical significance was set at $a < .05$ level.

IV. Results

The purpose of this study was to observe the difference between balance and power in older adults over the age of 65 with and without a history of falls. For each variable, the proper statistical comparisons and differences are presented. A statistical analysis was run to detect outliers. Outliers were detected in the analysis but test statistic results did not change when the data was analyzed with outliers set aside. Therefore, the outliers were retained for the analysis.

i. Demographics

A total of 62 community-dwelling older adults between the ages of 65 and 92 participated in the study. The demographic information is located in Table 1. Of the 62 participants, 25 were fallers (11 male and 14 female) and 37 were non-fallers (17 male and 20 female). The mean age for the fallers was 75.1 ± 7.6 years while the mean age for the non-fallers was 74.5 ± 6.3 years. All participants scored a 24 or higher on the MMSE. The average height for the fallers was 158.4 ± 23.4 cm and the average height for non-fallers was 163.2 ± 18.3 cm. Average weight for the fallers was 76.8 ± 18.7 kg and for the non-fallers it was 82.3 ± 15.2 kg. There were no significant differences between fallers and non-fallers in any of the demographic measurements taken.

i. Table 1

Demographic Information

	Fallers	Non-fallers	Significance
Age (years)	75.1 ± 7.6	74.5 ± 6.3	.71
Weight (kg)	76.8 ± 18.7	82.3 ± 15.2	.21
Height (cm)	158.4 ± 23.4	163.2 ± 18.3	.38
BMI (kg/m^2)	28.9 ± 6.1	29.5 ± 4.4	.72
BIA (% fat)	39.9 ± 5.9	38.1 ± 7.6	.35

Note. Values are mean ± SD. * denotes $p \leq .05$ for one way ANOVA between groups.

B. Hypotheses

Results were found for the four stated hypotheses. The first hypothesis was that older adults without a history of falls would have significantly greater power than those with a history of falls. This hypothesis was supported by data. The non-fallers had a significantly higher average power of 420.6 ± 154.9 watts compared to the fallers who had 325.5 ± 114.3 watts (p = .01). These results are presented in Figure 1. Fallers also had significantly lower relative power (4.20 ± 1.04 watts/kg) compared to the non-fallers (5.12 ± 1.53 watts/kg; p = .01). The second hypothesis proposed that older adults without a history of falls would have significantly greater balance compared to those with a history of falls. This hypothesis was supported by the collected data. Older adults without a history of falls had significantly greater balance (53.5 ± 3.1; p = .02) compared to those with a history of falls (50.4 ± 6.2; p = .02). This can be viewed in Figure 2. The third hypothesis stated that older adults with higher physical activity levels would have significantly greater balance and power compared to those with lower activity levels. Data only partially confirmed this hypothesis. Physical activity levels only showed to be significantly correlated to balance ($r = .33$; $p = .013$). This can be observed in Figure 3. Physical activity level did not show to be significantly correlated with power. The last hypothesis was that power and balance would be significantly correlated. Data confirmed this hypothesis. Power and balance were found to be significantly correlated ($r = .43$; $p = .001$). This can be viewed in Figure 4. Balance and relative power were also found to be significantly correlated ($r = .54$; $p = .001$).

i. Figure 1

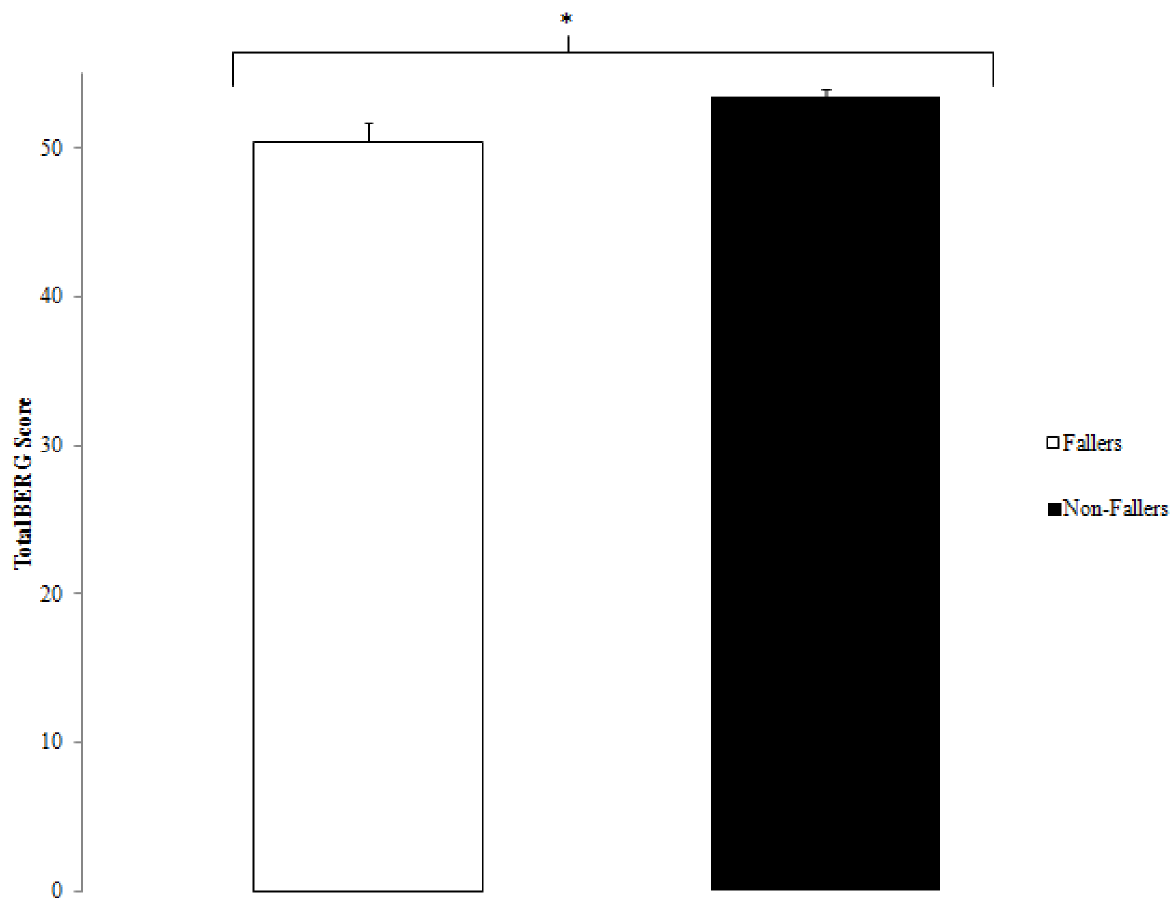

Figure 1. Average balance score of fallers vs. non-fallers. *Indicates significant difference between groups ($p = .02$).

ii. Figure 2

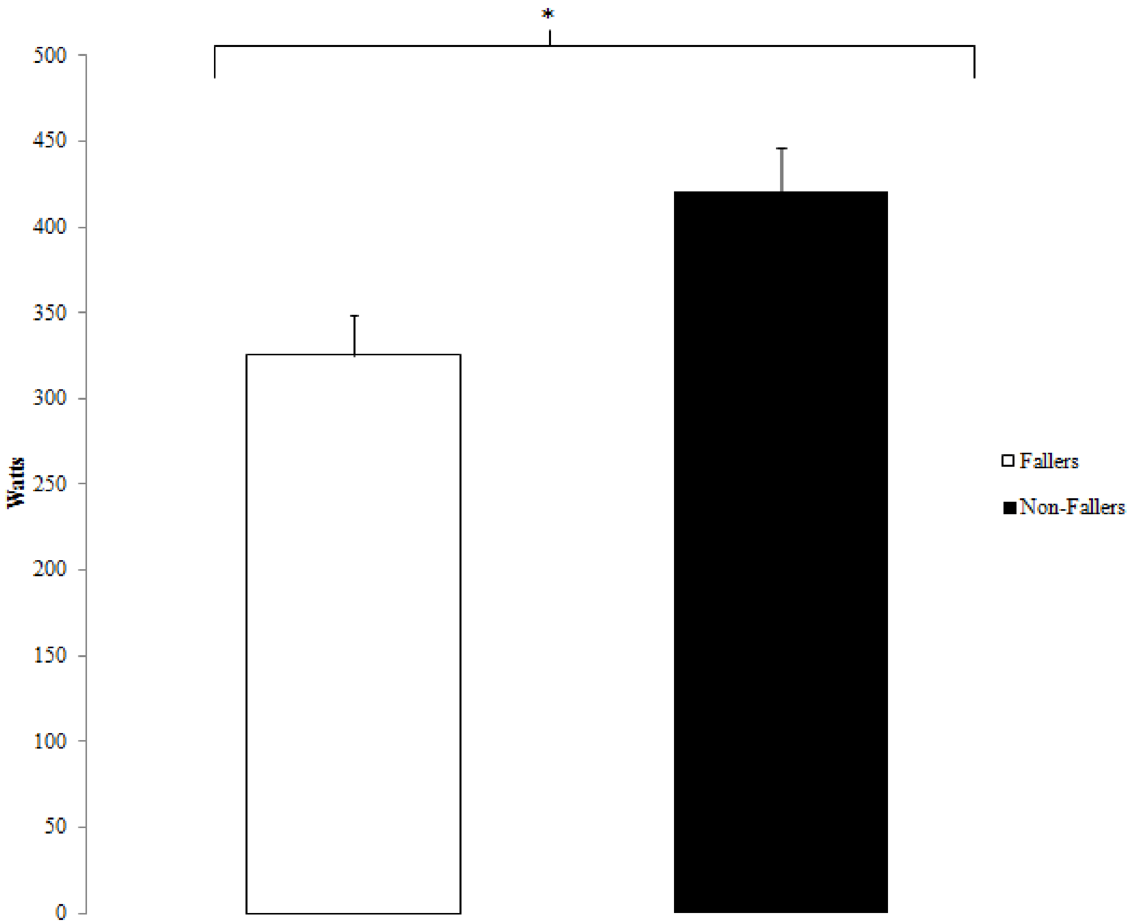

Figure 2. Average power of fallers vs. non-fallers. *Indicates significant difference between groups (p = .01)

iii. Figure 3

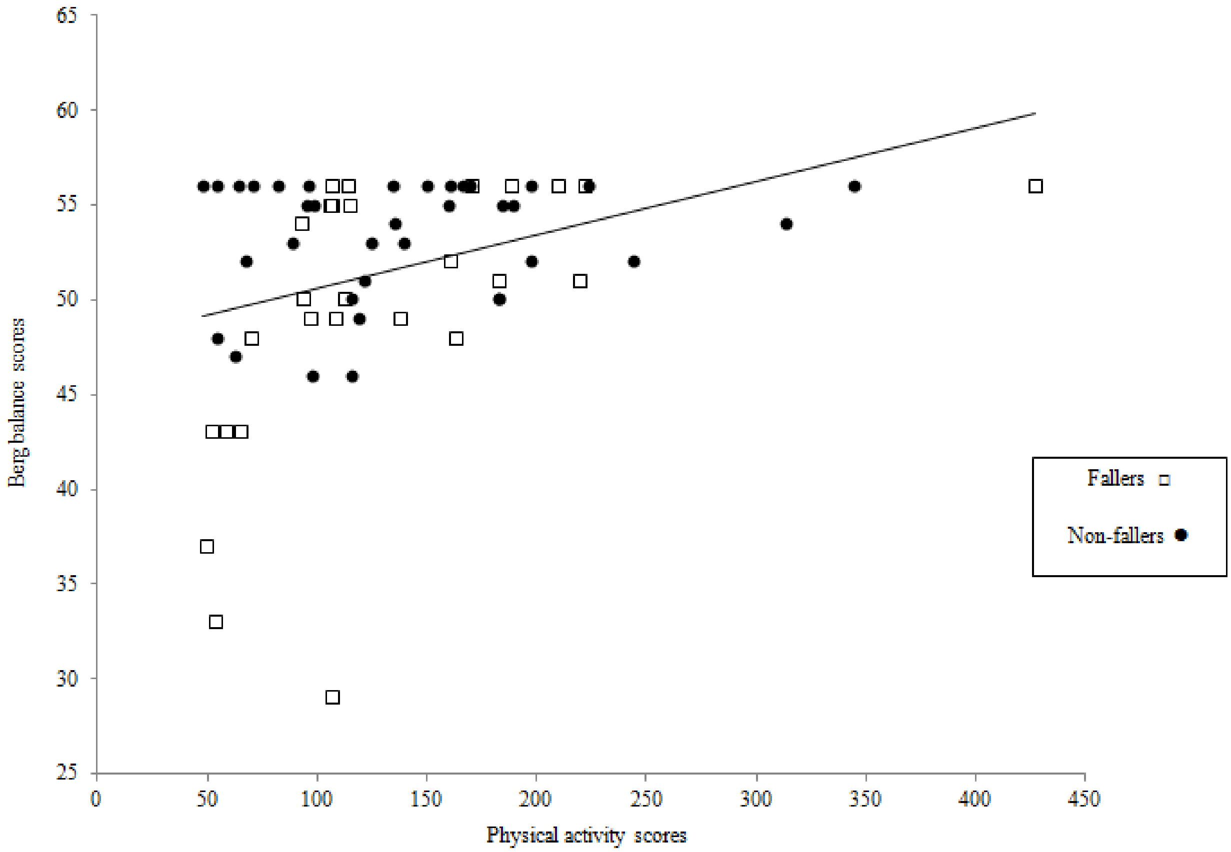

Figure 3. Relationship of physical activity and balance (r = .33, p = .01).

iv. Figure 4

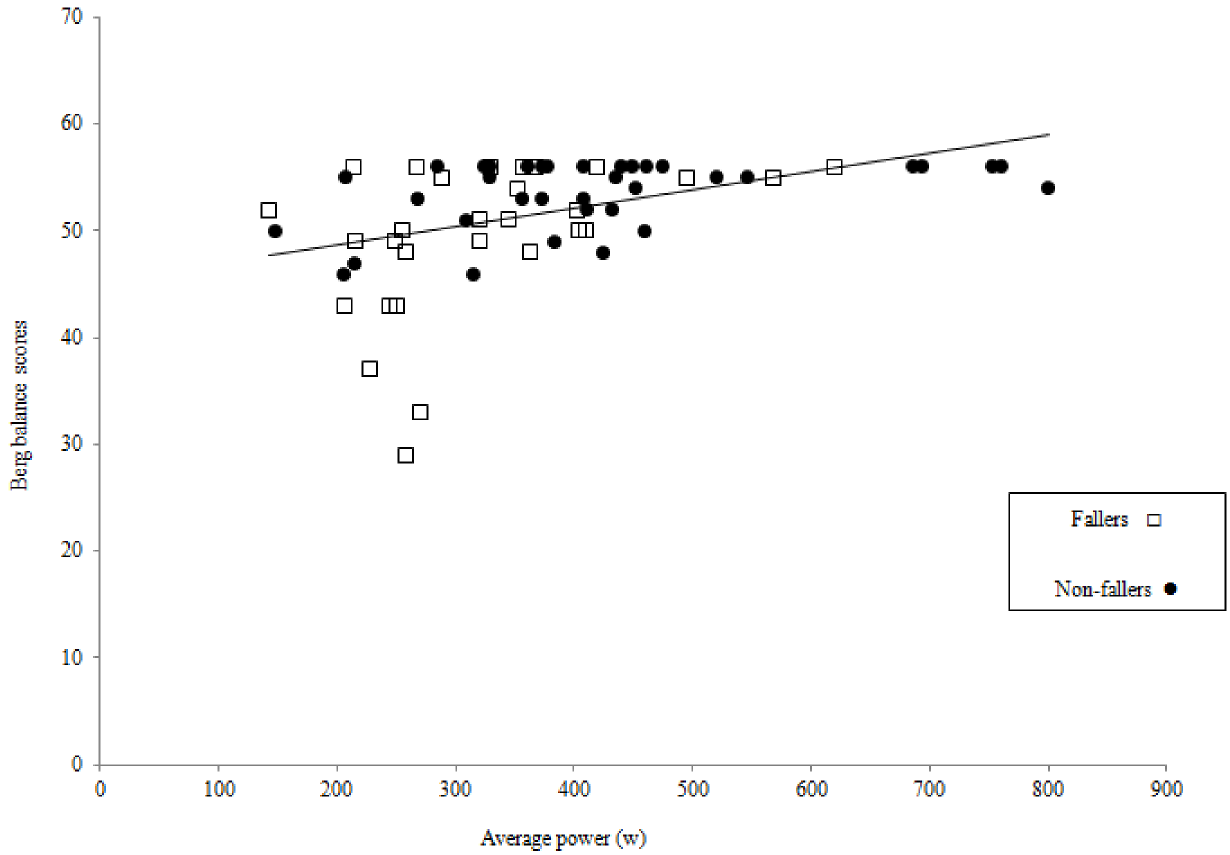

Figure 4. Relationship of power and balance (r = .43, p = .001).

V. Discussion, Summary, Conclusions, and Recommendations

A. Discussion

This study confirmed results for three out of the four hypotheses. Power, as well as balance was significantly higher in individuals who did not have a history of falls compared to those who did have a history of falls. For physical activity level measured by the PASE questionnaire, balance showed to be significantly correlated whereas power was not. Furthermore, balance and power were significantly correlated to one another.

Parallel with the hypotheses, power and balance were significantly higher in individuals who did not have a history of falls compared to those who did. The findings of the current study on power are similar with findings of previous studies. Whipple et al. (1987) found fallers to have significantly less power ($p < .001$) compared to that of non-fallers. In contrast to the current study, Whipple et al. (1987) measured power using the Cybex II Isokinetic dynamometer and used subjects from a nursing home rather than community-dwelling older adults. Subjects were eliminated if ambulatory status required the use of a walker or assistive device whereas in the current study participants were not excluded for this reason. It can be assumed that individuals who use an assistive device during ambulation will have significantly lower power than those who do not which could have made a significant difference in results found. Similarly, Perry et al. (2007) also found power to be lower in fallers compared to non-fallers ($p = .03$). Perry and colleagues measured lower extremity power through the Nottingham Power Rig. However, in all of these findings including the current study, a reduction in power could be caused from the fall itself. It cannot be known if the fallers had lower power before the fall or if the fall increased fear to carry on with everyday activities, thus lowering power output. Although the current study found similar results as previous studies, the measurement of power was different. Researchers have speculated the importance of power measurement through the activities being performed. Thus, recording power during an activity that mimics a functional activity especially regarding the older population, such as the sit-to-stand, is beneficial. Bassey et al. (1992) suggests the measurement of power depends on the resources that can be commanded by the nervous system and, therefore, power output should correlate with short term performance measures such as chair rising. Salem, Wang, Young, Marion, and Greendale, (2000) found power at 90% of 1-RM to explain more of the variance in the short physical performance battery sit-to-stand than when compared to a low relative intensity. A strong relationship was found between power at a high intensity and the sit-to-stand score. For some elderly individuals, activities of everyday living can push the limits of the muscles. The demands on the musculoskeletal system to rise from a chair are more than double the necessities for normal walking. A large portion of everyday activities involves being able to stand from a chair. This infers the importance of measuring power during a sit-to-stand motion, specifically in the elderly. Skelton et al. (2002) discovered fallers were 24% less powerful for body weight compared to the non-fallers. The TWA takes into account body weight in that the individual has to lift his or her weight to stand. In comparison to the Cybex or Nottingham Power Rig, the TWA involves a fall factor whereas participants tested on the Cybex or Nottingham Power Rig are seated 100% of the time. This supports the measurement of power utilizing the TWA during a sit-to-stand method compared to previous studies measuring power through pneumatic resistance equipment in which body weight is not taken into consideration.

In conjunction to previous studies, balance was significantly lower in the fallers. Researchers Orr et al. (2004) discovered fall history was related to a worse dynamic balance score ($p < .05$). Although these researchers used a balance platform, other studies measured balance parallel to the current study. Borg, Laxaback, and Bjorkgren, (2012) observed BBS in fallers and non-fallers. These researchers only found a significant difference between groups when comparing Berg Balance tasks 11 through 14 (p = .02). The current study found significance when comparing the total BBS but it did not go unnoticed that most participants performed well on the first part of the Berg Balance tasks. The significance found between fallers and non-fallers for balance may be due to "outliers" left in the results which could have skewed results higher or lower in either group. Some participants who were in the fall group scored well on the BBS as well as some participants who were in the non-faller group scored poorly on the BBS. Although results of the current study differ from Borg et al. (2012), other researchers (Mujdeci, Aksoy, and Atas, 2012) found results that compare to the current study in that the BBS average score of fallers was 47.9 while the non-fallers had an average score of 54.6 which was statistically higher ($p < .05$). The present study had an average score of 53.5 for the non-fallers and a 50.4 for the fallers. The differences in these BBS scores could be attributed to the group criteria for fallers. Fallers were considered having a history of two or more falls where as the present study only required one or more falls to be considered in the fall group. Mayson et al. (2008) found BBS greater than or equal to 50 to be associated with a lower fall risk. It is speculated a lack of balance may be due to inadequate balance mechanisms (Bassey et al., 1992). Allum et al. (2002) found older adults had a delayed response to a balance perturbation of 20-35 ms as well as a smaller balance correcting response amplitude when compared to the young ($p <$ .05). This may relate to the decrease in type II muscle fibers that occur with age in which these fibers are primarily responsible for power output. Borg et al. (2012) mentions no correlation was found between the BBS and leg extension force for fallers but found a moderate correlation for the non-fallers. Due to the fact that force is a component of power, one can infer that lack of balance could be due to not having enough power and the insufficient ability to utilize power for postural control.

Although the current study did not find power to be significantly correlated to physical activity levels, Aniansson, Grimby, and Hedberg, (1992) found fallers to be less physically active. Type II fiber atrophy, which is beneficial for power production was more prevalent in fallers when compared to non-fallers of the same age. Results suggest the lack of power in the fallers could be due to a decrease in physical activity. Other researchers found a weak correlation in women between leg extensor power and activity levels (p = .36). In comparison to the current study, Skelton, Greig, Davies, and Young, (1994) only observed women, and had 100 participants compared to the 64 participants in the present study. Skelton and colleagues used the graded habitual physical activity assessment on Grimby's 6-point scale to assess physical activity. This assessment involved questions on physical activity from the last 5 years. Questions included performing and competing sports, performing regular physical activity, walking at least 2 km or biking at least 5 km at least three days per week, walking or biking to work for more than 10 minutes daily, strolling or gardening, performing other kinds of exercise, or none of the above. Based on the answer, participants were classified as high, moderate, or low on the physical activity scale (Saltin and Grimsby, 1968). The current study utilized the PASE questionnaire as an assessment of physical activity. In comparison to the Grimby scale, the PASE not only focuses on exercise for physical activity but also focuses on activities of daily living such as cleaning house or caring for another individual. The PASE also assesses physical activity in the past week whereas the Grimby scale observes the last five years of which many older adults may have forgotten that far back. Physical activity was self-reported and questions were in reference to how physically active the individual was the previous week. Testing occurred during winter months in which some people could not travel or go outside to exercise due to bad weather. These factors could have skewed the results of physical activity levels and its relationship to power. Although the current study did not find a significant correlation between physical activity and power, many other studies found a relationship between functional status and power levels. Foldvarie et al. (2000) revealed both leg press power and physical activity levels to be independent predictors of functional status with leg press power being the strongest correlation ($p = -.47$, $p < .0001$). Although physical activity levels have been shown to decrease functional limitations with age, it is unclear whether physical activity has a direct effect on functional status or if the increase in functional status is due to other variables. Researchers speculate the lack of interaction between power and physical activity levels may suggest activity levels influence function through non-physiologic pathways such as psychological or disease modifications.

On the other hand, the current study did find a significant correlation between balance and physical activity levels. Previous studies have found comparable results. Research observing physical fitness of community-dwelling older adults also found physical activity levels to be significantly correlated with balance ($r = .38$; $p < .05$) (Purath, Buchholz, & Kark, 2009). Both the current study and the mentioned study measured physical activity through the PASE questionnaire and found similar results even though different balance measures were used. The mentioned study assessed balance through the 8-foot up-and-go which is highly correlated with the BBS ($r = -.76$) (Steffen, Hacker, & Mollinger, 2002). These researchers note a mean PASE score of 170 indicating the participants were more active than most other older adults. The mean PASE score of the current study was 137, which is suggestive that the older adults tested were less active than the previously mentioned study. In contrast to the current study, Thorbahn and

Newton, (1996) found physical activity level did not correlate to BBS scores. It is speculated the physical activity assessment used was not sensitive enough to variations in individual's activity patterns. These researchers also had very uneven gender groups with 50 women and only 16 men which could have had an effect on the scores. The present study used reliable measures of physical activity and balance as well as reasonably even gender and demographics.

Results demonstrate balance and power to be significantly correlated. Mayson et al. (2008) also observed an association between balance and power scores. High leg press power in community-dwelling older adults was associated with several measures of balance that are predictive of falling. Similar to the current study, Mayson et al. (2008) also measured balance using the BBS. Bean et al. (2004) had older adults train while wearing a weighted vest. Participants performed functional activities such as chair rising and stair climbing. Enhancements in power corresponded with improvements in balance and mobility. Other researchers found older adults who had a decreased capacity for explosive force production also showed a decrease in balance. It is thought that the decrease in the ability to develop force quickly is associated with a slower neuromuscular response in controlling for postural sway. As mentioned earlier, older adults have a slower response to a perturbation that may cause a fall (Izquierdo et al., 1999). The strong findings of the relationship between power and balance in the current study could be attributed to the measures used to assess these values. Both the BBS and the TWA measure balance and power in a way that is similar to activities of daily living.

B. Summary

The purpose of this study was to observe the relationship between balance and power in older adults over the age of 65 with and without a history of falls. When comparing fallers to non-fallers, the non-fallers demonstrated significantly higher balance and power scores.

Significant correlations were found between physical activity level and balance, however a significant relationship was not found among physical activity level and power. Lastly, a significant correlation was found between balance and power.

C. Conclusions

According to the present study, utilization of the TWA was a safe and effective way to measure lower body power in the older population. While pneumatic resistance equipment has been shown to be a reliable, valid measurement of power, the TWA can capture power in a way that is truly associated with an activity of everyday living. Lower body power was 25% higher in individuals who had not fallen compared to those who had fallen. Training to increase muscle power output through high velocity exercises can be more efficient in increasing lower extremity muscle power in a way that is feasible and well-tolerated. This study adds to the literature that measuring power output through the TWA in the older population is a more effective, meaningful measure in that it captures power during an activity of everyday living.

D. Recommendations

With the knowledge that strength, power, and balance play a key role in maintaining the independence and preventing falls in older adults, physical activity regimens should be focused on these components. While past literature has shown a strong focus on strength training in the older population to maintain functionality there is growing interest on power training. Researchers have come to the realization that power declines quicker in the older population when compared to strength. Future research directions should consider a power training intervention and its effects on balance using the BBS and the TWA as measurement tools. Through improving reaction time and balance, reducing the prevalence of falls, and improving the quality of life, leg extension power training in the older population should be considered.

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Appendices

Appendix A. Informed Consent

INFORMED CONSENT

Title: **Balance and Power in Older Adults With or Without Falls**

Researchers:

Stephanie Gray, B.S.Ed.
Michelle Gray, Ph.D.
Jennifer Vincenzo, PT, MPH
University of Arkansas
Department of Health, Human Performance,
and Recreation
501-328-7554
smg004@uark.edu
jvincenz@uark.edu

Administrative Contact Person:
Iroshi Windwalker
Compliance Coordinator
210 Administration Building
479-575-2208
irb@uark.edu

Purpose: The purpose of this project is to observe the relationship between balance and power in adults over the age of 65 with or without a history of falls. The secondary purpose of this study to assess the relationship between the Sway Balance smart-phone application, and balance score on the Berg balance test, balance confidence, and history of falls.

Inclusion Criteria: You must be at least 65 years of age to participate in the study with no cognitive impairment (MMSE $\geq$23), in relatively good health (no known uncontrolled cardiovascular disease, uncontrolled diabetes, uncontrolled hypertension, currently experiencing bouts of dizziness). If your doctor has ever said you should not participate in physical activity, you will be excluded from participation.

Description: All testing will be completed at the Rogers Adult Wellness Center (this will be changed per location it is at; i.e the Human Performance Lab at the University of Arkansas, Butterfield Trail Village, or Bella Vista recreation center). Before any physical assessment is conducted, you will be asked to complete the Mini-Mental State Examination (MMSE). If the score is less than 23 (out of 30) additional testing will not be performed. A health history questionnaire will be completed to ensure you are not at increased risk of injury when performing the physical measurements. A physical activity questionnaire will be administered to observe amount of physical activity. This questionnaire will include 11 questions on leisure time, household, and work-related activities. A questionnaire will be also given to you to determine the confidence you have in your balance. This questionnaire asks you to rate your confidence if you were to be performing 16 different tasks you may do every day. Demographic information including body weight, height, and body fat percentage will be determined before physical assessments are completed. Body weight will be measured using a physician's balance scale. Height will be assessed using a standing stadiometer. Body fat percentage will be measured using the Bioelectrical Impedance Analysis.

Physical tests will consist of balance using the Berg Balance Scale (BBS), the Sway Balance application, and power using the Tendo Weightlifting Analyzer (TWA). All tests have been validated to be used to test older adults. During the balance test an investigator will be standing beside you at all times to ensure safety.

The BBS is an assessment of balance including 14 functional tasks:

1. Sit to stand
2. Standing unsupported
3. Sitting with back unsupported with feet on floor or on stool
4. Stand to sit
5. Transfers
6. Standing unsupported with eyes closed
7. Stand unsupported with feet together
8. Reaching forward with outstretched arm
9. Pick up object from the floor from a standing position
10. Turn to look behind over left and right shoulders while standing
11. Turn 360 degrees
12. Place alternate foot on bench or stool while standing unsupported
13. Stand unsupported with one foot in front
14. Standing on one leg

Balance will also be assessed using the "Sway Balance" smart phone application. For this test, you will be standing and perform 5 tasks that are 10 seconds each.

1. standing feet together
2. standing with right foot in front of left (heel to toe)
3. standing with left foot in front of right (heel to toe)
4. standing on right leg only
5. standing on left leg only

You will be able to practice the test three times before performing four different trials (also three times each) in random order:

1. eyes open, arms across chest holding device
2. eyes closed, arms across chest holding device
3. eyes open, device held on chest by a halter
4. eyes closed, device held on chest by halter.

Muscular power will be assessed using the Tendo Weightlifting Analyzer. For this test, you will be seated toward the edge of a chair with both feet approximately shoulder-width apart. You will be asked to stand as quickly as possible consecutively five times as power is assessed with the Tendo.

Potential Risks: All assessments are designed to assess functional fitness, specifically, among older adults. However, with any physical assessment there is a chance of muscle soreness or loss of balance. Every effort will be made by the research team to decrease the incidence of injury. Each assessment will be thoroughly explained and demonstrated by a member of the research team. When balance is tested, a member of the research team will be within arm's length. The researcher will try to prevent any problem that could happen because of this research. If at any time there is a problem, you should let the researcher know and she will help you. However, the University of Arkansas does not provide medical services or financial assistance for injuries that might happen because you are taking part in this research.

Confidentiality: After initial contact with the primary investigator, a code number (e.g. 100,101, etc.) will be assigned to you. All data collection sheets and electronic data files will only have the code number to identify you. All information collected will be kept confidential to the extent allowed by law and University policy.

Right to withdraw: Your involvement in this research study is completely voluntary, and you may discontinue your participation in the study at any time without penalty.

Questions Regarding the Study: If you have any questions about the research study you are encouraged to ask the researcher; the phone number is at the top of this form. You will be given a copy of this signed and dated consent form to keep, upon request.

Participant: I, ____________________________, have read the description and information above.

(please print)

Each of these items has been read and explained to me by the investigator. The investigator has answered all of my questions regarding the study, and I believe I understand what is involved. My signature below indicates that I freely agree to participate in this experimental study and hat I have received a copy of this agreement from the investigator.

Signature: ____________________________ Date: _________________

Appendix B. Health Screening

Please answer the following questions. Today's Date: ____________

(1) Age

Date of Birth _____________ What is your current age? ____________

(2) Participation in strengthening activities within the past year

Do you currently participate in any form of physical activity? Yes No

Activities:

Frequency (days per week)________ Duration (min per day)______ Length of Participation _

Do you currently participate in any form of *strengthening* activity? Yes No

Activities:

Frequency________________ Duration___________ Length of Participation _____ ______

(3) No diagnosis of unstable or unmanaged cardiovascular disease, hypertension, or diabetes;

Have you ever had any of the following conditions? Check yes or no. If yes, explain.

Heart Disease

Heart Attack ☐ Yes ☐ No

Angina (Chest Pain) ☐ Yes ☐ No

Peripheral Artery Disease ☐ Yes ☐ No

Stroke ☐ Yes ☐ No

High Cholesterol (>220) ☐ Yes ☐ No

High Blood Pressure (>140/90) ☐ Yes ☐ No

Diabetes ☐ Yes ☐ No

Rheumatic Fever ☐ Yes ☐ No

Aneurysm ☐ Yes ☐ No

(4) Lack of neuromuscular or musculoskeletal disease or injury that prohibits participation in resistance exercise

Have you ever had any of the following conditions? Check yes or no. If yes, explain.

Arthritis, rheumatism, or gout ☐ Yes ☐ No
Any joint, bone, or muscle pain ☐ Yes ☐ No

Any joint, bone, or muscle injury ☐ Yes ☐ No

Any physical disability ☐ Yes ☐ No

(5) No history of hospitalization for any cause within the past year

Have you ever had any of the following conditions? Check yes or no. If yes, explain.
Severe Illness (in the last year) ☐ Yes ☐ No

Operations (in the last year) ☐ Yes ☐ No

Broken bone/fracture (in the last year) ☐ Yes ☐ No

(6) No history of a fall within the preceding one year

Have you fallen in the past 12 months? ☐ Yes ☐ No **If yes, explain.**

(7) Additional information

Have you experienced any of these symptoms? Check yes or no. If yes, explain.
Pain and/or discomfort in the chest, neck, jaw, or arms ☐ Yes ☐ No

Shortness of breath at rest or with mild exertion ☐ Yes ☐ No

Dizziness ☐ Yes ☐ No

Ankle edema (swelling) ☐ Yes ☐ No

Rapid or irregular beating heart ☐ Yes ☐ No

Leg pain, cramping, or tightness during exercise ☐ Yes ☐ No

Heart murmur ☐ Yes ☐ No

Fatigue or shortness of breath during the day ☐ Yes ☐ No

Do you smoke? ☐ Yes ☐ No ☐ Quit

Have you gained or lost weight in the past year? ☐ Yes ☐ No

(8) Please attach a list of all medication (prescription or over-the-counter) you are currently taking or use the form below.

Medication ***Reason Prescribed*** ***When do you take this medication?***
(check all that apply)

____________________ __________________ ☐ Morning ☐ Mid-Day ☐ Evening ☐ Bedtime

____________________ __________________ ☐ Morning ☐ Mid-Day ☐ Evening ☐ Bedtime

____________________ __________________ ☐ Morning ☐ Mid-Day ☐ Evening ☐ Bedtime

____________________ __________________ ☐ Morning ☐ Mid-Day ☐ Evening ☐ Bedtime

____________________ __________________ ☐ Morning ☐ Mid-Day ☐ Evening ☐ Bedtime

____________________ __________________ ☐ Morning ☐ Mid-Day ☐ Evening ☐ Bedtime

____________________ __________________ ☐ Morning ☐ Mid-Day ☐ Evening ☐ Bedtime

Appendix C. IRB Approval Letter

September 25, 2013

MEMORANDUM

TO:	Stephanie Gray Michelle Gray
FROM:	Ro Windwalker IRB Coordinator
RE:	New Protocol Approval
IRB Protocol #:	13-09-079
Protocol Title:	*Balance and Power in Older Adults with or without a History of Falls*
Review Type:	☐ EXEMPT ☒ EXPEDITED ☐ FULL IRB
Approved Project Period:	Start Date: 09/24/2013 Expiration Date: 09/18/2014

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 80 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.

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

Appendix D. Data Collection Template

Physical Activity Scale for the Elderly And Paffenbarger Physical Activity Index

Leisure Time Activities

1. Over the past 7 days, how often did you participate in sitting activities such as reading, watching TV or doing handcrafts?

   [0] never — Go to Q.2
   [1] seldom (1 to 2 days)
   [2] sometimes (3 to 4 days)
   [3] often (5 to 7 days)

   1a. What were these activities?

   ____

   1b. On average, how many hours per day did you engage in these sitting activities on these days?
   [1] less than 1 hour
   [2] 1 but less than 2 hours
   [3] 2-4 hours
   [4] more than 4 hours

2. Over the past 7 days, how often did you take a walk outside your home or yard for any reason? For example for fun, or exercise, walking to work, walking the dog ect?

   [0] never — Go to Q.3
   [1] seldom (1 to 2 days)
   [2] sometimes (3 to 4 days)
   [3] often (5 to 7 days)

   2a. On average, how many hours per day did you spend walking on these days?
   [1] less than 1 hour
   [2] 1 but less than 2 hours
   [3] 2-4 hours
   [4] more than 4 hours

   b. What was the total distance (kms/miles/blocks) that you walked in the past 7 days?
   [1] less than 1 mile
   [2] one but less than 2 miles
   [3] two to 4 miles
   [4] more than 4 miles

3. How many flights of stairs did you climb up in the past 7 days? (one flight=10 steps)
   [1] less than one flight
   [2] one but less than 2 flights
   [3] two to four flights
   [4] more than 4 flights

4. Over the past 7 days, how often did you engage in light sport or recreational activities such as light cycling on an exercise bike, lawn bowls, bowling, water aerobics, golf with a cart, yoga, tai chi, fishing from a boat or pier or other similar activities?

[0] never | [1] seldom (1 to 2 days) | [2] sometimes (3 to 4 days) | [3] often (5 to 7 days)

Go to Q. 4

3a. What were these activities?

____

3b. On average, how many hours per day did you engage in these light sport or recreational activities on these days?

[1] less than 1 hour   [2] 1 but less than 2 hours
[3] 2-4 hours   [4] more than 4 hours

5. Over the past 7 days, how often did you engage in moderate sport or recreational activities such as doubles tennis, ballroom dancing, golf without a cart, softball or other similar activities?

[0] never | [1] seldom (1 to 2 days) | [2] sometimes (3 to 4 days) | [3] often (5 to 7 days)

Go to Q. 5

4a. What were these activities?

____

4b. On average how many hours per day did you engage in these moderate sport or recreational activities on these days?

[1] less than 1 hour   [2] 1 but less than 2 hours
[3] 2 to 4 hours   [4] more than 4 hours

6. Over the past 7 days, how often did you engage in strenuous sport and recreational activities such as jogging, swimming, cycling, single tennis, aerobic dance, skiing (downhill or cross country) or other similar activities?

[0] never → Go to Q. 6
[1] seldom (1 to 2 days)
[2] sometimes (3 to 4 days)
[3] often (5 to 7 days)

5a. What were these activities?

____

5b. On average how many hours per day did you engage in these strenuous sport or recreational activities on these days?

[1] less than 1 hour
[2] 1 but less than 2 hours
[3] 2 to 4 hours
[4] more than 4 hours

7. Over the past 7 days, how often did you exercise specifically to increase muscle strength and endurance such as lifting weights or pushups ect?

[0] never → Go to Q. 7
[1] seldom (1 to 2 days)
[2] sometimes (3 to 4 days)
[3] often (5 to 7 days)

6a. What were these activities?

____

6b. On average how many hours per day did you engage in exercise specifically to increase muscle strength and endurance on these days?

[1] less than 1 hour
[2] 1 but less than 2 hours
[3] 2 to 4 hours
[4] more than 4 hours

Household Activities

8. During the past 7 days, have you done any light housework such as dusting or washing dishes?

[1] no [2] yes

9. During the past 7 days, have you done any heavy housework or chores such as vacuuming, scrubbing floors, washing windows, or carrying wood?

[1] no [2] yes

10. Over the past 7 days did you engage in any of the following activities?

	No	Yes
a. Home repairs such as painting, wallpapering, electrical ect?	[0]	[1]
b. Lawn work or yard care including snow or leaf removal, wood chopping ect?	[0]	[1]
c. Outdoor gardening?	[0]	[1]
d. Caring for another person such as a dependent child, dependent spouse, or another adult?	[0]	[1]

Work Related Activities

11.Over the past 7 days did you work for pay or as a volunteer?
[1] no [2] yes

10a. How many hours per week did you work for pay or as a volunteer? ________

10b. Which of the following categories best describes the amount of physical activity required on your job and or volunteer work?
(1) Mostly sitting with light arm movements (office work, watch maker, bus driver)
(2) Sitting or standing with some walking (cashier, general office worker, light tool and machinery worker.
(3) Walking with some handling of materials generally less than 50 pounds (mailman, waitress, construction worker, heavy tool or machinery worker)
(4) Walking and heavy manual work often requiring handling materials over 50 pounds (lumberjack, stone mason, farmer, or general laborer.

Berg Balance Scale

SITTING TO STANDING
INSTRUCTIONS: Please stand up. Try not to use your hand for support.
(   ) 4 able to stand without using hands and stabilize independently
(   ) 3 able to stand independently using hands
(   ) 2 able to stand using hands after several tries
(   ) 1 needs minimal aid to stand or stabilize
(   ) 0 needs moderate or maximal assist to stand

STANDING UNSUPPORTED
INSTRUCTIONS: Please stand for two minutes without holding on.
(   ) 4 able to stand safely for 2 minutes
(   ) 3 able to stand 2 minutes with supervision
(   ) 2 able to stand 30 seconds unsupported
(   ) 1 needs several tries to stand 30 seconds unsupported
(   ) 0 unable to stand 30 seconds unsupported

If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL
INSTRUCTIONS: Please sit with arms folded for 2 minutes.
(   ) 4 able to sit safely and securely for 2 minutes
(   ) 3 able to sit 2 minutes under supervision
(   ) 2 able to able to sit 30 seconds
(   ) 1 able to sit 10 seconds
(   ) 0 unable to sit without support 10 seconds

STANDING TO SITTING
INSTRUCTIONS: Please sit down.
(   ) 4 sits safely with minimal use of hands
(   ) 3 controls descent by using hands
(   ) 2 uses back of legs against chair to control descent
(   ) 1 sits independently but has uncontrolled descent
(   ) 0 needs assist to sit

TRANSFERS
INSTRUCTIONS: Arrange chair(s) for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.
(   ) 4 able to transfer safely with minor use of hands
(   ) 3 able to transfer safely definite need of hands
(   ) 2 able to transfer with verbal cuing and/or supervision
(   ) 1 needs one person to assist

( ) 0 needs two people to assist or supervise to be safe

STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds
( ) 1 unable to keep eyes closed 3 seconds but stays safely
( ) 0 needs help to keep from falling

STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: Place your feet together and stand without holding on.
( ) 4 able to place feet together independently and stand 1 minute safely
( ) 3 able to place feet together independently and stand 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold for 30 seconds
( ) 1 needs help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds

REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at the end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)
( ) 4 can reach forward confidently 25 cm (10 inches)
( ) 3 can reach forward 12 cm (5 inches)
( ) 2 can reach forward 5 cm (2 inches)
( ) 1 reaches forward but needs supervision
( ) 0 loses balance while trying/requires external support

PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: Pick up the shoe/slipper, which is place in front of your feet.
( ) 4 able to pick up slipper safely and easily
( ) 3 able to pick up slipper but needs supervision
( ) 2 unable to pick up but reaches 2-5 cm(1-2 inches) from slipper and keeps balance independently
( ) 1 unable to pick up and needs supervision while trying
( ) 0 unable to try/needs assist to keep from losing balance or falling

TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING
INSTRUCTIONS: Turn to look directly behind you over toward the left shoulder. Repeat to the right. Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.

( ) 4 looks behind from both sides and weight shifts well
( ) 3 looks behind one side only other side shows less weight shift
( ) 2 turns sideways only but maintains balance
( ) 1 needs supervision when turning
( ) 0 needs assist to keep from losing balance or falling

TURN 360 DEGREES
INSTRUCTIONS: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.
( ) 4 able to turn 360 degrees safely in 4 seconds or less
( ) 3 able to turn 360 degrees safely one side only 4 seconds or less
( ) 2 able to turn 360 degrees safely but slowly
( ) 1 needs close supervision or verbal cuing
( ) 0 needs assistance while turning

PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touch the step/stool four times.
( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3 able to stand independently and complete 8 steps in > 20 seconds
( ) 2 able to complete 4 steps without aid with supervision
( ) 1 able to complete > 2 steps needs minimal assist
( ) 0 needs assistance to keep from falling/unable to try

STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject’s normal stride width.)
( ) 4 able to place foot tandem independently and hold 30 seconds
( ) 3 able to place foot ahead independently and hold 30 seconds
( ) 2 able to take small step independently and hold 30 seconds
( ) 1 needs help to step but can hold 15 seconds
( ) 0 loses balance while stepping or standing

STANDING ON ONE LEG
INSTRUCTIONS: Stand on one leg as long as you can without holding on.
( ) 4 able to lift leg independently and hold > 10 seconds
( ) 3 able to lift leg independently and hold 5-10 seconds
( ) 2 able to lift leg independently and hold ≥ 3 seconds
( ) 1 tries to lift leg unable to hold 3 seconds but remains standing independently.
( ) 0 unable to try of needs assist to prevent fall

( ) TOTAL SCORE (Maximum = 56)

Height (in) ______________

Weight (Kg) ______________

Body fat percentage ________________

Tendo Weightlifting Analyzer

	Rep 1	**Rep 2**	**Rep 3**	**Average**
Average power (w)				
Average velocity (m/s)				
Peak power (w)				
Peak velocity (m/s)				