HIP POWER ASYMMETRY IN OLDER ADULT FALLERS AND NON-FALLERS

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ABSTRACT

The purpose of this study was to determine if a difference exists in hip power asymmetry between community-dwelling older adult fallers and non-fallers. *Hypothesis*: fallers would be more asymmetrical than non-fallers. *Participants*: 21 non-fallers (10 females, 11 males) and 18 fallers (14 females, 4 males) over the age of 65 (76.5 ± 6.9 yrs). *Method*: Isokinetic peak torque during flexion, extension, abduction, and adduction at four velocities was recorded as measures of leg power. Asymmetry equaled the percent of power difference between each leg. *Data analysis*: Differences in age, physical activity, height, weight, and BMI were assessed using independent t-tests. Two 2X13 ANOVA were run to determine whether group differences existed in hip power asymmetry and whether males and females differed in asymmetry for each test. The mean asymmetry for the 13 tests was also compared between groups using an independent t-test. *Results*: No group differences were seen in age, gender, physical activity level, weight, BMI, or height. Fallers were significantly more asymmetrical in hip power at 60°/sec flexion ($F(1, 36) = 6.96$, $p < .015$). No significant group differences were found in the remaining 12 asymmetry tests. Fallers were more asymmetrical in mean asymmetry throughout the 13 tests ($F(1,37)=7.9$, $p < .05$). Discussion: Global asymmetry may be more predictive of fall risk than hip power asymmetry in unidirectional movements. Additional research is needed to clarify the degree to which hip power asymmetry contributes to fall risk at both single and multi-planar levels.

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CHAPTER 1: INTRODUCTION

Fall Significance

Falls are the number one cause of morbidity and mortality in individuals over the age of 65 years, the population known as older adults.[1] The risk of falling is higher for older adults and greatly increases with advancing age.[2] In 2006, in the United States alone, a total of 16,650 individuals aged 65 or older died from fall-related causes and 1.8 billion were taken to emergency rooms for fall-related injuries.[2-3] Given the extreme incidence of falling in this population, fall prevention in older adults is clearly an important area for consideration. Furthermore, research in this area is even more important considering the upcoming rise in the older adult population as a result of the large baby boom generation. The injuries, costs, and other consequences that accompany falls have resulted in extensive research aiming to determine the mechanisms underlying falling, as well as developing strategies to reduce the risk and incidence of such events. Findings from such research may greatly impact the quality of life for older adults and those around them, as well as lead to a decreased economic burden.

A wide range of research exists regarding the causes of falls and their prevention within the older adult population, including medication, home atmosphere, diseases, and functional influences. While there are several external factors that may influence falls, exercise science research tends to focus on intrinsic physiological fall risk factors such as muscular strength, balance, and disease.[4-5]

Muscular Strength versus Muscular Power

A well-recognized predictor of falling is the amount of muscular strength an older adult possesses.[4-6] Muscular strength can be defined as the total amount of force one can generate. Although strength is a component of power, power is a distinct characteristic of muscular performance.[7] Muscular power is described as the ability to perform work (i.e., force x displacement) per unit of time, or put more simply, the product of strength and velocity (i.e., displacement/time).[7] Thus, power involves not just a strength component, but also a velocity component.

Muscular power plays an important role in the ability to carry out activities of daily living (ADL) effectively and with ease. For example, the ability to rise from a chair is an activity that depends on an individual's capacity to produce force rapidly.[7-8] Sarcopenia, the age-related loss of muscle mass, is prominent after the fifth decade of life and increases with age, affecting both muscle strength and power.[9-10] Age-related losses of muscle mass appear to lead to decreases in strength of about 1-2% each year after the age of 65, whereas decreases in power may occur at a rate of 3-4% each year due to decrements in both muscle strength and velocity.[7] Reductions in muscular leg power are beginning to be recognized as more detrimental to older adult mobility and function than muscular strength decrements.[7-8] Recent studies indicate that poor leg power may be a key contributor to fall risk, suggesting that power training might prove an effective method for reducing the risk of falls in older adults.[7, 11]

Leg Power and Fall Risk

Functional mobility is a term used to refer to balance and gait activities used in everyday life such as walking, turning, stair climbing, and standing up from a chair. Several studies have researched the relationship between leg power and functional mobility in tasks involving large leg power capacities.[8, 12-14] The general finding from this line of research is that leg power capacity is a significant determinant of ADL performance.[8, 12-14] In addition, these studies show that leg power is a stronger predictor of performance in functional tasks than leg strength alone, perhaps as much as 2-3 fold more.[8, 13-14]

Just as power and functional leg capacity have been highly linked, functional leg performance and fall risk have been shown to be strongly correlated.[4-5, 15-20] The same functional tasks that have been studied in association with muscular power, such as gait characteristics, balance, and the ability to climb stairs or rise from chairs, have also been associated with fall risk,.[5, 17] In other words, studies have found that the functional tasks that are reliant on leg power also factor into fall risk, strongly indicating that poor leg power is a risk factor of falling in this age group.

More recent research has actually focused on leg power capacity and older adult fall status. While this line of research is relatively new, leg power capacity appears to be a promising indicator of fall risk. Several studies have demonstrated that leg power output is significantly reduced in older adult fallers when compared to non-fallers of the same age group and that poor leg power capacity is correlated to fall incidence.[7, 11, 21-24]

Leg Power Asymmetry in Fallers and Non-Fallers

A newer topic in fall risk research is that of leg power asymmetry. Leg power asymmetry can be defined as a set or total percent difference between the power capacity of the right and left legs. Some studies looking at leg power asymmetry have examined mobility, function, or injurious falls rather than overall fall risk and have shown that high leg power asymmetry is associated with poor performance of certain functional mobility tasks: stair climbing, walking, and rising from a chair.[25, 26, 27] Only two known studies to date have examined leg power asymmetry between fallers and non-fallers.[7, 11] Contrary results were seen within these two studies, as one study found a significant group difference in leg power asymmetry, while the other did not. In combination, the findings from studies assessing functional mobility and asymmetry, plus the lack of scholarly attention this topic has received, validates further investigation in this area.

Problem Statement

Due to the growing population of older adults in combination with the incidence and consequences of falls for the individual and costs to society, the demand for research designed to establish preventative measures for falling is tremendous. Falls continue to occur due to medically unexplained mechanisms. Identifying the major causes of falls is important in understanding what measures should be taken to prevent such occurrences. Research examining the role of muscular leg power and leg power asymmetries in fall risk is encouraging in that power and power asymmetry may be treatable through preventative exercise and treatment strategies. Perhaps most concerning is the fact that only two known studies have analyzed leg power asymmetry between older adult fallers and non-fallers, each displaying opposite findings.[7, 11]

Research surrounding muscular power, functional mobility, and falls clearly shows that leg power capacity is an important component of falling. In addition, leg power asymmetry as it relates to fall status is an emerging topic in fall research. There are several gaps and problem areas within the research that has been conducted: including recruiting participants of only one gender, inadequate methodologies in power testing, overall lack of research, and the existence of contradictory findings between studies. Including only one gender in testing does not guarantee that the same findings will be applicable to the excluded gender. The only studies that have tested leg power asymmetry measured power through one exercise, making it impossible to analyze power output asymmetries in individual joints. The problem of insufficient research within the area of leg power asymmetry and fall risk is worsened by the contradictory findings within the current research. Due to these inconsistencies and the limited range of research within the area of falls and leg power capacity, research aiming to establish whether both older adult male and female fallers exhibit more or less leg power asymmetry than non-fallers is necessary.

Purpose

The purpose of this study was to determine if a difference exists in leg power asymmetry output of the hip joint within community-dwelling older adult fallers and non-fallers of varying activity levels.

Research Hypotheses

Based on research that supports a relationship between high leg power asymmetry and poor functional performance and fall risk within older adults, several hypotheses were made for this study.[7, 25-27] For each performance movement and each speed where asymmetry was measured, it was hypothesized that the amount of power asymmetry between legs would be significantly higher in older adult fallers compared to older adult non-fallers.

Significance of the Study

Findings from this study will provide more information about the relationship between leg power asymmetry and fall risk within older adults. If the hypotheses are confirmed, high leg power asymmetry might be more seriously considered as a risk factor for falling and future research analyzing the effectiveness of power training, and asymmetry reduction for fall prevention in older adults particularly will be stimulated. Also, greater support for the integration of strength training at higher velocities and/or a focus on decreasing power asymmetries in fall prevention programs for older adults may be established if the results confirm the hypothesis. If the hypotheses are not confirmed, this study will support similar findings from previous studies, inform future work, and contribute to the knowledge about leg power asymmetry as a possible predictor of falling.

Study Limitations

Every attempt was made to identify and control all variables that might influence the results. A limitation of this study lies within the difficulty of controlling the motivation and willingness of the participant to perform muscular leg power tests with maximal effort. If participants did not put forth their full effort for whatever reason, the maximal leg power data may not be accurate and could lead to unreliable inferences. Additionally, due to the population homogeneity within the geographic area from which subjects were recruited, a large proportion of participants were Caucasian. The inclusion of a high proportion of Caucasian individuals may limit the ability to generalize results to other ethnic groups.

Operational Definitions

Below is a list of common terms used within this study followed by their definitions specific to this research:

- Fallers: Individuals who have experienced a minimum of two unintended falls within the prior 12 months.
- Fall: an incident in which an individual comes to rest on the ground, or some lower object, as a result of intrinsic mechanisms leading to a loss in balance. A fall was not considered in this study if caused by syncope or stroke or from external forces.[7, 18]
- Power: the rate of force production, the product of force and velocity, or work divided by time.[8]
- Leg power asymmetry: percent difference of asymmetry between the right and left legs in power output.[11]

CHAPTER 2: LITERATURE REVIEW

An Overview of Falls in Older Adults

Falls in older adults often result in serious health and economic consequences. In 2006, within the United States, more than 5.8 million individuals over the age of 65 reported having fallen at least once within a 3-month period, and 1.8 million of these persons suffered a fall-related injury.[2] Deaths and injuries associated with falls incur significant financial costs, and by 2020, the projected annual cost of fall-related injuries is 42.8 billion dollars in the United States; placing a significant burden on the American economy.[28] Furthermore, population models predict that the number of individuals over 65 years of age is expected to double from the year 2007 to 2030, to make up approximately 20% of the U. S population.[29] This expansion in the older adult population will be mostly attributed to the aging of the baby boomers, but could also be the result of longer lives. Based on these predictions, it is expected that the incidence of falls and the associated consequences will also be on the rise.

The risk of falling increases with age and linearly with the number of fall risk factors an individual possesses.[30-31] Individuals that exhibit no risk factors may have an 8% chance of experiencing a fall compared to a 78% chance for those who maintain four or more risk factors. Older adults who have fallen multiple times in one year have a substantially increased risk of falling multiple times in the subsequent year.[32] It is often difficult to pinpoint whether an individual will fall or not, because falls are typically the result of multiple influences; however, some risk factors, such as certain physiological deteriorations, may be prevented or minimized in the hopes of reducing fall risk. It is important to understand what physiological deficits, such as leg power asymmetry, constitute risk factors and whether they can be manipulated to decrease fall risk, and reduce the negative impact of falls.

Age-Related Muscular Deficits

Aging leads to skeletal muscle mass and strength deterioration through the process known as sarcopenia. Sarcopenia is the loss of skeletal muscle mass caused by a reduction in the number of muscle fibers and fiber atrophy.[33] Several factors may contribute to sarcopenia, including reduced physical activity, poor nutrition, neural adaptations, and age-associated waning hormone concentrations, such as estrogen, testosterone, and growth hormone, as well as increases in inflammation and catabolic cyotkines.[34] Neural adaptations include denervation or the loss of nerve supply to muscles.[35] This means each motor neuron innervates more muscle fibers in aged muscle compared to young and contributes to strength decrements.[35] Aged muscle may also be weaker per unit of cross-sectional area, requiring more muscle fiber activation for a given load than that in younger adults.[12] Decreases in force production are seen as a result of these age-associated skeletal muscle changes.[36-37]

Power performance is dependent on both force production and velocity of movement. Studies examining muscular performance in older adults show that the ability to produce power actually declines earlier and at a steeper rate with increasing age than strength capacity alone.[12, 36-38] Metter et al. found that muscular strength begins to decline after 50 years of age, whereas muscular power starts deteriorating by age 30 or 40.[37] Due to the discrepancy in the rate of age-related strength and power losses, the sarcopenia responsible for strength losses cannot be the only factor responsible for power depletions; rather, it is likely that reductions in maximal contractile velocity are a dominant underlying cause of decreased power.[39] Petrella et al. found that older adults had 25-41% lower knee extension power than young adults, and that this discrepancy was unaffected by adjustments for lean body mass.[39] They concluded that muscular velocity capacity drastically declines with aging and is the primary agent of losses in power.

Type II fibers contribute heavily to power production and may be capable of producing four times the amount of power as Type I fibers.[40] Reductions in maximal contractile velocity could be related to the preferential sarcopenia of Type II fibers over Type I fibers.[33] In addition, slower nerve conduction velocities and decreased firing rates have been reported in aged motor neurons.[41-42] These changes can lead to decreases in the efficiency of muscle recruitment and reduce the speed at which muscles are capable of contracting and relaxing.

While it is important to understand the mechanisms responsible for detriments in power production, the focus of the present study lies within the relationship between muscular leg power asymmetry and fall risk. Before reviewing the research that is specific to this relationship, research conducted within power, functional mobility measures, and fall risk should be discussed.

Complementary Research

The Role of Leg Power in Functional Mobility

The ability to generate leg power is fundamental for successful ADL, as many normal movements such as standing up, walking, and reacting to a trip require the capacity to produce force quickly.[8, 13] Many studies within this field have assessed lower-extremity functional performance through the Short Physical Performance Battery (SPPB).[43] This test measures several forms of static balance, time to rise from a chair five times, and time to walk eight feet or other designated distances at a normal gait speed. SPPB scores have demonstrated significant correlations to leg power capacity as measured through leg extension or leg press movements.[8-9, 14, 43]

Extensive research with older adults has demonstrated the link between leg power capacity and several parameters of gait including habitual and maximal gait speed over short distances (typically 4-6 meters), stride length, tandem gait performance, and gait speed over long distances, such as the Six-Minute Walk Test.[8, 13-14, 39, 43-45] In addition to the SPPB and gait performance measures, performances during other exercises that mimic everyday tasks have shown a significant relationship to leg power output in older adults. Poor performance or the inability to perform altogether in movements that require considerable recruitment of the main leg muscles, like that of stair climbing (over various flight distances) and chair stands (from one to 10 repetitions), have also been strongly linked to leg power capacity.[13, 21, 37, 44, 46] Other tests that are used to assess balance, such as the Get-up-and-Go Test or the Berg Balance Test (BBT), have been associated with leg power performance in older adults as well.[20, 47] The Get-Up-and-Go Test requires a participant to stand from a seated position, walk a certain distance, and return back to a starting seated position. The BBT consists of several standing, reaching, and turning balance tasks, including tests performed with the eyes shut.

Many studies that measured both leg strength and power output found that power explained more of the variance in functional performance than strength.[8, 13-14, 43] Bean et al. found that power explained 22-38% of the variance in the performance of the SPPB tasks, stair climb, habitual gait speed, and balance exercises, while strength explained slightly less at 21-36%.[8] These authors claimed that because power includes the velocity at which force is induced, power may be more important for functional tasks that are very dynamic in nature. These findings are consistent with studies that illustrate that power declines earlier and more quickly than strength with age.[36-37]

Functional Mobility in Older Adult Fallers

Several studies have also compared functional capabilities in groups of older adult fallers and non-fallers as they relate to fall risk.[4-5, 15-17, 18-20] Many of the tasks that these studies assessed do not directly measure power, but are considered tests of functional leg power, such as the vertical jump and stair climb. These studies established an inverse relationship between falls and power dependent tasks, which suggests that leg power is an underlying component in fall risk.

Relationships between falling and habitual gait speed, stride length, and/or tandem gait have also been established in the same or similar tasks as those used in studies analyzing leg power and function.[16-19, 30, 32] Poor performance in single and repeated chair stands and stair climb tests have shown to be predictive of falls and more common in older adult fallers compared to non-fallers.[4, 17-18, 30]

Measures of balance, such as a short timed one-legged stance test and the Get-Up-and-Go Test, have also been shown to relate to falling.[5, 15, 17, 19] For example, Gunter et al. assessed both fall status and leg power performance in relation to performance on the Get-Up and-Go Test and found that leg power was directly related to performance on the Get-Up-and-Go Test and inversely related to fall risk.[15] Vertical jump height is a commonly used method for assessing lower limb muscular power. In lab-induced trips, jump height was positively related to the ability to prevent a fall in older adults.[47] These studies provide strong evidence for the role that leg power plays in both fall risk and functional performance. Research analyzing leg power capacity and functional performance in combination with that assessing functional task performance and fall risk has provided a substantial base for establishing the link between leg power and fall risk.

Leg Power and Fall Risk in Older Adults

It can be concluded from the research surrounding the relationship between leg function and leg power or fall risk that low power capacity is a significant risk factor for falling. Based on studies looking at the relationship between lower limb power and functional mobility, it is clear that leg power is fundamental to several tasks that underlie fall risk, such as gait speed, balance, and rising from a chair. Leg power output may also be important in the ability to effectively recover from balance losses and in the prevention of falls.[7] In order to correct a movement error in gait, an individual must generate enough leg power to counteract the kinetic energy resulting from a loss in balance.[7] This type of recovery requires quick muscular contractions and is likely where the velocity component of power acts in preventing a fall. Studies are finding that just as leg power is more predictive of mobility and functional performance than force production of the legs, leg power may also be more predictive of a future fall than leg strength.[7, 11] Using induced trips, Pijnappels et al. observed lower rates of torque generation during the push-off phase of balance recovery around all leg joints in those who fell compared to those that did not, indicating the importance of power generation in reestablishing balance and preventing a fall.[47]

In the first known study to measure leg power output in fallers and non-fallers, Whipple et al. found that older adult fallers had significantly decreased power in both the knee and ankle flexors and extensors compared to age-matched non-fallers.[22] All participants were nursing home residents and fall status was determined retrospectively, with at least one fall in the previous year marking an individual as a faller. Of the two joints tested on an isokinetic dynamometer at velocities of $60°/sec^{-1}$ and $100°/sec^{-1}$, ankle power was more significantly decreased than knee power in fallers and was only 19.8% of the ankle power of non-fallers. In addition, fallers were less able to produce power at higher velocities than non-fallers, as revealed by a smaller increase in torque with greater velocities when compared to non-fallers, suggesting that fallers are markedly sensitive to the velocity component of muscle contractions. While this novel study produced encouraging results in understanding an unacknowledged mechanism responsible for falling, few studies followed that might confirm these findings until over a decade later.

In 1991, Fleming et al. measured leg power output in fallers and non-fallers ranging from 19-92 years old.[21] Leg power was determined as the maximum rate of standing or sitting down from a chair measured through a force transducer positioned under the participants' feet. This procedure for measuring power was acknowledged as being more practical as well as efficient in measuring power in multiple joints by simultaneously and maximally recruiting muscles controlling the hips, knee, and ankle. The results showed that peak leg power was negatively correlated with age. Fallers moved at a significantly slower rate when standing and sitting from the chair compared to non-fallers, indicative of poor leg power. In fact, the peak power results from this study could correctly identify 17 out of 21 fallers and only falsely classified one non-faller as a faller. It is noted that the four fallers who could not be pinpointed as fallers likely fell for reasons others than poor leg power. The researchers that conducted this study concluded that the ability to rise quickly from a chair is related to the capacity to climb stairs, walk, and execute quick movements, tasks which require similar muscle groups and that predict falls when performed poorly.

Several studies began to emerge after the turn of century that demonstrated that leg power is significantly lower in fallers when compared to non-fallers.[7, 11, 24] A study by Skelton et al. recruited 20 female older adult fallers (having had ≥ 3 falls within the preceding year) and 15 community-dwelling female age-matched non-fallers.[9] In this study, when leg extension power output values were adjusted for body mass, fallers were 24% less powerful in their weakest leg than non-fallers. Without adjusting power output for body mass, no difference was seen between the two groups. Skelton et al. also tested isokinetic concentric strength of the quadriceps, hamstrings and plantar- and dorsi-flexors, isometric strength of the quadriceps and hamstrings, and eccentric quadriceps strength; other than weight adjusted ankle dorsi-flexion, none of these strength tests were significantly different between fallers and non-fallers. These findings suggest that lower limb explosive power is likely more indicative of a future fall potential than leg strength. Furthermore, 65% of the fallers had power outputs less than 1.5 W/kg, the functional threshold that has been proposed as the minimum leg power capacity needed to securely step up onto a 30-centimeter step.[48] In contrast, 26% of the non-faller group fell under this value.

Perry et al. conducted a retrospective study very similar to that by Skelton et al. and measured 44 older adult non-fallers (75.9 ± .6 years), 34 older adult fallers (76.4 ± .8

years), and 44 healthy young adults (29.3 ± .6 years).[7, 11] Compared to Skelton et al. this study considered fallers as individuals who fell at least once in the year prior to the study. It was found that the older adult fallers had significantly lower leg extension power and leg extension strength than the older adult non-fallers. Power decrements were more pronounced in the fallers compared to the non-fallers than strength; the fallers generated 85% of the leg extension strength of the non-fallers, but only 79% of the leg extension power of the non-fallers. In addition, the healthy young adults were significantly more powerful than both older adult groups, showing that leg power is affected by age. The authors concluded that because leg power reflected apparent differences between fall conditions and age groups, it seems to be the most legitimate indicator of future fall risk.

In Italy, Sieri and Beretta also grouped participants as fallers or non-fallers based on their fall history over the year prior to the study.[16] They too assessed lower limb strength and power, as well as balance, gait parameters, and several clinical measures. Knee extension/flexion and ankle dorsi-/plantar-flexion power were measured on an isokinetic dynamometer. Male fallers had a significantly reduced average ankle plantar-flexion power of 0.13 W at 60º/sec, compared to the non-fallers who produced an average 0.20 W. Female fallers exhibited less power than the non-fallers during knee extension at both 60º/sec (.22 W and .34 W, respectively) and 120º/sec (.33 W and .49 W, respectively).

Chu et al. tested and monitored several potential functional and clinical fall risk components and recorded fall incidents (defined as two or more falls) over a one-year period as well.[24] They recruited 1571 Chines emale and female community-dwelling older adults. One of the functional measures included was single knee extension power and this was a significant predictor of single and especially recurrent falls. However, only leg power on the left leg was an independent predictor of falling (relative risk = 0.84, 95% CI: 0.79, 0.97). As discussed previously, this study also found functional measures such as gait speed and balance to be strong predictors of falls, once again supporting the conclusion that poor leg power may underlie poor performance on functional tasks. With these findings, the authors recommended that functional predictors, such as lower limb muscle power should be included in assessments of fall risk.

In a large prospective cohort study done by Chan et al., 5,995 community-dwelling older adult men were tested for fall risk predictors.[23] Physical activity measures such as leg extension power, gait characteristics, grip strength, and chair stand performance were analyzed. The follow-up time in this study averaged 4.5 years, during which time participants were contacted on a tri-annual basis to determine the number of fall incidents occurring. They found that men in the three highest leg extension power quartiles were at a decreased risk of falling compared to the bottom quartile (highest leg power quartile vs. lowest: relative risk = 0.82, 95% CI: 0.73, 0.92). Given the number of participants in this study, and the consistency of results from other studies, leg power is a significant determinant of fall risk for older adults.

Key Research

Leg Power Asymmetry and Fall Risk in Older Adults

Studies assessing leg power and functional task performance have traditionally compared measurements from the stronger or dominant leg or the total power of both legs combined.[16, 38] However, recent research indicates that while power asymmetries between legs may not hinder younger adults, leg power asymmetry may be a strong predictor of functional performance and falling in older adults.[7, 11, 25] Having one leg that is significantly less powerful than the other may disrupt postural stability and the ability to counteract balance losses leading to a fall.[26] In terms of functional performance, high leg power asymmetry between legs has been associated with slower walking speed, poorer balance, and decreased stair climbing capacity — the same tasks in which poor performances increase fall risk.[4-5, 15-20, 25, 27]

Few studies have examined leg power asymmetry in relation to fall risk. In the first known study to investigate leg power asymmetry in fallers and non-fallers, Skelton et al. found that in community-dwelling older adult women, a group of 20 fallers were more asymmetrical when it came to leg extension power than a group of 15 aged-matched non-fallers.[7] Participants' power on each leg was measured on a specialized leg press machine called the Nottingham Power Rig, which was designed for testing older adults. In this study, 60% of fallers and only 13% of non-fallers had more than a 10% difference in leg power between legs while there were no differences in strength asymmetry. In combination with their finding that fallers were 24% less powerful than non-fallers in their weakest leg, these power asymmetry findings further support the role of lower limb power in fall risk rather than strength alone.

Perry et al. also studied leg extension power asymmetry between a group of fallers and non-fallers on the Nottingham Power Rig.[11] As discussed previously, these researchers used a retrospective approach to identify male and female fallers and their participants were divided into 44 older adult non-fallers, 34 older adult fallers (one fall in the previous 12 months), and 44 healthy young adults. Again, they found that fallers were

21% less powerful than the non-fallers; however, in contrast to Skelton et al., fallers within this study were no more asymmetrical in leg extension power than the non-fallers.[7]

There are several explanations that Perry et al. proposed for the differing results seen within their study and those by Skelton et al.[7, 11] First, the study by Skelton et al. recruited only women participants, and it could be that the inclusion of less asymmetrical men altered the findings. Furthermore, Perry et al. noted that individuals who participated in their study were relatively physically active, possibly producing less asymmetry. In addition, while Skelton et al. considered a faller someone who had experienced at least three falls in the past year, Perry et al. classified a faller as someone who had at least one fall in the past 12 months. Perry et al. questioned whether the use of less active and frailer individuals in the earlier study led to the significant differences found by Skelton et al.

A prospective study by Portegijs et al. also established greater power asymmetry between legs as a predictor of injurious falling.[26] A large sample size of 433 older adult females was tested on the Nottingham Power Rig. After testing, a one-year follow-up procedure was conducted. Of the women who fell, 22% and 12% had a single or recurrent injurious fall within the follow-up period, respectively. This study defined leg power asymmetry as a value falling in the lowest tertile. Compared to the participants who did not exhibit leg power asymmetry, women with asymmetry were 1.7 times more likely to experience one injurious fall and 2.2 times more likely to experience recurrent injurious fall. Based on their findings, the authors concluded that leg extension power asymmetry is a distinct and powerful determinant of single and particularly recurrent injurious falls. While this study followed individuals for one year and benefited from a large sample size, only falls resulting in injury were recorded and it is unclear whether leg power asymmetry would be a more or less significant risk factor for non-injurious falls had these falls been included in the analysis.

The relationship between leg power asymmetry and fall risk in older adults has not been widely researched and has produced inconsistent findings. Only two studies were found that directly assessed leg power asymmetry between older adult fallers and non-fallers, each with contradictory results.

Power Asymmetry and Falls Research Flaws

In addition to the lack of research within leg power asymmetry and fall risk, the literature directly assessing differences in leg power asymmetry between fallers and non-fallers consists of several flaws.

Gender of Participants

The inclusion of only one gender within this research area is common. The study by Skelton et al. summarized previously utilized only female participants and found that fallers were significantly more asymmetrical in leg extension power than non-fallers.[7] It is unclear, however, whether the results would be similar for male fallers. The study by Perry et al. also used very similar methods to that of Skelton et al and found that leg extension power asymmetry was lower in fallers than in non-fallers across *both* genders, but not significantly so.[11] Perhaps leg power asymmetry in men contributes to falling more so than in women, which might explain why these inconsistent findings were seen. Because of these inequalities, it is essential that research within fall prevention utilize both genders in order to draw conclusions that represent all fallers.

Muscle Groups Tested

The three studies that examined leg power asymmetry and fall risk used a Nottingham Power Rig leg press machine for assessing power in each leg. While this machine recruits the major muscles of the legs, it does not separately test muscular power at individual joints. No studies have been found that measured the power asymmetry of the hip, knee, or ankle joint independently. In addition, studies that measure power asymmetry in anything but the sagittal plane are lacking. It is important to measure each joint separately to test in multi-planar directions in order establish whether each joint's power asymmetry is associated with falling.

Effective movements in both the frontal and sagittal plane at the hip joint have proven to be integral for successful recovery steps after tripping or losing balance.[49-50] Research has shown that reductions in maximum step length, which have been associated with higher fall risk, are also associated with declines in strength and speed during extension at the hip joint.[51] The hip adductor and abductor muscles are also particularly important in countering medial-lateral imbalances that could lead to falling via lateral recovery steps.[50] In addition, fall-related hip fractures are typically the result of lateral falls, making the hip abductors and adductors especially critical for the prevention of these injuries.[52]

This study will focus specifically on the hip joint as this had not been researched before. This is necessary to fully understand the exact nature of hip power asymmetry in fall risk. In addition, due to the fact that a limited number of studies have examined leg power asymmetry and fall risk, studies that begin to analyze leg power asymmetry in individual joints are warranted.

Definition of a Faller

It is important to acknowledge that the definition of what constitutes a faller varies among leg power and fall risk literature. One study considered an older adult a faller when they had one or more fall incidents within a 12-month period.[11] Another study used two or three falls within a year to identify a faller.[7] Nevitt found that the relationship between individual risk factors and those having fallen only once was lower than that between risk factors for multiple falls.[32] Single falls are less predictable occurrences and are often the result of a condition that would cause a younger individual to fall, rather than intrinsic musculoskeletal or neural deficiency.[32] Thus, this study defined fallers as those who fell two or more times the year prior to data collection.

Conclusions

Within this research, the finding that poor leg power is predictive of falls has been generally supported, while the relationship between leg power asymmetry and fall risk is less understood. Inconsistencies in participant gender and the definition of a faller, as well as inadequate research, are concerns within leg power asymmetry and fall risk research. Research has begun to support the use of power training for the older adult population, but a better understanding of leg power capacity and asymmetry at specific joints, such as the hip, between older adult fallers and non-fallers is needed.[53]

Summary of the Literature Review

As fall incidents represent the number one cause of morbidity and mortality within older adults, the importance of understanding the causes and developing prevention strategies is evident.[1] Falls not only lead to a poorer quality of life for older adults and those they are close to, but also result in significant health care costs. While many other factors may be involved in the severity of fall risk such as medications prescribed, environmental hazards, fall history, certain diseases, and age, those that may be most preventable with physical conditioning, including leg power changes, warrant attention. Age-related losses in muscular mass through the process known as sarcopenia lead to reductions in both muscular force production and power capacity. Power decrements may be dramatic and begin earlier in life than deteriorations in force production capacity.[37]

Many studies have examined the relationship between leg power and fall risk with functional performance. These studies indicate that leg power capacity is a significant determinant of both functional performance in a variety of tasks and that the performance of these functional tasks is related to fall status. The relationship between fall risk and leg power capacity has also been well supported within the literature. However, studies looking at leg power asymmetry are few and contradictory. Based on the limitations in the current research that have been identified through this review of the literature, further research is warranted. The purpose of this study was to determine if a difference exists between older adult fallers and non-fallers in the degree of leg power asymmetry exhibited at the hip. Leg power asymmetry has shown to be related to functional tasks that contribute to fall risk. Thus, it was hypothesized that fallers will exhibit greater asymmetry of leg power between their hips than non-fallers

Study Benefits

Given the overwhelming incidence and associated consequence of falls within the older adult population, research regarding the cause and prevention of such episodes is imperative in finding the most successful prevention and treatment programs. The results of this study may provide a better understanding about the role of muscular leg power and asymmetry in determining fall risk for older adults. Coupled with findings from previous studies, information obtained through this study could also help determine the most appropriate methods for fall prevention training programs for older adults.

CHAPTER 3: METHOD

The purpose of this study was to determine whether a difference existed in hip flexion, extension, abduction, and adduction power asymmetry in community-dwelling older adult fallers and non-fallers. Fallers were hypothesized to be more asymmetrical in hip power in each direction at each testing speed.

Participants

Male and female community-dwelling older adults 65 years and older were recruited for this study (mean age 76.5 ± 6.9 years). Two groups were devised consisting of fallers (mean age 76.4 ± 6.5 years) and non-fallers (mean age 76.5 ± 7.5 years). Originally a sample size of 25 participants per group was selected as the desired recruitment number. This value was determined appropriate by a power analysis, using group means and standard deviations from a similar study.[7, 54] In the end, 18 fallers and 21 non-fallers participated. Fallers were defined as individuals who have experienced a minimum of two fall incidents within the last 12 months.

Recruitment

Participants were recruited from the following programs and/or locations: Boise State University kinesiology department senior strength training program, Boise Fit and Fall Proof programs, Boise YMCA centers, and the Hearing and Balance Center at the Boise Elks Rehabilitation Hospital. Phone calls, e-mails, and fliers were used to announce the need for participants at these locations. Recruitment was also performed via word of mouth.

Participant Protection

Approval from the Boise State University Institutional Review Board (IRB) was obtained prior to beginning this study (see "IRB Approval" in Appendix A). Participation was strictly voluntary and a written informed consent was obtained from each participant prior to taking part in the study (see "Consent to be a Research Participant" in Appendix B).

Exclusion Criteria

Based on information provided in a health history questionnaire, individuals who indicated any of the following conditions were excluded from the study: unstable or acute disease, pain that might interfere with testing performance, hip or knee replacements, neurological disorders, or the inability to walk independently.

Measurements and Instruments

Health History Assessment

An American College of Sports Medicine health history questionnaire was completed after a participant had signed the informed consent form (see "Health History Questionnaire" in Appendix C).[55] This form was used to determine participant characteristics such as age, weight, height, BMI, disease history, pain and/or disability experienced, medications used, cognition, and fall characteristics and incidence.

Physical Activity Assessment

Physical activity level was assessed using the Physical Activity Scale for Elders (PASE) (see "PASE" in Appendix E).[56] The PASE is a brief questionnaire aimed at determining the level of physical activity in older adults over a week. It consists of questions regarding time and intensity of leisure time, sport, and recreational activities. A

PASE score is calculated by multiplying the number of hours spent in specific activities and participation (yes/no) in an activity by empirically assigned points for all activities. The PASE has shown to be both a reliable and valid instrument in assessing the physical activity level of older adults.[56]

Leg Power Assessment

Leg power was measured on a Cybex II isokinetic dynamometer machine (The Cybex Ergometer Company, Ronkonkoma, NY). Research shows that isokinetic machines are both reliable and valid when measuring peak torque in older adults and that both experienced and inexperienced test facilitators have been shown to be equally reliable when testing older adults on these instruments.[57-59, 60] With an isokinetic dynamometer machine, a constant movement velocity is maintained while the performer executes a dynamic contraction as forcefully as possible. With limb and adjacent joints in a fixed configuration, the machine matches the force that is produced by the subject, producing a close to constant intensity throughout the entire range of motion.

While not a direct measure of power (force or torque multiplied by velocity), isokinetic peak torque has shown to be strongly related to isokinetic power within several studies (r = 0.76-0.98).[61-63] Kannus et al. found that total work, which is a component in calculating power, measured at multiple velocities offers little additional information than that obtained by peak torque measurements (r = 0.70-0.93).[64] Furthermore, research indicates that power dependent functional tasks such as the vertical jump and single-leg hops are strongly correlated to leg peak torque measurements on isokinetic machines (r = 0.71-0.767).[65-66] Because velocity is held constant by the isokinetic machine, one can assume that changes in peak torque values are the result of changes in muscular contraction velocity rather than overall strength. Power is calculated by measuring the area under the peak torque curve, which, without the computer programs that accompany these, may be more difficult to attain. Peak torque is an easily obtained value on new and old isokinetic machines, which increases the applicability of this research. Thus, in this study, peak torque was measured as an indicator of power at the hip joint.

Procedure

Participant Orientation and Early Screening

Informed consent forms including a study description, as well as health history and physical activity questionnaires were handed out to those interested in participating (see "Informed Consent" in Appendix A and "Healthy History Questionnaire" in Appendix B). These forms took 30-45 minutes to fill out. Two groups were then created, fallers and non-fallers.

Practice Sessions and Testing

Isokinetic testing was conducted at the Idaho Sports Medicine Institute (ISMI) in Boise, Idaho. This practice session lasted between 30-60 minutes. Upon arrival, each participant completed a short warm-up on a bike followed by low-intensity elastic band exercises that mimicked those used in testing. Practice and testing consisted of the following concentric movements: hip abduction/adduction and hip flexion/extension. For the practice session, participants were instructed on how to use the isokinetic machine and practiced at speeds ranging from 60-300º/sec on their right leg, simply to develop a feel for the movement.

The first several individuals, consisting of both fallers and non-fallers, participated in pilot testing to determine the most appropriate testing velocities for data collection. Four velocities were determined ideal for testing for both hip flexion/extension and hip abduction/adduction: 60°/sec, 120°/sec, 180°/sec, and 240°/sec. These velocities were chosen based on the observation that many of the pilot participants could not match speeds greater than 240°/sec for abduction and flexion, movements where gravity does not positively aid contraction speed in the selected testing positions. In addition, it was deemed important to test at a variety of velocities ranging from slow to fast for a more extensive analysis of the relationship between hip power asymmetry and fall status.

The testing session was similar to the practice session. After warming up, weight and height were measured. Next, participants were tested at the four velocities for hip flexion, extension, abduction, and adduction. All participants were tested in the same order: 1) hip flexion and extension, and 2) hip abduction and adduction. The right leg of each participant was tested first for each movement. For both tests, the axis of rotation of the participant's hip was aligned with the mechanical axis of rotation on the machine. For hip extension/flexion testing, participants laid supine on a padded table with a pillow under their head. The lever of the machine was attached just above the knee and a belt placed around the hip region to secured the participant to the table. Participants were instructed to raise their leg up with a flexed knee (hip flexion) and bring the leg back down to an extended position (hip extension) for each repetition with maximal force. The leg that was not being tested rested in a flexed knee position with the bottom of the foot resting on the table.

For abduction/adduction testing, participants laid on their side with a pillow under their head. The lever arm of the machine was again positioned proximal to the knee.

Participants were instructed to complete a straight leg raise (hip abduction) and bring the leg down (hip adduction) with as much force as possible.

Participants were instructed to perform at maximal effort, maintaining the set velocity, and strong verbal encouragement was provided. One set of three consecutive repetitions at each velocity for each movement was executed. An additional set was added at a specific speed if it was deemed the individual performed unusually or failed to carry out maximal effort. The highest peak torque values obtained in each movement and velocity were used for analysis.

Research Design and Data Analysis

For hip power abduction and adduction tests, there were several speeds in which a large proportion of the participants in both groups could not maintain the targeted speed. When speed is not matched, no actual torque is produced. When this occurs for both legs in the same test, it is not possible to calculate asymmetry. In general, a higher percentage of fallers were unable to attain speeds at the aforementioned speeds. Data for abduction at 180 and 240 °/sec as well as adduction at 240 °/sec was not analyzed based on the observation that majority of participants were unable to perform quickly enough to produce results in these tasks.

The statistical hypotheses for the this study were that fallers would be more asymmetrical in: 1) hip flexion at 60 °/sec, 2) hip flexion at 120 °/sec, 3) hip flexion at 180 °/sec, 4) hip flexion at 180 °/sec, 5) hip extension at 60 °/sec, 6) hip extension at 120 °/sec, 7) hip extension at 180 °/sec, 8) hip extension at 240 °/sec, 9) hip abduction at 60 °/sec, 10) hip abduction at 120 °/sec, 11) hip adduction at 60 °/sec, 12) hip adduction at 120 °/sec, and 13) hip adduction at 180 °/sec.

All data were analyzed using SPSS version 17.0 (SPSS Inc., Chicago, IL). Hip power asymmetry was calculated by the percent difference in peak torque between each leg. Descriptive statistics were carried out for peak torque asymmetry measurements, age, weight, height, BMI, and physical activity level. A 2x13 (falling status X testing condition) ANOVA was conducted to determine whether a group difference existed between each of the 13 test measures. The grouping independent variable for this analysis was fall status (faller vs. non-fallers). The dependent variables were hip flexion, extension, abduction, and adduction at each of the selected speeds. Effect size for these tests was analyzed by calculating Cohen's d. While not a main purpose of this study, group differences in average relative power were also assessed using 2x13 ANOVA.

As there were a total of 13 dependent variables being tested, a factor analysis was conducted to determine interdependencies among these variables. The factor analysis revealed the following groups: 1) 60º/sec flexion, 120º/sec flexion, 60º/sec extension, 120º/sec extension, 2) 180º/sec flexion, 240º/sec flexion, 180º/sec extension, 240º/sec extension, 3) 120º/sec abduction, 60º/sec adduction, 180º/sec adduction, 240º/sec adduction, and 4) 120º/sec flexion, 60º/sec abduction. Based on the findings from the factor analysis, a Bonferroni correction was used to adjust the alpha level from .05 by 4 or 2 depending on which group the test variable fell in. Since flexion at 120º/sec was grouped in two factors, alpha was divided by 4, which was the number of variables in the largest factor it was associated with. Thus, all variables were tested using an alpha level of .015 except for abduction at 60º/sec, which was tested at an alpha level of .025.

A global hip power asymmetry score was calculated by averaging the raw asymmetry scores for each individual on each hip movement test.

Group differences in age, physical activity level, weight, height, and BMI and mean asymmetry over the 13 tests were assessed using independent t-tests. Differences in asymmetry between genders were analyzed using a 2x13 ANOVA where the grouping variable was gender and the dependent variables were the 13 hip power tests. Again, the alpha level was adjusted using the Bonferroni correction method.

CHAPTER 4: RESULTS

Descriptive Characteristics

Within this study, the non-faller and faller groups consisted of 21 (10 females, 11 males, mean age 76.4 ± 6.5 years) and 18 (14 females, 4 males, mean age 76.5 ± 7.5 years) participants, respectively. Fallers reported falls in multiple directions, including forward, backward, and lateral; however, the majority of falls listed were backward falls. Independent t-tests showed that no group differences were seen in age, body mass, height, BMI, or physical activity level (see Table 1). A 2x13 ANOVA determined that no group differences in gender existed in any of the 13 asymmetry tests; however, throughout all tests, there was a tendency for women to be more asymmetrical than men.

Table 1.1 Group Means and Standard Deviations for Descriptive Characteristics

	Age (years)	Gender (M/F)	Body Mass (kg)	Height (m)	BMI (kg/m^2)	Physical Activity (PASE Score)
Fallers	76.5 ± 7.53	14/4	71.2 ± 21.8	1.6 ± .1	26.7 ± 8.1	97.4 ± 48.1
Non-fallers	76.43 ± 6.5	11/10	73.7 ± 11.2	1.7 ± .1	26.7 ± 3.0	117.0 ± 48.8

The two groups did not differ in age, body mass, height, BMI, or physical activity level.

<u>Overall Power Differences</u>

There was a trend for fallers to be less powerful over the 13 tests performed when the power of each leg was adjusted relative to body mass and averaged (see Figure 1.1, 1.2, and 1.3). However, no significant differences were found in overall hip power between groups. The percentage of fallers who could not produce torque at abduction at

180º/sec, abduction at 240°/sec, and adduction at 240°/sec was 83.3%, 72.2%, and 61.1%, respectively. In comparison, the percentage of non-fallers who did not generate data for these tests was 61.9%, 47.6%, and 38.1%.

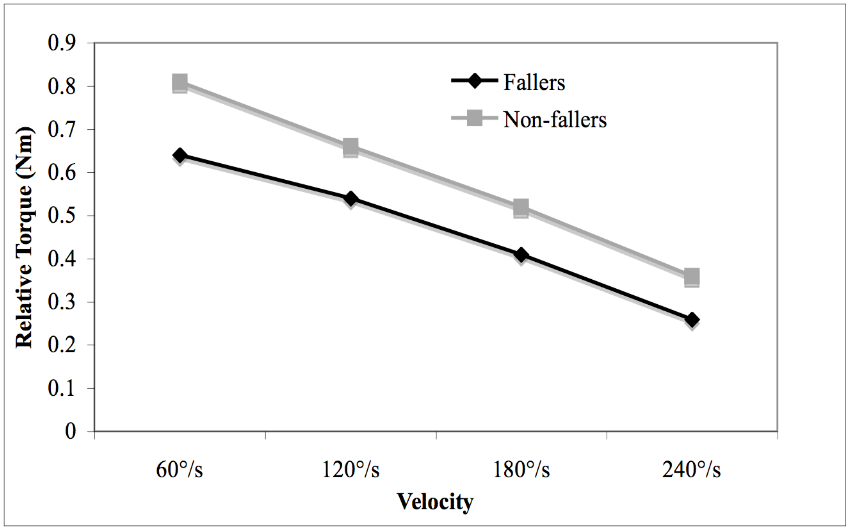

Figure 1.1 Group Differences in Flexion Power

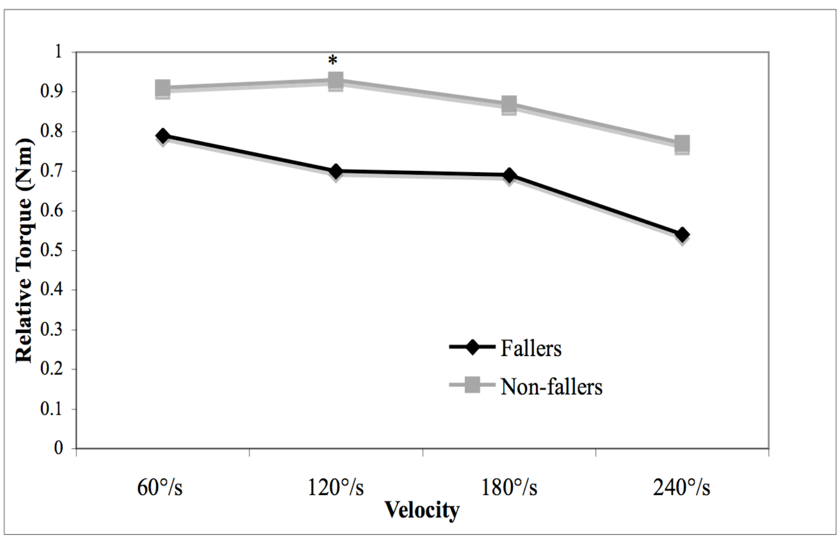

Figure 1.2 Group Differences in Extension Power
Significantly different ($p < .015$)

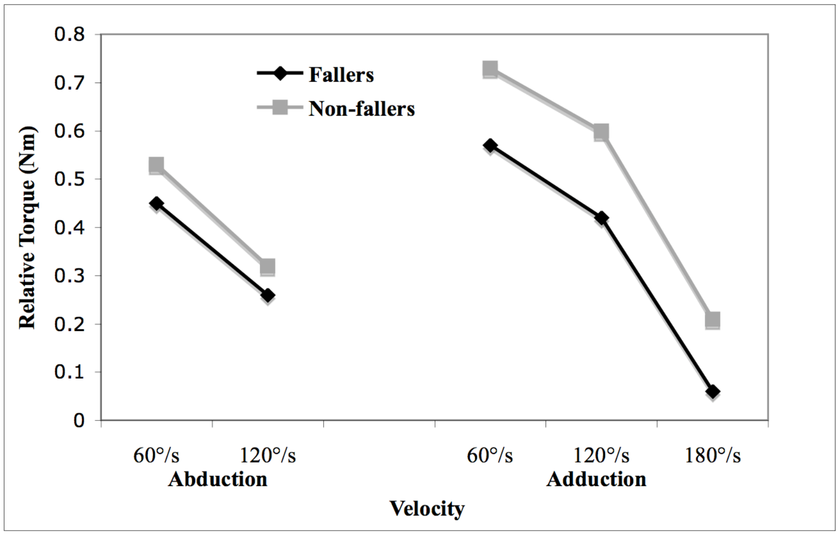

Figure 1.3 Group Differences in Abduction and Adduction Power

<u>Global Asymmetry</u>

When asymmetry was averaged for each person across the 13 power tests, it was found that fallers were overall more asymmetrical than non-fallers ($F(1,37) = 7.9$, $p < .05$) (see Table Figure 1.4).

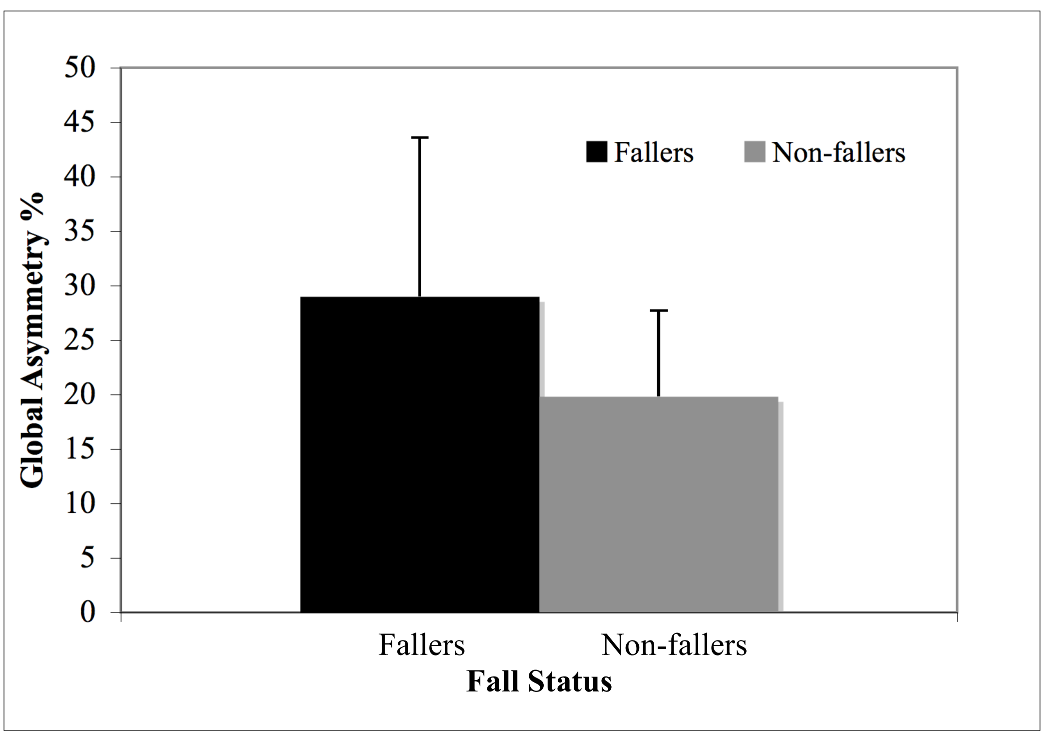

Figure 1.4 Group Differences in Global Asymmetry

Hypotheses Testing: Hip Power Asymmetry

Flexion/Extension Power Asymmetry

A one-way ANOVA showed a group difference in asymmetry at 60°/sec flexion, with fallers being significantly more asymmetrical than non-fallers ($F(1, 36) = 6.96$, $p < .015$). No statistical group differences were identified in flexion at 120°/sec, 180°/sec, and 240°/sec, and extension at 60°/sec, 120°/sec, 180°/sec, and 240°/sec, yet fallers were more asymmetrical in every test (see Table 2.1 and Figure 2.1). One faller was unable to produce torque at 180°/sec and two were unable to produce torque at 240°/sec flexion. One non-faller's data was not analyzed for flexion at 60°/sec because errors in data collection were made that lead to ambiguous recordings of torque. Effect sizes for these variables can be seen in Table 2.1.

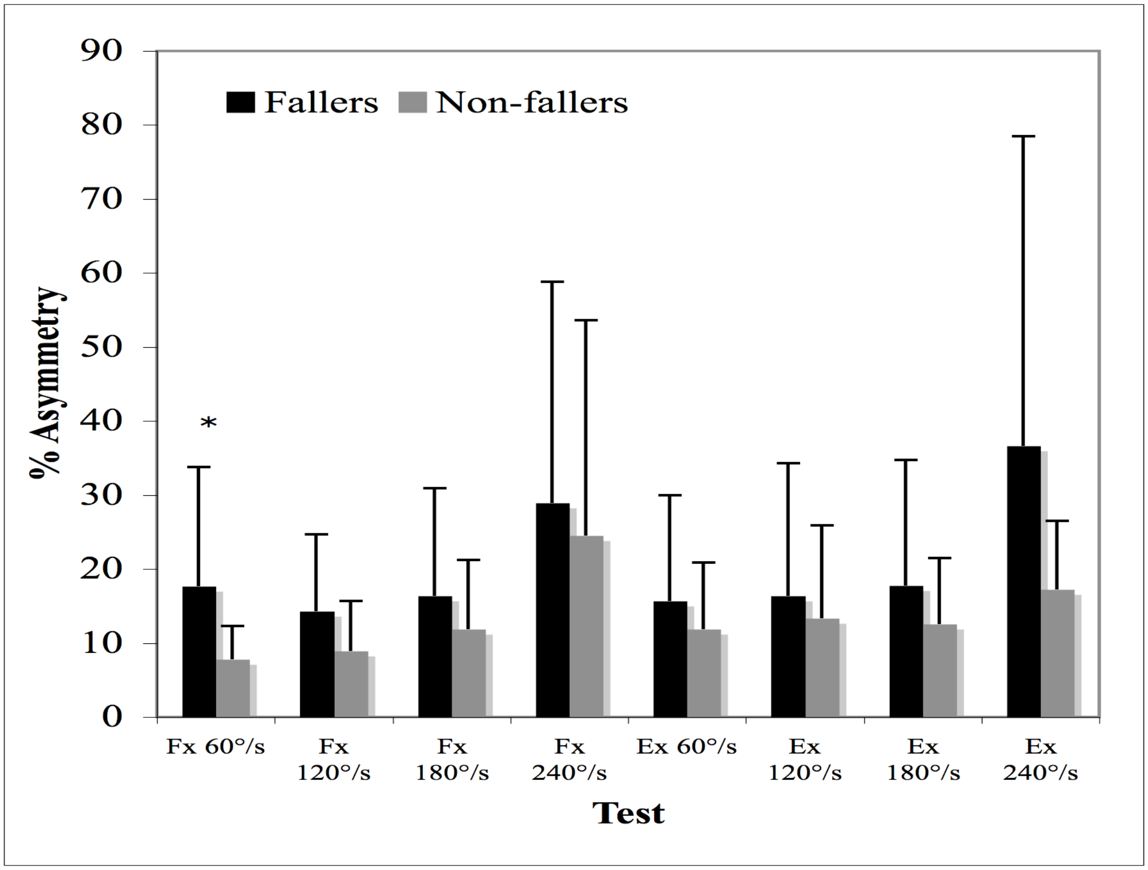

Figure 2.1 Hip Power Flexion & Extension Asymmetry Between Groups
*Significantly different (*p* < .015).

Table 2.1 Hip Power Asymmetry Means for 13 Tests

	Fallers (% power asymmetry)	Non-fallers (% power asymmetry)	Effect Size (Cohen's d)
Flexion 60 °/sec	17.7 ± 16.1	7.8 ± 4.5	0.8
Flexion 120 °/sec	14.3 ±10.4	8.9 ± 6.8	0.6
Flexion 180 °/sec	16.4 ±14.5	11.9 ± 9.3	0.38
Flexion 240 °/sec	28.9 ±29.9	24.5 ± 29.1	0.15
Extension 60 °/sec	15.7 ± 14.3	11.9 ± 9.0	0.32
Extension 120 °/sec	16.4 ±17.9	13.3 ± 12.76	0.21
Extension 180 °/sec	17.8 ± 16.9	12.6 ± 9.0	0.35
Extension 240 °/sec	36.6 ± 41.9	17.2 ± 9.3	0.97
Abduction 60 °/sec	29.1 ± 36.2	16.3 ± 19.9	0.44
Abduction 120 °/sec	42.0 ± 37.2	50.0 ± 44.1	0.2
Adduction 60 °/sec	27.6 ± 23.7	22.4 ± 16.5	0.26
Adduction 120 °/sec	37.9 ± 33.2	20.6 ± 27.4	0.56
Adduction 180 °/sec	65.1 ± 47.1	44.7 ± 41.4	0.46

* Significantly different (p < .015)

Abduction/Adduction Power Asymmetry

No significant differences were seen between groups in any of the abduction and adduction asymmetry means. Although not significant, fallers were more asymmetrical than non-fallers in all abduction and adduction tests except abduction at 120º/sec. Unlike flexion and extension, there were no participants in either group who failed to produce torque for the tests chosen for analysis (see Table 2.1 and Figure 2.2).

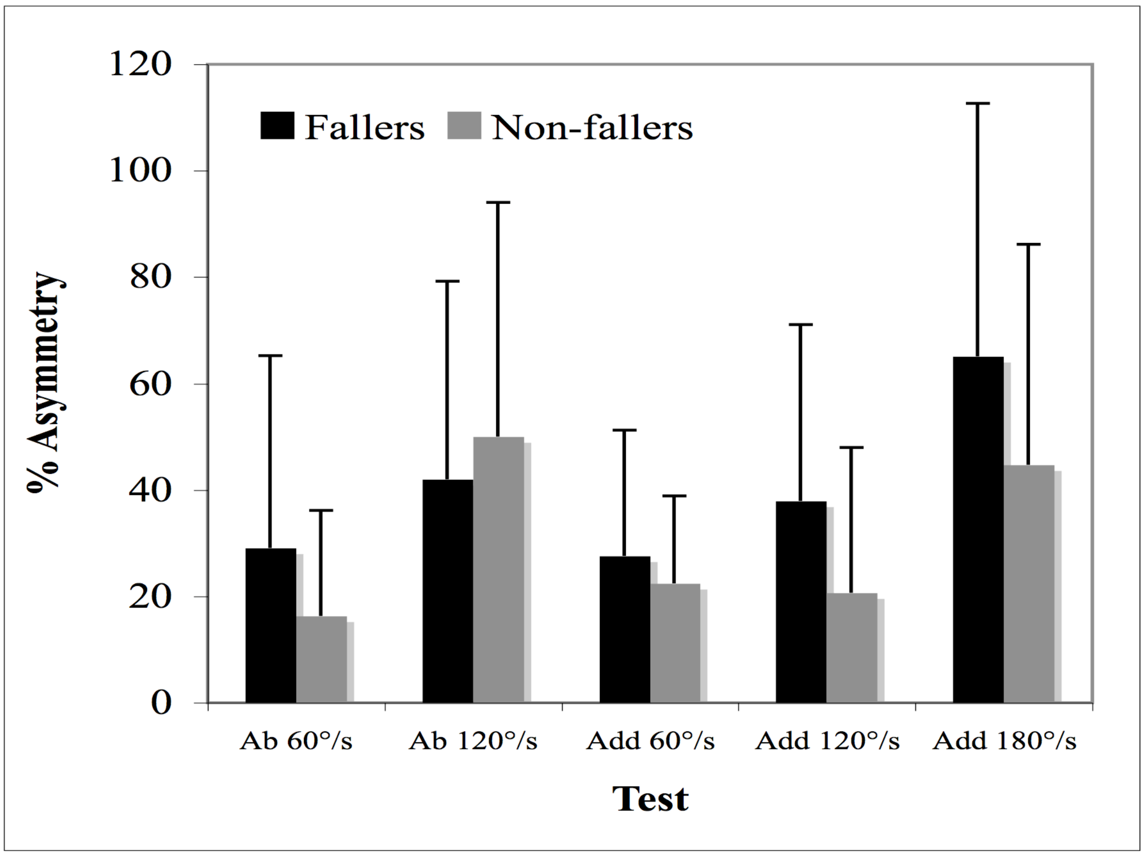

Figure 2.2 Hip Power Abduction & Adduction Asymmetry Between Groups

CHAPTER 5: DISUCSSION

Leg power declines with increasing age and poor leg power has been shown to be predictive of falling.[7-9, 11] The purpose of this study was to determine if leg power asymmetry, specifically at the hip, is greater in older adult fallers compared to non-fallers when assessed with isokinetic peak torque at a variety of speeds.

Aside from hip power asymmetry, fallers were less powerful than non-fallers on all tests, however, not significantly. A greater percentage of fallers were unable to produce torque during abduction at 180 °/sec, and 240 °/sec abduction and adduction. For these tests, torque was not produced by many individuals because they were unable to achieve the speeds set on the isokinetic dynamometer. Thus, contraction velocity, a component of power, was clearly a limiting factor. This finding, as well as the trend for lower levels of hip power in fallers compared to non-fallers over all tests, is similar to research that shows a significant decrease in power in individuals who fall compared with those that do not.[7, 11]

In addition to overall power differences, analysis of the covariates revealed that women were slightly more asymmetrical then men, but not significantly so. Furthermore, no significant group differences in age, height, weight, BMI, or physical activity were found; however, fallers were overall slightly less physically active than non-fallers.

Asymmetry of Hip Power

Within power testing, there was a trend for fallers to be more asymmetrical in hip power in every movement and speed except for abduction at 120º/sec; however, only flexion at 60 º/sec was significant. Reduced hip flexion speed has been shown to be related to decreased ability to recover from a slip.[49] Having one leg that is significantly less powerful in flexion may be enough to prevent a successful recovery step.

Based on these results, the hypotheses that fallers would be more asymmetrical at 60º/sec flexion was confirmed. A large effect size of .80 was shown for this test, suggesting that the relationship between fall status and hip power asymmetry at 60º/sec flexion is strong. The remaining hypotheses, which stated that fallers would also be more asymmetrical in the other eleven tests, were not confirmed.

Although a hypothesis was not developed for global asymmetry, in hindsight, this value did significantly differ between groups. In overall average asymmetry throughout the 13 tests, fallers were more asymmetrical than non-fallers. Given that 12 out of the 13 tests did not show significant group differences, it could be that the combined asymmetry in both the sagittal and frontal plane may be more related to fall risk than unidirectional and uni-planar movements. Perhaps effective leg stability and/or recovery steps are not limited to one direction or one plane, but rather the combination of power in multiple directions. This could explain why the majority of the asymmetry tests in single directions did not significantly differ, yet when the combination of these movements was analyzed group differences were revealed.

This study included a large number of performance tests with inconsistent results. Given these incongruent results, this study supports both of the two prior studies that are similar in nature to this study, yet produced contradictory results. The study by Skelton et al. and that by Perry et al. both utilized the Nottingham Power Rig, a specialized leg press machine, to measure leg power asymmetry.[7, 11] Skelton et al. found that fallers were significantly more asymmetrical than non-fallers, while Perry et al. found no difference. The findings from the present study showed that although there was a trend toward asymmetry, fallers were only statistically more asymmetrical in 60 º/sec hip power flexion — in agreement with those found in Skelton et al.'s study.[7] On the other hand, results from the remaining tests showed that fallers were not significantly different and this supports Perry et al.[11]

Explanations of Findings

An explanation as to why only one of the hip power asymmetry tests was significantly different between the groups is challenging to establish. It is important to note, once again, that although hip power asymmetry was only significantly different between groups for two tests, 11 out of 12 of the remaining tests showed that fallers were generally more asymmetrical. Perry et al. observed similar findings despite seeing no significant group differences in leg power asymmetry.[11] Several of the tests that were not significant had medium to large effect sizes, suggesting that the trends were not just apparent but meaningful as well. There are several possible reasons why group differences in asymmetry did not reach significance throughout all of tests within the study at hand.

Skelton et al. found that their fallers were less active than the non-fallers counterparts, which could have influenced the degree of power asymmetry difference between groups.[7] Perry et al. considered this and reasoned that perhaps their findings did not agree with Skelton et al's because they recruited more physically active individuals.[7, 11] All participants within the current study were recruited from physical activity classes; thus, they were more like those in Perry et al.; and like Perry et al., there was no significant difference between fallers and non-fallers in the majority of tests. Perry et al. questioned whether using more frail individuals would yield different results and the same suggestion can be made for this study.

Within this study, a larger proportion of the faller group was comprised of women and there was an overall non-significant tendency for women to be more asymmetrical than men for all tests. This finding supports previous work suggesting that older adult women experience falls more frequently than older adult men.[7, 67] Perry et al. recruited both males and females and saw no group difference in asymmetry, while Skelton et al. recruited only females and did observe a group difference.[7, 11] The results of the present study as well as those from the two previous studies raise the question as to whether hip power asymmetry affects fall risk for women more so than men.

It is possible that the fallers in this study did not experience enough falls to allow for these tests to be discriminatory. Nevitt et al. suggests that the definition of a faller should be someone who experiences two or more falls in one year, as one-time falls are less associated with underlying risk factors and more with spontaneous circumstances.[32] However, perhaps testing participants with three or more falls, as Skelton et al. did, would reflect stronger predictions of fall risk factors. They found that fallers were more asymmetrical in leg press power than non-fallers. Contrary to these findings, Perry et al., who defined falling as a single event, found no significant group difference in leg press power asymmetry between fallers and non-fallers.[11] The findings of this study are most congruent with those of Perry et al. and different classifications of fallers within the research may contribute to the confounding results. It could be that two falls in one year are more spontaneous and less predictive of underlying deficiencies than 3 or more falls in one year. Future research should recruit a larger participant population to allow for correlating the number of fall incidents and hip power asymmetry to determine whether fallers who experience more frequent falls display more asymmetry.

The two previous studies conducted on leg power asymmetry and fall risk used a machine that measured total leg power asymmetry. It could be that high leg power asymmetry overall is a stronger risk factor than power at a single joint. It is unclear whether individuals would display similar degrees of asymmetry at each joint. Measuring power at the hip only may have masked asymmetries at the knee or ankle. Perhaps, if measurements were taken at each joint, the group difference in power asymmetry at the knee or ankle would be more similar to those of Skelton et al., who found a significant group difference.

The sample size of the present study may have contributed to the lack of conclusive results. However, Skeleton et al. recruited similar numbers of women only, 20 non-fallers and 15 fallers and found a group difference in leg power asymmetry.[7] Perhaps, because of potential gender differences, when males and females are combined, a larger sample size is warranted to identify significant findings. Although there are possible explanations for why group differences were not seen in all asymmetry tests in the present study, no clear relationship seems to exist to explain why significant differences were seen in only one of the tests. What is certainly clear is that an obvious trend existed with fallers displaying more hip power asymmetry than non-fallers.

Limitations

Limitations for this study may have impacted the data. When conducting a retrospective study such as this, uncertainty exists in knowing whether older adult participants accurately remember their fall incidents or lack thereof. Cummings et al. found that many older individuals do not always remember their fall history with complete accuracy.[68] To support this, some of the original non-falling participants who could not initially recall any falls, subsequently indicated they had fallen. Many non-fallers, particularly men, seemed very reluctant to admit falling as if it would label them negatively, indicate an inability for self-care, and/or affect other people's opinion of them. It is unknown whether any other non-fallers actually did experience a fall but were either unwilling to acknowledge, or unable to remember falling.

Secondly, this study recruited only community dwelling older adults who were all recruited from physical activity classes. Whether the results of this study would be replicated in more frail older adults, such as those residing in nursing homes, or whether less independent individuals would display different patterns of hip power asymmetry, is unknown. Also, a limitation of this study is the inability to determine whether hip power asymmetry preceded falling in those who fell, or if the asymmetry was a result of a fall incident and subsequent adaptations.

The hip was chosen for analysis in this study because no study has looked at a single joint and effective movements at the hip are essential for recovery step when falling.[49-50] It is common when conducting isokinetic testing to test at several velocities and with multiple repetitions. Furthermore, with the tests in this study participants were required to work at maximal effort. Therefore, the time and physical stress of testing was taken into account when selecting how many joints to test. It was decided that testing one joint might be most appropriate for this population. However, testing only one joint limits the impact of this study as it is unclear whether asymmetry of one joint contributes to fall risk more so than others.

During testing, the degree of effort that fallers and non-fallers exerted seemed to differ. Through observation, it appeared that fallers were more hesitant and less consistently performed with maximal effort when compared to non-fallers. It has been found that experiencing falls often causes older adults to limit their activity and be plagued by a constant fear of falling.[32] If one does not perform at their maximal capacity on these tests, it is likely that each leg might perform at a similar submaximal level, therefore leading to an underestimating of the actual asymmetry that exists.

Another limitation when assessing falls is that the nature of fall risk has proven to be multi-faceted.[5] Even if research shows that asymmetry is a risk factor for falling, it would not mean that it contributes to all falls. Most individuals possess several risk factors, and it is likely that most falls are the result of multiple influences.[5] While most fallers within this study demonstrated hip power asymmetry, there were some who did not. It could be that group differences were not significant across all tests within this study because for some fallers, hip power asymmetry contributed to fall incidence while it did not for others.

Causes of Asymmetry

Leg power is believed to decline with age via losses in both strength and power owing to declines in physical activity, poor nutrition, and neural and hormonal adaptations.[34] However, the exact cause of asymmetry within the older adult population, and in particular fallers, is uncertain. It is unknown as to whether the fallers exhibited hip power asymmetry prior to falling or whether responses to their falls are the source of such asymmetry. Since falling has the tendency to increase anxiety that leads to reduced physical activity, it could be that asymmetry for many fallers is a result of lower levels of activity brought on by the fear or physical limitations of a previous fall or multiple falls.[32] Hip power asymmetry could also be the aftermath of a previous leg injury or disease, either as a results of, or causing, a fall.[11]

Future Research and Application

There are several directions that future studies exploring this topic might take. First, as noted previously, a major limitation of retrospective studies of this manner is the inability of many older adults to successfully remember their fall history. If the time length of research is not an issue, it may be more appropriate to test a large group of older adults and then perform a long-term follow-up study recording fall incidents on a regular basis. Older adults are likely more apt to remember their falls if they have happened recently, rather than over the course of a year. If this method is not feasible, using a past-history of 6 months rather than a 1-year time frame for fall incidents may increase the strength of fall recollection.

Within this study, there was a clear tendency for higher levels of hip power asymmetry in women compared to men. Since gender may play a role in the degree of hip power asymmetry an individual has, it is important to continue to control for gender, either by gender-matching groups, studying only one gender at a time, or through statistical means.

As mentioned previously, Skelton et al. found significant group differences in leg power asymmetry between fallers and non-fallers.[7] They defined fallers as individuals who had experienced three or more falls in the year prior to data collection. Research that uses a higher number of falls to identify fallers than the present study may be more revealing of underlying risk factors. Future researchers might consider using a definition of fallers similar to that of Skelton et al. In addition, with a large sample size, stratifying fallers into multiple categories based on number of fall incidents might provide more information on the nature of hip power asymmetry and fall risk.

Although hip power asymmetry has not yet proven to be a consistent significant fall risk factor, fallers were generally more asymmetrical in this study. Although less asymmetrical than fallers, many non-fallers had very high levels of hip power asymmetry as well. In addition, overall leg power asymmetry has been associated with aging, fall risk, and functional performance.[7, 11, 25] Thus, it might be argued that improvements in hip and overall leg power asymmetry would at least benefit function, if not also reduce fall risk. Furthermore, future research should seek to determine the causes and treatment for leg power asymmetry in the older adult population. The findings that leg power declines more significantly than leg strength in older adults and that poor leg power is associated with falling has led to research analyzing the effects of power training in older adults.[53, 69] It has been shown that older adults who participate in power training (i.e., resistance training at high velocities) can improve leg power, even with advanced age.[53, 69] However, the effects of resistance training on leg power asymmetry have yet to be determined.[7]

As noted previously, it is uncertain whether asymmetry in the hip, knee, or ankle contribute to fall risk equally. More research is needed to compare the differences in power asymmetry between the hip, knee, and ankle to determine whether each is related to fall risk and which joint affects fall risk most significantly. Research should also begin to analyze the difference in uniplanar vs. multiplanar asymmetry as it relates to fall risk.

Conclusions

This study found a trend for fallers to be more asymmetrical in power at the hip at most speeds of flexion, extension, abduction, and adduction, but only significantly so at 60º/sec flexion. The inconsistent findings within this study may be attributed by factors such as gender discrepancies in hip power asymmetry, performance effort between groups, ability of the older adult population to recall past falls, participant physical activity levels, and the definition of what constitutes a faller. In addition, it could be that global asymmetry is a greater contributor to fall risk than asymmetry in one movement plane and at one speed. This was the first study to measure leg power asymmetry specifically at the hip; thus, additional research is needed to better establish the effects of hip power asymmetry, as well as power asymmetry at other lower extremity joints and the lower extremity as a whole, on fall risk.

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APPENDIX A

Institutional Review Board Approval Letter

BOISE STATE UNIVERSITY

Office of Research Compliance
Institutional Review Board
HumanSubjects@boisestate.edu | 208.426.5401

DATE: Friday, December 18, 2009

TO: Lauren McDonald (PI)
Dr. Shawn Simonson (co-PI)

FROM: Institutional Review Board (IRB)
c/o Office of Research Compliance

SUBJECT: IRB Notification of Approval
Project Title: *Hip Power Asymmetry in Older Adult Fallers an Non-fallers*

The Boise State University IRB has approved your protocol application. Your protocol is in compliance with this institution's Federal Wide Assurance (#0000097) and the DHHS Regulations for the Protection of Human Subjects (45 CFR 46).

Review Type: Expedited
Approval Number: 103-MED10-014
Annual Expiration Date: December 17, 2010

Your approved protocol is effective for 12 months. If your research is not finished within the allotted year, the protocol must be renewed by the annual expiration date indicated above. Under BSU regulations, each protocol has a three-year life cycle and is allowed two annual renewals. If your research is not complete by **December 17, 2012**, a new protocol application must be submitted.

About 30 days prior to the annual expiration date of the approved protocol, the Office of Research Compliance will send a renewal reminder notice. The principal investigator has the primary responsibility to ensure the ANNUAL RENEWAL FORM is submitted in a timely manner. If a request for renewal has not been received 30 days after the annual expiration date, the protocol will be considered closed. To continue the research after it has closed, a new protocol application must be submitted for IRB review and approval.

All additions or changes to your approved protocol must also be brought to the attention of the IRB for review and approval before they occur. Complete and submit a MODIFICATION/AMENDMENT FORM indicating any changes to your project.

When your research is complete or discontinued, please submit a FINAL REPORT FORM. An executive summary or other documents with the results of the research may be included.

All relevant forms are available online. If you have any questions or concerns, please contact the Office of Research Compliance, 426-5401 or HumanSubjects@boisestate.edu.

Thank you and good luck with your research.

Ron Pfeiffer

Dr. Ronald Pfeiffer
Chairperson
Boise State University Institutional Review Board

APPENDIX B

Informed Consent Form

CONSENT TO BE A RESEARCH PARTICIPANT

BOISE STATE UNIVERSITY

A. PURPOSE AND BACKGROUND

Lauren McDonald, a masters graduate student in the Boise State University Kinesiology department is conducting a research entitled "Hip power asymmetry in fallers and non-fallers". The purpose of this study is to determine whether a difference exists in the amount of muscular power discrepancy between hips, within older adult individuals with and without a history of falling. Muscular power is the rate at which muscles can develop force. You are being asked to participate in this study because you are a healthy volunteer, over the age of 65.

B. PROCEDURES

If you agree to be in the study, the following will occur:

1. You will be asked to fill out a health history and physical activity questionnaires and will be participating in maximal muscular testing on an isokinetic dynamometer machine. The isokinetic dynamometer machine is similar to machine-based weight lifting machines, except it involves movement through a constant speed. This machine matches the amount of resistance that you produce against it.

2. After completing all necessary forms, two appointments will be made in which you will first come in and practice on the isokinetic dynamometer machine. During this session you will warm-up on a bicycle for 5-minutes, complete some elastic band exercises and then practice on the actual testing machine. A week after this practice session you will come back to complete actual testing.

3. For the testing session you will first be weighed and have your height measured. Then you will perform a similar physical warm-up as the practice session, including a 5-minute warm-up on a bicycle, light elastic band exercises, and submaximal practice leg contractions on an isokinetic dynamometer machine. Each leg will be tested separately. In each test, a device will be strapped to the thigh just above the knee and you may be belted around the abdominal region to ensure stability. Two hips tests will be done while lying down on a padded table. In one test you will lie on your back and be instructed to push your knee up and then bring it down. For the second hip test, you will lie on your side and raise your straightened leg up, and then down. For both tests the machine will be strapped to your thigh just above the knee.

4. After the warm-up is completed, maximal testing will begin. Two different movements will be tested at the hip. Each movement will be tested at 3-5 different movement speeds. For each of these speeds one test trial will be performed with three consecutive repetitions. A two-minute rest period will separate trials.

These procedures will be done at the Idaho Sports Medicine Center located at the Boise State Football Stadium on campus. There is free parking outside the clinic. All participants must sign in at the front desk before the testing session begins.

C. RISKS/DISCOMFORTS

1. Maximal testing on isokinetic dynamometer machines requires maximal effort performance and you may experience some fatigue or feel uncomfortable in the testing positions. These feelings are only temporary and if at any point you wish to discontinue, your decision will be respected.

2. There is a slight chance of muscle injury when maximally testing, especially when individuals are not properly warmed-up. Every attempt will be made to ensure that you are ready to test. If an injury should occur, you will not be expected to continue participation. Individuals who have experience with these types of injuries with be available at all times to take proper action. The Idaho Sports Medicine Institute employs physical therapists, medical doctors, and other personnel that are experienced in all health related emergencies.

3. The health history form includes an in-depth list of questions regarding your health status. These questions may make you uncomfortable or upset, but you are free to decline to answer any questions you do not wish to answer or to stop your participation at any time.

4. Confidentiality: Participation in research may involve a loss of privacy; however, your records will be handled as confidentially as possible. Only Lauren McDonald and the individuals serving on her research committee will have access to the study records. No individual identities will be used in any reports or publications that may result from this study. All personal data will be stored in a coded format in a locked office.

D. BENEFITS

In participating in this study you will gain knowledge about isokinetic and weight lifting machines that is perhaps new to you. The information that you provide may help health professionals better understand the degree to which leg power discrepancies underlie falls.

E. COSTS

A cost of this study is the time spent to participate. Additionally, individuals may experience slight muscle soreness as a result of maximal testing.

F. PAYMENT

There is no payment for participating in this study.

G. QUESTIONS

If you have any questions or concerns about participation in this study, you should first talk with the chair of my thesis committee: Shawn Simonson, by calling (208) 426-3973 or emailing: shawnsimonson@boisestate.edu. If for some reason you do not wish to do this, you may contact the Institutional Review Board, which is concerned with the protection of volunteers in research projects. You may reach the board office between 8:00 AM and 5:00 PM, Monday through Friday, by calling (208) 426-5401 or by writing: Institutional Review Board, Office of Research Compliance, Boise State University, 1910 University Dr., Boise, ID 83725-1138.

H. CONSENT

You will be given a copy of this consent form to keep.

PARTICIPATION IN RESEARCH IS VOLUNTARY. You are free to decline to be in this study, or to withdraw from it at any point. Your decision as to whether or not to participate in this study will have no influence on your present or future status as a participant in future research or programs at BSU or with the facility that you were recruited from.

I give my consent to participate in this study:

______________________________ ______________
Signature of Study Participant Date

I give my consent to be audio taped in this study:

______________________________ ______________
Signature of Study Participant Date

______________________________ ______________
Signature of Person Obtaining Consent Date

THE BOISE STATE UNIVERSITY INTSTITUTIONAL REVIEW BOARD HAS REVIEWED THIS PROJECT FOR THE PROTECTION OF HUMAN PARTICPANTS IN RESEARCH.

APPENDIX C

Health History Questionnaire Form

Health History Questionnaire

Instructions: This form should be completed after the informed consent has been assigned. Please fill this form out with as much detail and accuracy as possible. If you are unsure what a question is asking or unfamiliar with any of the terminology in this questionnaire, please ask for assistance from the study administrator. All information provided here will remain strictly confidential.

Name: ________________________________ Age: ____ Gender: ________

Race: ______________ Phone number: _______________________________________

E-mail address: ____

Emergency contact phone number: __________________ Relation: ______________

<u>Personal Health History</u>

Please list any medications (prescription and non-prescription) that you are currently taking:

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Please report any fall incidents that you have experienced in the past 12 months. Please provide detail about how you fell, what you fell on and the approximate date in which each fall occurred:

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Please describe any past or present serious injuries or illnesses:

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Please list any past hospitalizations and what they were for:

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If you have ever had or now have any of the following, please check "Yes" and provide details at the end.

Yes__ No__ A recent significant change in the resting ECG suggesting myocardial infarction (heart attack) or other acute cardiac event

Yes__ No__ Recent complicated infarction

Yes__ No__ Unstable angina (chest pain)

Yes__ No__ Uncontrolled ventricular or atrial arrhythmia that comprises heart function

Yes__ No__ Third degree A-V block without a pace maker

Yes__ No__ Acute congestive heart failure

Yes__ No__ Severe aortic stenosis

Yes__ No__ Suspected or known dissecting aneurysm

Yes__ No__ Active or suspected myocarditis or pericarditis

Yes__ No__ Thrombophlebitis or intracardiac thrombi

Yes__ No__ Recent systemic or pulmonary emboli

Yes__ No__ Acute infection

Yes__ No__ Significant emotional distress (psychosis)

Yes__ No__ Resting diastolic blood pressure >115 mmHg or resting systolic blood pressure > 200 mmHg

Yes__ No__ Moderate valvular heart disease

Yes__ No__ Known electrolyte abnormalities (e.g., hypokalemia, hypomagnesmia)

Yes__ No__ Fixed rate pacemaker

Yes__ No__ Frequent or complex ectopy

Yes__ No__ Ventricular aneurysm

Yes__ No__ Uncontrolled metabolic disease (e.g., diabetes, thyrotoxicosis or myxedema)

Yes__ No__ Chronic infectious disease (e.g., mononucleosis, hepatitis, AIDS)

Yes__ No__ Neuromuscular, musculoskeletal, or rheumatoid disorders that exacerbated by exercise

If you answered yes to any of the follow conditions, please explain:

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Please list any other medical conditions or contraindications to exercise that have not been noted:

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I have read this questionnaire and have answered all questions truthfully and to the best of my knowledge.

______________________________ ____________
Signature of participant Date

_____________________________ __________
Signature of witness Date

*Adapted from ACSM's Guidelines for Exercise Testing and Prescription, Lea & Febiger, 1995 (pg. 42).

APPENDIX D

PASE

For more information on the PASE, please visit: www. Neriscience.com/web/default.asp