Fall Risk in Older Adults with Hip Osteoarthritis: Decreasing Risk Through Education and Aquatic Exercise

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ABSTRACT

Purpose: The **primary purpose** of this project was to determine the effect of aquatic exercise and aquatic exercise combined with an education group program on decreasing both psychosocial and physical fall risk factors in community-dwelling older adults with hip osteoarthritis (OA). **Secondary purposes** were to 1) describe fall risk, history and nature of falls and near-falls in older adults with hip OA, 2) determine the association of the timed up and go test (TUG) to history of falls and near-falls, 4) explore the relationship of both psychosocial and physical factors to history of falls and near-falls, and 5) evaluate the role of falls-efficacy in predicting balance performance. **Methods:** Participants were recruited from the community and screened for presence of hip osteoarthritis and fall risk. Baseline fall history and a battery of measures for balance, muscle strength, functional ability and falls-efficacy were administered. Participants were then randomly assigned to one of three groups: Aquatic Exercise, Aquatic Exercise and Education or a Control Group. The interventions were twice per week for 11 weeks. Fall risk factors were measured after 11 weeks. Study 1 described history of falls and near-falls and evaluated the association of the TUG screening test with fall and near-fall history. Study 2 summarized the relationships of physical and psychosocial fall risk factors and identified the primary predictors of fall risk, based on associations with fall history. Study 3 evaluated the randomized controlled clinical trial comparing the impact of the interventions (aquatic exercise and education) on fall risk outcomes. **Results:** Older adults with hip OA reported a high frequency of falls and near-falls. The TUG, using a cut-off score of 10 sec., was associated with frequent near-fall history. There was a strong association of frequent near-falls to history of actual falls, with the association increasing 7-fold if lower falls-efficacy was present. Falls-efficacy was also an independent predictor of balance impairment. Screening for history of near-falls and falls-efficacy may be important in predicting risk of future falls. The combination of Aquatic Exercise and Education improved falls-efficacy and functional mobility compared to Aquatic Exercise only or no intervention. Aquatic Exercise on its own was not effective in decreasing fall risk factors or improving falls-efficacy. **Significance of Findings:** The accumulation of both physical and psychosocial risk factors in older adults with hip OA increases their vulnerability to falls and injury. Fall prevention programs for this population should be designed to include both exercise and education to address falls-efficacy and physical fall risk factors.

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You can find the following quote in Lord of the Rings by J.R.R. Tolkien: "*There is nothing like looking, if you want to find something. You certainly usually find something, if you look, but it is not always quite the something you were after.*" To me this summarizes the adventure and excitement of doing clinical research. The participants become part of the research team, interweaving their experiences into the tapestry of theory and inquiry. I have gained an abundance of knowledge by listening to their stories. Each time I enter a project I end up finding something else and this always comes from the participants who have allowed me to enter into their lives. I would like to acknowledge all of the older adults who volunteered for this study; I truly believe that this is your research, not mine.

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Dedication

This thesis is dedicated to my parents, William and Joan McCusker. Losing both of you within 8 months of each other was the hardest thing I have ever endured; but of course it was you who taught me how to carry on through the good times and bad times, to stick to my dreams and persevere. Your consistent and quiet support of everything I have done and accomplished in my life is the foundation of who I am. I miss you, but you are with me always.

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Conceptual Definitions

Activities of Daily Living: Activities related to personal care and include bathing or showering, dressing, getting in or out of bed or a chair, using the toilet, and eating.

Exercise: A single or acute bout of bodily exertion or muscular activity that requires an expenditure of energy beyond resting level, and generally results in voluntary movement.

Physical activity: A general term used to describe movement in which the goal is to sustain daily living or recreation. Similarly to exercise it requires energy expenditure and often provides health related benefits.

Impairment: Loss or abnormality of anatomic, physiologic or psychologic structure or function.

Disability: The inability to perform actions, tasks, and activities usually expected in specific social roles.

Functional limitation: Restriction of the ability to perform, at the level of the whole person, a physical action or task in an efficient, typically expected or competent manner.

Passive motion: Mobility performed without any muscular activation (someone or something else performs the movement).

Passive overpressure: Adding a sustained manual pressure or stretch force at the end of the joint range of motion.

Planes of motion: There are three imaginary planes that motion occurs in relation to an axis in the human body: transverse (rotational movements), sagittal (front to back motion) and frontal (movement outwards or away from the body and then inwards).

Internal rotation: A transverse plane movement that the anterior aspect of the segment rotates inwards.

External rotation: A transverse plane movement that the anterior aspect of the segment rotates outwards.

Abduction: A frontal plane motion that the segment moves away from the central axis of the body.

Extension: A sagittal plane movement that the segment moves posterior from the body's neutral position.

Flexion: A sagittal plane movement that the segment moves anterior from the body's neutral position.

Arthroplasty: Any reconstructive joint procedure, with or without a joint implant, designed to relieve pain and/or restore joint motion. A total hip arthroplasty is a complete joint replacement.

Self-Efficacy: People's beliefs about their capabilities to produce effects and exercise influence over events that affect their lives.

Mastery: Building coping skills and instilling the belief that one can exercise control over outcomes and potential threats.

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List of common abbreviations used:

AIMS-2: Arthritis Impact Measurement Scale Version 2
ABC: Activities and Balance Confidence Scale
ADL: activities of daily living
BBS: Berg Balance Scale
BMI: body mass index
CI: confidence interval
cm.: centimeter
C: celsius
HHD: Hand held dynamometry
kg.: kilogram
MSL: Maximal Step Length
MANOVA: multivariate analysis of variance
m.: meter
MCTSIB: Modified Clinical test of Sensory Interaction and Balance
OR: odds ratio
OA: osteoarthritis
PASE: Physical Activity Scale for the Elderly
PT: physical therapist
RCT: Randomized controlled clinical trial
Refsqrt: reflect and square root
RR: relative risk
ROM: Range of motion
Sqrt: square root
TUG: Timed up and Go
vs.: versus
%: percent

CHAPTER 1

INTRODUCTION, PURPOSE AND OBJECTIVES

The cost of falls to individuals, society and the health care system is substantial. One out of three adults over the age of 65 years and one out of two over the age of 80 years falls annually[4]. It is not just the higher incidence of falling in older adults that is a concern, but the combination of high incidence and a higher susceptibility to injury. The elderly sustain a disproportionate percentage of serious injury from trauma, accounting for nearly 1/3 of deaths while representing only 12% of the trauma population[11]. Falling accounts for 77% of all elderly injury-related hospital admissions in Saskatchewan and is the cause of 57% of injury related deaths among females and 36% among males in Canada[170, 189].

Up to 90% of all hip fractures in older adults are linked to falls[157] and contrary to popular opinion, falling is the strongest single risk factor for fracture, not osteoporosis[100]. Over 80% of low trauma fractures occur in people who do not have osteoporosis as defined by bone mineral density[190]. A one standard deviation change in bone mineral density increases fracture risk 2 to 2.5 times; whereas a sideways fall increases hip fracture risk 3 to 5 times and when a sideways fall causes direct impact to the greater trochanter of the femur the risk of hip fracture increases to 30 times[165]. A hip fracture can have devastating effects on survival and future quality of life. A Saskatchewan study found that 26% of older adults with hip fracture die within the first year post fracture with up to 70% not returning to their previous functional status and many admitted into long-term care[91]. There is a one in six lifetime risk of hip fracture for women, higher than the risk of breast cancer, with a greater mortality rate[173]. For seniors who do survive a fall or recover from serious injury, the consequences of chronic pain, decreased functional ability, stopping involvement in social and recreational activities and increased fear of falls can lead to decreased quality of life and progression to frailty[70, 152, 207].

An estimated cost of fall related injuries for seniors in Canada in 1994 was 2.8 billion dollars[70]. These data do not take into account the long term consequences of falls such as admission to long term care, hospitalization or need for home care. The incidence of hip fracture is increasing steadily, at approximately 40% per decade[12]; directly related to demographic projections of an aging population. For example, it's estimated that the percentage of the population over age 65 years will almost double from 12% in 1996 to 23% in 2041 resulting in approximately 10 million seniors in Canada[70]. These changing demographics will account for about 60% of the projected increase in hip fractures over the same time[174]. Clearly finding solutions and preventative measures to falls and their consequences is a serious health care concern. Identifying older adults at highest risk of falls is the first step in instigating effective community fall prevention programs. The first study in this thesis describes the number, nature and circumstance of falls in the population of older adults studied and evaluates the ability of a commonly used screening test to identify those at higher risk.

Osteoarthritis (OA) affects 1 in 10 Canadians [10] and is a common cause of functional deterioration in older adults. The presence of hip OA, although associated with increased bone mineral density, is not necessarily protective of fragility hip fractures[6, 7, 103]. The reason for this may be due to inaccuracy of bone density measurements to estimate fracture risk in this population, or it may be due to increased incidence of falling in older adults with hip OA, thus exposing them to greater risk of fracture. Indeed, clients with new episodes of hip pain do have increased occurrence of falls[149]. In a review of 16 fall risk studies[4] one of the priority risks identified is the presence of any type of arthritis, with a higher mean relative risk of predicting future falls than age or cognitive status. Lower limb weakness, slower gait, decreased mobility and pain, all outcomes of hip OA, are also established fall risk factors[44, 118, 214].

Interventions to prevent falls include environmental modifications, education on decreasing fall risk, exercise incorporating balance and/or strengthening and various combinations of these delivered individually or in group settings. The optimal type of exercise or combination of exercise with other interventions to prevent falls has not yet been established. However, programs targeting specific intrinsic factors for those at greatest risk have shown the most benefit[44, 80]. Multi-factorial programs that include education combined with exercise may have greater benefit than exercise alone, but the research is not conclusive[80]. Education focused at decreasing fear of falls and improving confidence to participate in physical activity may result in greater opportunity to improve physical function and thus, decrease the risk of falls. Fear of falls is common in older adults and is more prevalent in populations with joint pain[68, 98, 145]. Improving confidence or self-efficacy to avoid a fall (falls-efficacy) may decrease this fear and its consequences. Self-efficacy has been positively associated with motivation, mood and positive attitudes linked to developing behaviors to prevent disease and promote health[13, 134]. Further research is needed to evaluate exercise combined with falls-efficacy enhancing group programs, particularly for vulnerable populations where there is increased fear of falls, social isolation and depressed mood, such as older adults with joint pain due to arthritis.

Aquatic exercise has been recommended as an effective alternative exercise compared to balance and strengthening activities on land to decrease fall risk for individuals who are frail, severely kyphotic or suffer from pain or poor balance[75]. As well, aquatic exercise is often recommended as an optimal exercise for individuals with OA due to a decreased loading impact on joints, and subsequent diminished pain with exercise[5]; however, the research to substantiate this benefit is lacking[76].

As the population in Canada over the age of 65 continues to grow and the incidence of hip fracture rises, the need to identify older adults at risk of falling and intervene with the appropriate program to alleviate falls and fracture is a significant public health priority. This study will provide valuable knowledge of 1) the nature and incidence of falls in older adults with hip OA, 2) the relationship of psychosocial factors such as falls-efficacy to physical fall risk factors such as balance and the association of these factors to history of falls and 3) the impact of an exercise program rarely studied, aquatic exercise, combined with an educational program designed to enhance falls-efficacy. This will add a unique contribution to a growing body of research on the best type of intervention to improve fall risk factors in higher risk populations. There is little research on the efficacy of exercise or education in the population of older adults with hip OA, despite the growing numbers of adults over age 65 years with this common condition. Improving function and delaying need for surgical intervention may substantially improve quality of life, decrease surgical waiting lists and reduce health care costs.

The design of this study leads naturally to three parts or three studies that will be discussed separately in Chapters 3 to 5. The first two studies are primarily descriptive in nature based on screening and baseline data derived for the intervention study (Chapter 5) which is the primary focus study. The preliminary descriptive studies in chapters 3 and 4 are included as there is a paucity of research related to fall risk in older adults with hip OA. These two studies were not designed separately to address the comparison of fall risk to a control population; therefore, any conclusions derived from them are limited; nevertheless, the results may help in developing future research questions in this area. The specific objectives and hypotheses for each study are described below.

STUDY 1: The history of falls and the association of the TUG to falls and near-falls in older adults with hip OA

Objective: The primary purpose of this study was to describe fall risk, history and nature of falls and near-falls in community living adults over age 65 with hip OA. A secondary purpose was to determine the association of the TUG with fall and near-fall history. This study is descriptive for this population, with no hypothesis.

STUDY 2: The relationship of physical and psychosocial factors to fall history and near-fall history and the association of falls-efficacy to balance performance in older adults with hip OA

Objectives:

1) Determine the relationship of history of falls and near-falls with physical and psychosocial fall risk factors in older adults with hip OA.
2) Evaluate the role of falls-efficacy in predicting balance performance in older adults with hip OA.

Hypotheses:

1) Factors associated with the presence of hip OA such as low falls-efficacy, balance deficits, delayed reaction time and decreased strength will be associated with history of falls and near-falls.
2) Higher levels of falls-efficacy for dual task function, reactive balance and more challenging functional tasks will predict better performance of dual task TUG, reaction time, BBSm (Berg Balance Scale modified), and the MCTSIB (Modified Test of Sensory Interaction and Balance).

STUDY 3: The effect of aquatic exercise and education on improving indices of fall risk in older adults with hip OA: A randomized controlled clinical trial

Objective:

Determine the effect of aquatic exercise and aquatic exercise combined with an education group program on fall risk factors in community-dwelling older adults with hip osteoarthritis.

Hypotheses:

1) Both aquatic exercise alone (Aquatic) and the combined aquatic and education program (Aquatic-Education) would improve primary and secondary **physical** fall risk factors in balance, gait, lower body strength, function and mobility compared to Control.

2) Aquatic-Education would result in greater improvement in **falls-efficacy** as compared to both Aquatic and Control.

3) Aquatic-Education would show greater improvement in primary and secondary **physical** fall risk factors involving more complex balance and functional tasks (dual task TUG (TUG_{cog}), 30 second chair stand, BBSm, MCTSIB and reaction time) compared to Aquatic.

CHAPTER 2

REVIEW OF LITERATURE

The literature review summarizes: 1) the current evidence and knowledge related to the relationship of hip OA to fall risk in the elderly, 2) the efficacy of exercise programs, in particular aquatic exercise, on improving the consequences and fall risk factors related to OA, and 3) the role of education combined with exercise in promoting positive health change for the elderly.

SECTION I: FALL RISK AND HIP OA

2.1 Defining Falls and Near-Falls

The reduction in frequency of falling is one of the established outcomes of fall prevention programs; however, the conclusions from these data are not definitive because the definition of falls and determination of falls incidence are inconsistent across studies. In a review of the literature from 1987 to 2005, 30 definitions of falls were identified [230]. The most common definition used is by the Kellogg group [105] where a fall is defined as "an event which results in a person inadvertently coming to rest on the ground or other lower level and other than as a consequence of the following: sustaining a violent blow, loss of consciousness, sudden onset of paralysis as in a stroke, epileptic seizure" [105, 230]. This definition does not account for falls that might occur as the result of cardio-vascular related events causing dizziness, syncope or other unexplained reasons. Others have utilized definitions that provide more leeway for causes of falls and further delineate the landing surface. Tideiskaar[205] defined a fall as "any event in which a person inadvertently or unintentionally comes to rest on the ground or another lower level such as a chair, toilet, or bed".

Previous falls predict the chance of subsequent falls; however there are also factors such as perturbations of balance or "near-falls" that are important predictors. Many would argue that it is just as important to measure near-falls as actual falls. Although the greatest injury is likely to be sustained in a fall to the ground or floor, the frequency of near-falls may be more important in identifying the population who is at greatest risk of sustaining a future fall related injury. Few studies have defined or evaluated near-falls. One of the difficulties in determining a definition is the uncertainty that participants will accurately recall falls and near-falls. Falls to the ground resulting in a major injury such as a fracture may be remembered for months after the incident, while near-falls or falls with minor injury may not be recalled as easily. These difficulties in reporting fall incidences were evident in a study done by Cummings et al.[57]. In this study of 304 men and women over age 60 years, 32% did not recall a documented fall incident while 6% of the subjects who reported a fall actually had not fallen. As well, if a clear definition of falling and near-falling is not used, participants may only interpret falls as those where injury is sustained, and under report minor and near-falls [230]. A near-fall is defined as a slip, trip or loss of balance where the person starts to fall but is able to stop or prevent the fall to the ground or other lower surface [168]. In this way slips (sliding of the support leg), trips (impact of the swinging leg with an external object) can be a near-fall but could also be a reason for an actual fall. Differentiating and clearly defining falls and near-falls is important in order to clarify participants' descriptions and capture all recalled fall-related events.

2.2 Fall Risk Factors

The reasons, consequences and location of falls vary depending on the population and environment studied. The majority of falls in the elderly (65 to 77%) have been found to occur indoors at home[44, 47, 228]. Other studies, however, have found more falls occur outside of the home[26, 153]. More serious falls resulting in fracture occur more often at home in older individuals who are less healthy and are poorer ambulators, whereas fall related injury in adults aged less than 75 years more often occur outdoors as the result of external factors such as ice, obstacles, or rough ground[1, 153]. Environmental hazards have been identified as contributing factors in at least 50% of reported falls and the number of environmental hazards in the home increases one's risk of falling [47]. There is no clear distinction between environmental versus intrinsic cause, though; impairment in balance or strength may have contributed to the fall despite the presence of an environmental hazard.

There was no seasonal variation in fall-related hip fracture in a study of older adults in an urban setting in New York, but more falls occurred during daylight hours, peaking in the afternoon[1]. Although one would suspect there might be more falls during the winter months in climates with harsher weather such as in Canada, this does not appear to be true. One Canadian study has done a comprehensive epidemiological review of fall related hospital admissions for all age groups (retrospective population study of 14 million people in Ontario). Although there was a seasonal pattern apparent for children (more falls in warmer months) and the 30 – 59 years age group (more falls in the winter months), the seasonality pattern was not present for the age group over 60 years[132].

Determining the risk factors and the interactions of risk factors for falling is complex. There are several factors affecting both the initiation of a fall and the degree of injury sustained from a fall. These factors include bone strength (bone mass, architecture, geometry and quality) at the time of the fall, the circumstances of the fall (initiation, descent and impact), environmental or extrinsic factors (weather, surface, lighting, etc.) and a variety of intrinsic factors (muscular strength, mobility, medical, cognitive status, etc.). There are at least 130 fall risk factors identified in the literature[44, 146]. Some studies and reviews have attempted to prioritize fall risk based on relative risk values and prediction equations; however, the relationship of risk to fall event is not completely clear as there are likely complex interactions taking place. A comprehensive review of the literature and development of clinical guidelines for fall risk assessment and management were published in 2001 by the American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention [4]. They quantified the relative risk values of primary risk factors identified in the literature (Table 1.1). The primary risk factors in order of decreasing priority were muscle weakness, history of falls, gait deficits, balance deficits, use of assistive devices, visual deficits, arthritis, impaired activities of daily living (ADL), depression, cognitive impairments, and age > 80 years. Further, fall prediction equations have demonstrated an additive effect of the risk factors; for example, one-year fall risk was 12% with none of the top three risk factors to 100% with all three factors present[4]. This review does not include all of the risk factors for falls. The primary intrinsic and extrinsic risk factors for falls will be reviewed below, with emphasis on the following intrinsic factors that are the focus of this study: muscle weakness, gait deficits, balance, physical activity level, functional ability and fear of falls. Cognitive status, depression, visual deficits, medication and supplements, and walking aids are also reviewed as secondary variables.

Table 2.1 Results of univariate analysis of most common risk factors for falls identified in 16 studies that examined risk factors [4]

Risk Factor	Significant/Total *	Mean RR or OR**	Range
Muscle weakness	10/11	4.4	1.5 – 10.3
History of falls	12/13	3.0	1.7 – 7.0
Gait deficit	10/12	2.9	1.3 – 5.6
Balance deficit	8/11	2.9	1.6 – 5.4
Use assistive device	8/8	2.6	1.2 – 4.6
Visual deficit	6/12	2.5	1.6 – 3.5
Arthritis	3/7	2.4	1.9 – 2.9
Impaired ADL	8/9	2.3	1.5 – 3.1
Depression	3/6	2.2	1.7 – 2.5
Cognitive impairment	4/11	1.8	1.0 – 2.3
Age > 80 years	5/8	1.7	1.1 – 2.5

* number of studies with significant odds ratios or relative risk ratio in univariate analysis / total number of studies that included each factor
** OR = odds ratio   RR = relative risk

ADL: Activities of Daily Living

2.2.1 **Intrinsic Risk Factors**

Intrinsic risk factors for falling such as balance, gait, strength, and falls-efficacy are generally associated with aging; therefore intervention strategies that aim to reduce the age-related deterioration of these physical and psychosocial factors should also decrease the rate of falls in older adults.

Muscle weakness: Muscle strength (defined as the maximum force or tension generated by muscles[136 p. 452]) declines after approximately age 30, at a rate of about 1 to 2 percent per year; however, declines up to 5% per year have been prospectively observed in adults over age 65 [19]. Muscle power (the product of force and velocity of contraction)[142 *p. 161*] also decreases with age and has been found to be 70 – 75% less in older adults in their 70s compared to younger adults in their 20s [31]. Power rate losses for adults over age 65 are up to 4% per year, often greater than declines in strength [182]. Type II or fast twitch muscle fibers exhibit the greatest amount of degeneration with aging. This decline results in a decreased ability to generate muscle force quickly, an important component of balance reactions. Bassey et al.[18] found that leg extensor muscle power accounted for 86% of the variance in walking speed in the frail elderly, with gait speed being a primary predictor of falls [4].

Several studies have shown a relationship of muscle weakness to increased fall risk. A meta-analysis by Moreland et al.[141] reported lower extremity weakness independently increased the risk of falling 2 to 3 times for any future fall and recurrent falls respectively. The most common muscle groups measured in fall risk studies are knee extensors and ankle dorsiflexors. Hip strength has not been evaluated as much; nevertheless, there is some evidence linking hip strength to balance and gait abnormalities [51]. Several researchers also have found functional strength measures of the large muscles surrounding the hips, such as the ability to get up and down from a chair, are significantly associated with fall risk[4, 61, 141, 152]. Repetitive chair stands is a functional task that co-ordinates hip and knee strength, balance, mobility and endurance. Upper extremity weakness also has been associated with fall risk, but the relationship is not as strong as lower extremity weakness[141].

Gait deficits*:* Both a slower gait velocity[14, 60] and a higher velocity[158] have been linked to fall risk. Fifty percent of falls have been reported to occur during locomotion[171]. Age related gait changes include slower speed, decreased stride length, increased double limb support time, decreased hip flexion during swing phase and decreased hip extension moment[14, 107-109, 131]. The relationship of gait parameters to fall risk is less clear. Slower gait and decreased stride was associated with fear of falls but not independently to risk of falling in 75 elderly men and women. It is not clear if fear of falling determines the change in gait commonly seen in fallers or if changes in gait patterns are a direct predictor of falls[131]. Barak et al.[14] found elderly subjects reporting falls had decreased stride length, increased stride frequency, as well as decreased hip extension during push-off (terminal stance) and decreased medial - lateral sway compared to non-fallers. Decreased medial – lateral sway may be a result of an adaptation to gluteus medius weakness in the elderly. Gluteus medius controls lateral balance and propulsive force during the stance phase. Thus, weakness in the gluteus medius may make the elderly more prone to lateral falls. Decreased walking speed may be an adaptation to improve stability as muscles may not be able to stabilize gait as well as in the younger years; however, some researchers have found that decreased speed does not necessarily result in increased stability. For example, despite decreased walking speed, elderly fallers actually demonstrate increased gait unsteadiness or greater kinematic variability[14, 226]. It is possible that these responses may decrease the ability to adapt to situations where there is a need to increase speed, avoid an object or prevent a fall. This decreased ability to adapt to speed may be the reason some studies have found increased gait speed to be associated with falls when gait is interrupted by an unexpected obstacle[158].

Balance: Balance is a state of equilibrium that is achieved when one is able to maintain the body's center of gravity over the base of support[48 *p. 15*]. Others have suggested a broader term be used such as postural control to conceptualize the complexity of controlling the body within a variety of positions and environmental situations [97]. Postural control "involves controlling the body's position in space for the dual purposes of stability and orientation" [175 *p. 164*]. Orientation refers to the ability to place the body segments in an appropriate relationship to the environment to successfully perform a task, while stability is ***balance***, or the ability to maintain equilibrium. Orientation and stability are thus distinctly different goals. For example, a football linebacker jeopardizes stability from a posterior force in order to orient body segments to block anterior forces. The demands of stability and orientation vary depending on the specific task and environmental condition. For the purposes of measuring postural control as a fall risk factor, researchers typically measure stability or balance. Although recognizing the importance of the body's position in space, it is the ability to maintain the equilibrium, no matter what the position is, that is important in preventing a fall.

There are three movement strategies used to recover balance: ankle strategy, hip strategy and the stepping strategy [176]. These strategies are described based on the muscle synergies observed in response to perturbations. The ankle strategy consists of movements and synergistic action of the muscles surrounding the ankle joint, often observed in small perturbations of balance when standing on a firm support surface. When displacements become larger, a hip strategy is more often used involving large and rapid motion at the hips. This reaction commonly is seen when standing on a compliant surface or narrower surface such as a beam, or when unable to control equilibrium with an ankle strategy alone. Stepping strategies are a quick step in any direction to prevent a fall, or a protective response, when hip and ankle strategies fail. However, older adults will often use a stepping response even when the perturbation is small. It is not clear if this is due to fear, loss of range of motion, strength, or a combination of all of these [156].

There are several systems that affect balance: vision, sensation, neuromuscular control, mobility, cognition, and vestibular function. A complex interaction of the individual's systems as well as the environment and task can affect the ability to maintain balance. For example, some individuals may have difficulty closing their eyes and balancing in any condition, whereas others may only have difficulty with this if also on an unstable surface. Therefore, in order to measure balance and identify deficits effectively, it is important to include a wide range of tasks, conditions and environmental conditions that challenge all systems [176 *p 160*]. Unfortunately, many balance measures do not include all of these aspects. With no gold standard, it is difficult to compare studies that include a balance outcome. Nevertheless, in spite of some of the weaknesses in measurement of balance, it is clear that this parameter is a significant predictor of falls in several studies[4, 126, 129, 152].

Physical Activity Level*:* There has been debate in the literature regarding the effect of increasing levels of physical activity on fall risk. Prospective observational studies of usual physical activity levels on fall risk suggest there may be a U-shaped association in which the least active and the most active have a higher risk[83]. In theory, increased physical activity level may expose an individual to more fall-risk circumstances; however, the research in this area is equivocal and there is a general lack of valid measurement of physical activity and control for potential confounding variables in several studies. There is more convincing evidence that increased levels of physical activity decrease hip fracture risk. Reduced risk of hip fracture for active men and women compared to non-active is 20 – 40% [83]. As well, there is evidence, which will be discussed in a subsequent section, that exercise interventions decrease the incidence of falls. Thus, even though there is the possibility of short term increased fall risk for some individuals with increased physical activity, it appears that the outcome of improving strength, balance, and bone health has greater long term effects in reducing risk of falls and hip fracture.

Functional Ability/Activities of Daily Living: Specificity in sport is defined as "optimal training…when an athlete's training exercise is very similar to the task for which he/she is training" [22]. Similarly, for other exercise training, if the purpose is to improve functional independence and ability to move in daily tasks without losing balance, designing exercise to optimize functional specificity is imperative. Because most falls occur during basic functional tasks (such as getting up from a chair, walking on level surfaces, and reaching to the floor), improving the ability to perform these tasks successfully should decrease the risk of falling. There is some literature to support this theory, however randomized comparisons of functionally specific exercise to more traditional resistance training has not been done [22]. Results from meta-analyses support the theory that exercise programs to reduce the risk of falls should include functional balance components (daily tasks that challenge balance) [162] and be multi-dimensional in including education and environmental modifications to address the complexity of fall risk[50, 80, 219].

Fear of Falling: Fear of falling is a complex phenomenon that is not well understood; but, recent prospective studies suggest that it is both a fall risk factor and an outcome of falling [77]. Up to 70% of recent fallers experience what is called "post fall anxiety syndrome" or an increased fear of falling. The consequence of this emotional state is often loss of function, socialization, and ultimately strength and agility, which further increases fall and fracture risk. Fear of falling is discussed further in section 3.3.

Depression: Decreased quality of life, depression and diminished social involvement have been associated with increased fall risk [26]. Depression also has been found to predict higher levels of fear of falls [38]. Exercise has been found to improve depressive symptoms, social and recreational involvement, self esteem and anxiety in elderly fallers and non-fallers [138]. Exercise and falls-efficacy interventions have been found to play a mediating role in the association of fear of falls to depression [53]. Thus, quality of life and emotional status are important outcomes to include in fall prevention studies.

Cognitive Status: Impaired cognitive status appears to be a factor more often in falls with minimal upset (i.e. indoors during basic tasks of daily living), in older individuals and when intrinsic impairments such as balance or gait are factors[26, 40]. Cognitive status was found to be an independent predictor of falling in a prospective one year study in a senior residence[54]. However, as shown in Table 2.1, cognition has a mean relative risk of 1.8, compared with 9 other risk factors exhibiting stronger prediction to falls. As well, cognitive status was found not to change the effect of the benefits of a fall risk intervention in a recent meta-analysis [155].

Medication/Supplements: Taking certain types of medications (i.e. psychotropics or medication causing postural hypotension[39, 210]) and the number of medications (i.e. 4 or more prescription medications [4, 39]) have been linked to increased fall risk particularly in women. Dietary supplements such as Vitamin D may play a role in decreasing fall risk. Muscle weakness and gait unsteadiness has been observed in individuals with low serum levels of Vitamin D [117], but the direct effect of Vitamin D on fall risk is not clear. There is evidence that supplementation of Vitamin D combined with calcium in long term care settings has an effect on both hip fracture rate and fall rate [33, 155]; however there have been equivocal findings of no effect of Vitamin D supplementation on fall rates or muscle strength and no evidence to support the effect in the community dwelling elderly[30, 69].

Visual Deficits: Impaired vision does increase the risk of falls in older adults. Visual acuity, contrast sensitivity and depth perception have all been identified as risk factors. Multi-focal glasses may also contribute to risk as it becomes more difficult to detect environmental hazards[127].

Walking Aids: The use of canes and walkers have been cited both as a means of preventing falls[4, 184] and as a hindrance resulting in increased fall risk[20]. Walking aids may assist balance and ambulation, but biomechanical studies have also found that they can interfere with lateral stepping strategies that may impede the ability to prevent a lateral fall[20].

2.2.2 **Extrinsic Risk Factors**

Environmental risk factors such as lighting, interior and exterior hazards and weather contribute to fall risk. However, although approximately 50% of fallers report some environmental factor as contributing to the fall, it is not clear if the factor actually was the primary cause [152]. Biomechanical studies suggest that even in the event of an environmental hazard such as an unexpected trip or slip during walking, individuals can avoid the fall if intrinsic factors such as balance, strength and mobility are optimal [57, 125]. These results support the notion that there is an interaction of both intrinsic and extrinsic factors in fall risk [152]. Therefore, although exercise intervention programs focus on improving intrinsic factors such as strength, balance, etc., to reduce fall risk, it is perhaps equally important to also reduce the environmental hazards as much as possible. Figure 2.1 provides an overview of the theoretical relationship of intrinsic and extrinsic factors and their interaction with fall initiation, descent and impact in proceeding to a fracture endpoint.

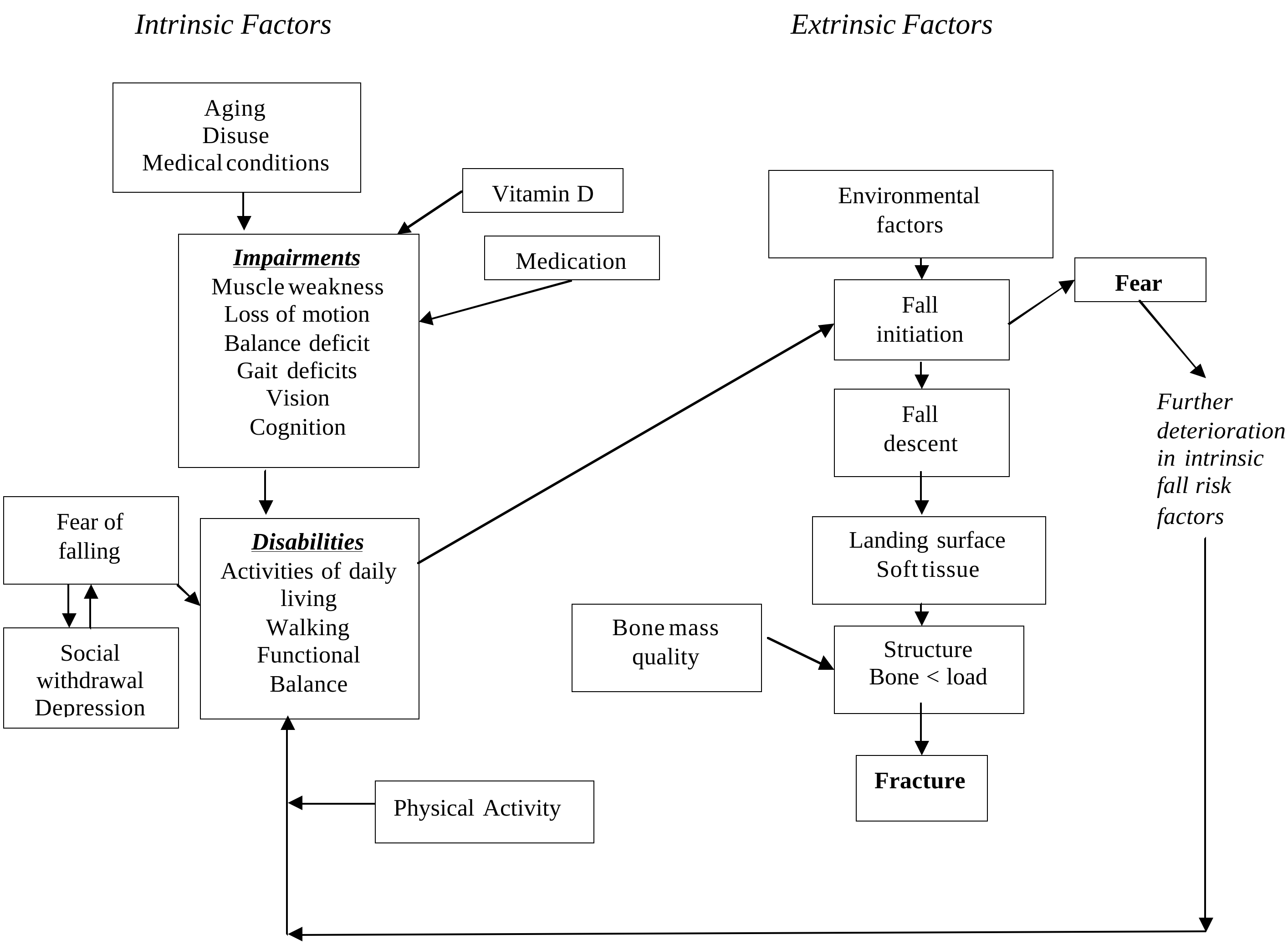


Figure 2.1: The relationship of fall risk factors to falling and fracture
(adapted from Carter, Kannus and Khan [44])

2.2.3 **Measuring fall risk factors**

There are different approaches to measuring intrinsic fall risk in the elderly. Because of the complexity and interaction of risk factors, most researchers have attempted to identify several key risk factors that include both physical and psychosocial parameters. Some instruments such as the Physiological Profile Assessment [128] incorporate several factors into a composite fall risk score such as balance, reaction time, strength, proprioception and vision; however, it is difficult for any instrument to capture all components of fall risk. Composite scores also run the risk of missing one area of high risk, as they can be masked by better scores in other areas. Individual measures of physical and psychosocial characteristics of the population being studied can be justified as appropriate markers of fall risk. Many of these have been found to be reasonable predictors of fall risk on their own or in combination[4, 50].

2.3 Hip Osteoarthritis

2.3.1 **Definitions and classification of hip OA**

Osteoarthritis (OA), formerly referred to as degenerative joint disease, is the most common type of arthritis. The American College of Rheumatology defines OA as "a heterogeneous group of conditions that lead to joint symptoms and signs which are associated with the defective integrity of articular cartilage in addition to related changes in the underlying bone at the joint margins" [9 *p 289*]. OA affects the entire joint complex including subchondral bone, ligaments, capsule, synovial membrane, and periarticular muscles. Clinically the disease presents as joint pain, tenderness, limited movement, crepitus (grating sound on movement), and occasional joint swelling[32 *p.1*].

The primary symptoms of hip OA are pain with movement and weight-bearing activity. Later progression of the condition may result in pain at rest, often at night. The location of pain is typically at the front of the joint, or inner thigh; however occasionally it may present as pain in the buttock or down the front of the thigh due to referral from peripheral nerves. The presence of pain in the hip region for most days in the past month is the common criteria used in the clinical examination for hip disease[3]. The clinical diagnosis of hip OA is confirmed with pain reproduced with isolated passive movement of the hip joint, accompanied by restricted motion [143 *p 236*]. Internal rotation limitation combined with hip pain has been found to be the most sensitive (able to detect presence of hip OA) and specific (able to rule out other conditions or causes of pain) indicator of the presence of radiographic hip OA compared to other planes of movement particularly for severe OA[3, 28]. Combining restriction of movement in more than 1 plane improves specificity but not sensitivity[28]. The traditional classification system advocated by the American College of Rheumatology (ACR) that yields the best sensitivity and specificity (91 and 89% respectively) combines clinical, laboratory and radiographic findings[32 p7]. However, symptoms are usually poorly correlated with radiographic evidence[71, 32 p5-6] and this classification may miss early painful osteoarthritis which is often not accompanied by radiographic changes. If using clinical criteria only, the ACR recommends the measurement of both internal rotation and flexion of the hip, using restriction of flexion as a secondary criteria for determining presence of joint disease when radiographs are not available (87% and specificity of 75% [3, 143]). However, health professionals should be aware of the high sensitivity for clinical classification, but more limited specificity. It is often difficult to distinguish the presence of pain associated with joint disease as opposed to radiating pain in the hip region from the spine, bursa, or surrounding musculature. The presence of end range pain in internal rotation and flexion with a secondary restriction of abduction is a commonly reported capsular pattern of restriction for the hip joint [67 p 174]. The confirmation of disease by radiograph may be needed in the presence of hip pain where there is not a clear pattern of hip restriction.

2.3.2 Etiology and Incidence of Hip OA

The most common type of arthritis in Canada is osteoarthritis (OA), affecting 3 million Canadians, or one in every 10. [10] The incidence of symptomatic, radiographic hip OA ranges from 1% to 5% , with up to 16% in women over age 65 [32 p. 9; 143 p. 9]. There is a substantial increase in the incidence of hip OA both in men and women with advancing age. The incidence rate per 100,000 person-years increases from < 100 age 50 to 59 years for both genders to 500 per 100,000 person-years for women and 400 for men age 70 to 79 years [32 p 10]. The prevalence of hip OA increases with age, with a marked increase after age 65[143 p 12; 32 p. 9]. OA is one of the leading causes of disability in the elderly and by 2020 it is projected that the number of persons with arthritis will increase by 57% due to the increased number of older adults [32 p. 9]. Systemic risk factors include age, gender, genetic susceptibility and nutrition. Intrinsic vulnerabilities in the joint such as previous damage, malalignment, muscle weakness, laxity or proprioceptive deficiencies may increase susceptibility to develop OA. Other extrinsic factors such as obesity and repetitive exposure to high loading activity may also play a role in development and progression [71]. Hip OA is the primary pathology leading to hip replacement surgery. Long-term disability in Canada due to OA accounted for almost 80% of the economic costs of arthritis in 1998, at nearly $3.5 billion[42]. The average annual cost related to hip and knee OA is $12,200 per individual in Canada, with the number of people with OA disability expected to double by the year 2020[84].

2.3.3 **Surgical Intervention for Hip OA**

Non-surgical management is always the first treatment consideration for hip OA (exercise, medication, use of walking aids, weight reduction). However, individuals who fail to gain a reduction in pain or suffer a major loss of function due to progressive disease, will be considered for surgical management [9 *p. 613*]. Some surgeons argue that those with the best pre-operative status will result in the greatest functional gain, thus there remains debate on the best timing of surgical intervention and whether the length of waiting time has an impact on long term outcome[86, 221]. Total hip arthroplasty is the surgical intervention most commonly used for hip OA, and recoveries post surgically are more rapid than knee arthroplasty [169]. Pain reduction occurs within 7 days post surgery. Function, patient satisfaction and quality of life significantly improve within 1 month, with the most rapid gains occurring within 6 months with minimal improvements observed from 6 months to 12 months[169, 221]. Full functional ability is typically completed restored by 3 months post-surgery[206 p62]. Implant loosening is the most common long term complication of total hip arthroplasty and occasionally pain and restriction of mobility can persist[9 p 618, 221].

Impairments secondary to hip OA such as pain, muscle weakness and decreased mobility have a direct effect on primary fall risk factors such as balance, ability to safely perform daily tasks and gait. Psychosocial factors (such as depression, increased fear of injury and social withdrawal), can interact with these impairments to further aggravate the disabilities and deteriorate functional status. In theory, if hip OA increases risk of falling, then the physical and psychosocial factors linked to falls should also have an increased prevalence in this population. This theoretical relationship is illustrated in Figure 2.2 and is discussed in the next section.

2.4 The relationship of functional consequences of hip OA to fall risk

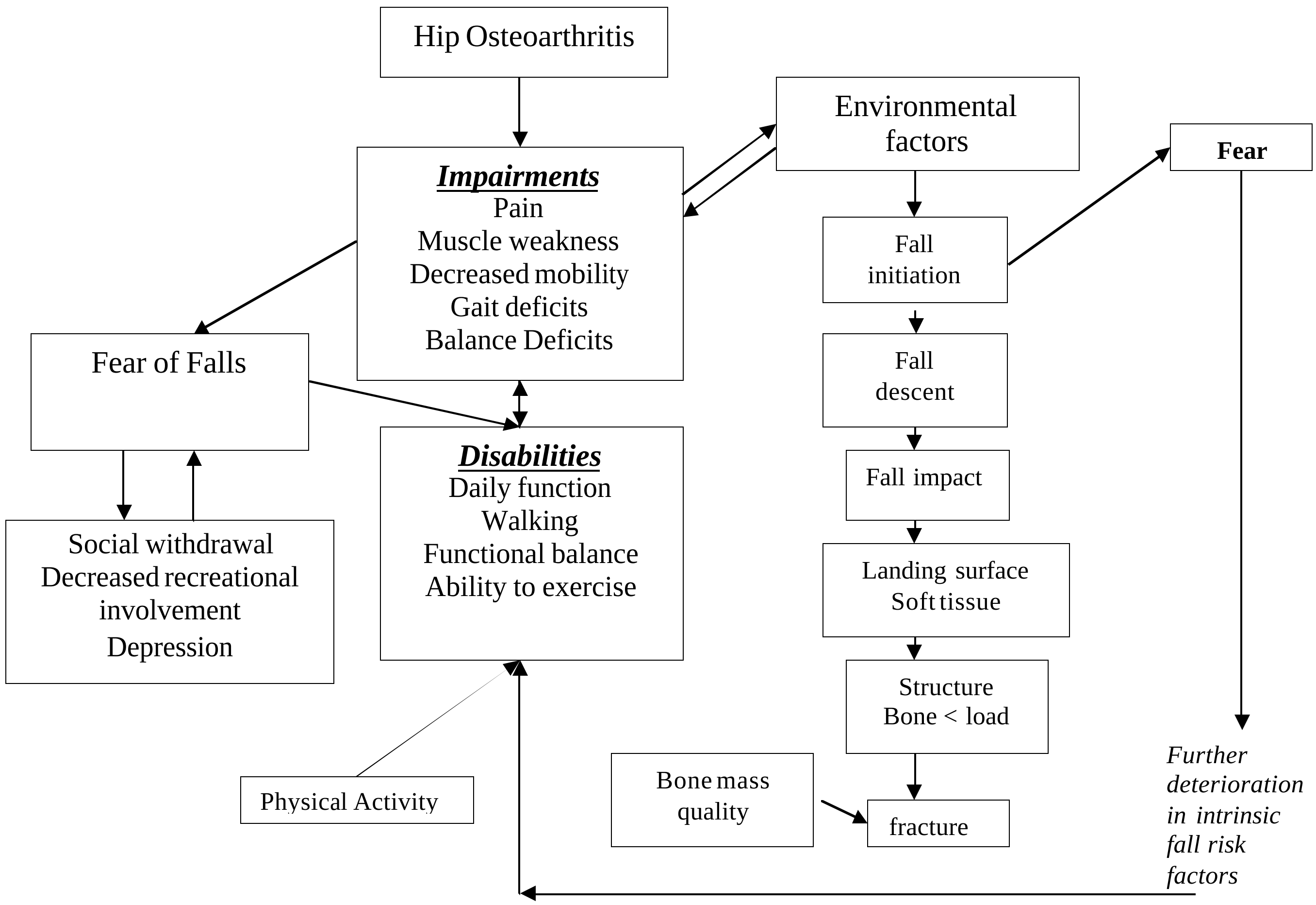


Figure 2.2: The relationship of functional consequences of hip OA to fall risk factors

When walking, an individual must bear 81% of her/his body weight on a single limb for 60% of the gait cycle*;* this equates to a loading force through the hip greater than 4 times the body weight [133]. This force is counter-balanced by the hip abductor muscles. Adequately conditioned muscles and the ability to generate force quickly can attenuate impact loads[32 p 301]*;* conversely, muscle wasting and loss of static and dynamic strength can greatly increase the compressive forces on the hip. Individuals with muscle weakness and/or hip pain will often compensate by limping during gait and shifting the center of body mass over the support limb in order to increase the efficiency of the abductor muscles (primarily the gluteus medius muscle [133 p 52]). This compensation results in an abnormal gait with a displacement of the center of gravity toward the side of the painful hip. As a result, balance may be jeopardized and risk of falling increased; particularly if combined with environmental obstacles, poor visual cues or decreased proprioception. This sequence of events is compounded further by the age-related changes in gait: slower speed, decreased stride length, increased double support, decreased plantar flexion propulsion, and decreased hip extension[14, 226]. The accumulation of gait adaptations due to hip pain and aging, possibly further compounded with fear of falls could increase the risk of falling during locomotion in this population.

Static and dynamic strength deficits of up to 60% in the lower extremity muscles have been observed in individuals with OA[32 *p. 301, 192*]. Neuromuscular inhibition of the quadriceps is the most common muscle weakness associated with knee OA, but there are few studies identifying specific weakness deficits for hip OA. Loss of hip extension and hip abduction strength has been postulated as the most important contributor to gait changes and thus, changes in postural control during dynamic activity. Hip abductor and extensor weakness result in decreased ability to stabilize the limb and shift the weight forward in the stance phase, resulting in slower gait, and a more flexed posture. There is evidence that loss of hip extension range and strength may be biomechanical contributors to fall risk[51, 107]. Biomechanical studies also suggest that the ability to prevent a fall in the event of a trip depends on where the center of gravity is located at the time of the trip. An anterior shift of the center of gravity due to flexed posturing or loss of hip extension is associated with falling when a trip is induced. Buckling of the limb, which can occur due to pain or muscle weakness, is also associated with a greater risk of falling[158, 159].

The presence of joint pain has been found to cause local muscle inhibition[142 *p. 87*] and alter balance reactions[121, 192, 220]. Studies of populations with lower limb arthritis have shown decreased static and dynamic balance reactions[192, 220] and another study reported those with widespread musculoskeletal pain had a greater incidence of falling than those with mild or isolated pain [118].

In summary, the consequences of hip OA, pain, loss of mobility, balance and strength combined with deterioration in neuromuscular function associated with aging, may result in an increased risk of falling. In particular, loss of hip extension range and weakness of the hip abductors and extensors may cause abnormal gait patterns that alter the ability to successfully shift the center of gravity (as in normal walking) and decrease the ability to react to perturbations in weight-bearing positions.

In spite of the theoretical connection, there has been controversy in the literature whether the presence of OA increases, decreases or has no effect on fall risk and fracture. Historically, it has been assumed that the presence of OA resulted in an increase in bone density local to the area of OA due to increased proliferation of subchondral bone growth, and thus having OA would decrease the risk of fracture at that site. However, it is not clear if this increase in bone density results in a stronger bone that is less likely to fracture. Two studies support that, despite higher bone density, OA is not protective of fragility fractures[7, 103]. Arden et al.[6] found that fracture risk for OA may depend on where the OA is located, with a 2-fold increase in non-traumatic fracture risk for hip OA as compared to controls, but not for other OA joint sites such as the knee, spine and wrist. One rationale of why OA at the hip is not protective against fragility fractures as opposed to other joint sites is that individuals with hip OA have a greater incidence or risk of falls and subsequently would have a higher fracture risk due to the increased exposure to trauma, regardless of bone density values.

Not all studies support this site-specificity of arthritis-related fall risk. The presence of any arthritis or joint pain has been shown to be a risk factor for falls[39, 81, 118, 152, 214]. Risk ratios are moderate with the presence of OA at any joint (*RR = 2.4, CI 1.9 – 2.9* [4]), signs of hip OA (*RR = 1.7, CI 0.99 – 3.0* [39]) and history of arthritis or presence of hip or knee pain on passive ROM (*RR = 1.9, CI 1.3 – 3.7*[152]). It makes intuitive sense that the presence of arthritis in the lower limbs would have the greatest impact on fall risk. Lower limb weakness, balance reactions (primarily controlled by trunk and lower extremity neuromuscular control) and functional ability such as gait and ability to rise from a chair have direct associations with fall risk [4, 146, 191]. Jones et al.[103] found significantly increased postural sway and quadriceps weakness for those with self-reported arthritis in a study of 1,821 men and women (mean age 69 years). Sturnieks et al.[192] found increased fall risk (as measured by a composite fall risk measure, the Physiological Profile Assessment) in older adults with hip and knee arthritis as compared to a sample of healthy elderly. Arden et al.[6] studied 1353 women age 45 to 64 years, with radiographically diagnosed hip OA, and found a significant increased risk of non-traumatic fracture compared to all other OA sites (knees, spine, hands) with an OR of 2.4 compared to controls. In contrast, Arden et al.[7] found a significant decrease in fall risk for women with more severe radiographic changes of hip OA (RR = 0.7, CI 0.5 to 0.95), but an increased risk for those with self-reported OA (RR = 1.4, CI 1.2 to 1.5). Arden's findings may suggest that those with more severe disease, due to more limited functional ability, do not put themselves at as great a risk compared to those with milder OA. The authors concluded that although hip OA patients had higher bone density values, they did not have a reduced risk of falls or fracture. Results from other studies support the notion of increased fall risk for those with milder or early signs of hip OA; patients with new episodes of hip pain had increased occurrence of falls [149].

SECTION II: EXERCISE FOR FALL PREVENTION

2.5 Exercise to decrease fall risk in older adults

2.5.1 **Does exercise reduce fall risk?**

Exercise programs that are designed to affect several primary intrinsic risk factors such as muscular strength, balance and mobility may be optimal intervention strategies to prevent falls. However, there remain many questions about the precise type, duration, intensity and frequency of exercise needed to decrease fall and fracture risk across different target populations.

Most of the research evaluating the effect of exercise on fall risk and fall rates has been conducted in the last 10 years, with a surge of reviews and randomized trials in the last 5 years. Since 1995, there have been three meta-analyses and one systematic review assessing the effect of fall prevention programs, including exercise. There are 12 critical reviews on either general fall prevention or exercise specific intervention on decreasing fall rate in older adults. Clinical practice guidelines have been recently developed collaboratively by the American Geriatrics Society, British Geriatric Society and the American Academy of Orthopedic Surgeons on the prevention of falls in Older Persons[4] . The results of the meta-analyses and systematic review will be discussed below followed by a critical review of recent randomized controlled trials with exercise as an intervention to decrease rate of falls.

The first meta-analysis of randomized controlled trials was the FICSIT trials[162] . This was a pre-planned meta-analysis of 8 randomized controlled trials designed to investigate the effects of strength, mobility and balance on fall risk in frail, older adults and to investigate ways in which falls and fall-related injuries could be reduced by environmental and health behavior activities[111]. Five of the 8 studies showed that treatment including an exercise component helped prevent falls (incident rate ratio 0.9, CI 0.81 to 0.99), with exercise programs including a balance component being more effective (incident ratio 0.83, CI 0.70 to 0.98).

A Cochrane systematic review [80], reviewed 62 trials with the majority including interventions of exercise or physical therapy (n=23) or multi-disciplinary, multi-factorial risk screening and intervention (n=21). Findings for the community dwelling elderly showed that the interventions likely to be beneficial in reducing risk were: 1) multi-factorial risk screening and intervention in the community (4 trials), 2) individually prescribed muscle strengthening and balance re-training in the home by a trained professional (3 trials), 3) home hazard assessment and modification for older adults with a history of falls (3 trials), 4) withdrawal of psychotropic medication (1 trial), and 5) 15 weeks of Tai Chi group exercise (1 trial). Interventions of unknown effectiveness included group exercise interventions (9 trials), individual lower limb strengthening (1 trial) and interventions using a cognitive/behavioral approach alone (2 trials). Practice guidelines derived from these major reviews recommended that for community dwelling older adults multi-factorial interventions including exercise programs with balance re-training should be prescribed[36, 150]. There was less conclusive evidence of the benefit of single intervention programs, but balance re-training, particularly Tai Chi was the most promising intervention[80].

Two other more recent meta-analyses have been conducted by Weatherall et al.[219] and Chang et al.[50]. Weatherall et al. included trials of the community dwelling elderly for at least one year duration, using the number of subjects with at least one fall or the number of subjects with a fracture as a fall outcome. There were 4 randomized controlled trials included with exercise as the sole intervention and 11 studies of a multiple intervention strategy (may have included exercise, gait training, education, and medication modification, medical treatment of various disorders affecting fall risk or modification of home hazards). The fixed effects odds ratio for exercise as the sole intervention was 0.81 (CI 0.58 to 1.14), resulting in 19.5 persons needed to be treated to prevent one fall. The OR was more favorable for multiple intervention strategy, 0.64 (CI 0.47 to 0.88), with 9.8 persons needing to be treated to prevent one person having a fall. However, it is difficult to make conclusions on the specific type of intervention that is beneficial as the definition of a multiple intervention strategy was too general. In contrast, the meta-analysis by Chang et al. further delineated types of intervention to 1) multi-factorial risk assessment and management, 2) exercise 3) environmental modification and 4) education. This classification presents a clearer distinction of intervention types. These authors found the multi-factorial assessment and intervention to be the most effective (reduction in fall risk, risk ratio = 0.82, CI 0.74 to 0.94) with number needed to treat to prevent one fall equal to 11. Exercise intervention alone also showed a beneficial effect with a risk ratio of 0.86 (CI 0.75 to 0.99) and number needed to treat equal to 16. There was no evidence for an independent effect of educational or environmental program intervention. This meta-analysis was more informative than the FICSIT trials as it provided a comparison of exercise to other fall prevention interventions. Thus, data from these reviews support the role of exercise intervention in fall risk reduction; however, an analysis of the cost effectiveness of exercise as a sole intervention as compared to more costly multi-factorial interventions has yet to be done. As well, the ideal populations to target for these interventions has not been determined, as existing data have included both healthy community dwelling elderly and those at higher risk.

Since these last major reviews (2002 to 2007), I identified fifteen additional randomized controlled trials meeting at least 50% of van Tulder's criteria for internal validity[213]. All the trials evaluated the impact of an exercise intervention on improving fall risk factors in community living elderly with no major neurological impairments. Results from 13 of these 15 studies showed a significantly positive effect of exercise intervention on decreasing fall risk in at least one fall risk factor, however not all fall risk factors measured were consistently positive[15, 35, 55, 62, 63, 65, 79, 119, 120, 123, 130, 172, 227], while the other two showed no significant effects of exercise on fall risk[92, 195]. Only one of these studies included aquatic exercise[65]. In this study fifty women, age 65 years and older, exercised twice per week for 10 weeks. The exercise program consisted of strengthening and balance exercises in the water supplemented with 10 minutes of education with each exercise class. Results showed the exercise group, compared to controls, had significant increases in functional strength and balance as well as self-report of physical and social function;

but, there were no differences between groups in fear of falling scores. The other studies utilized various types of land exercise that incorporated strengthening and/or progressive balance training. The majority of these studies demonstrated a positive effect on fall risk factors. Programs varied in duration and frequency ranging from 12 sessions in 6 weeks[227] to twice per week for 6 months with individualized assessment and counseling[130], with positive effects still found despite differing duration and frequency. The effect of different types of exercise were investigated by Liu-Ambrose et al[123]. In this study, an agility program (balance challenge) and free weight training with no balance training were compared with a control program. Results showed that both exercise programs significantly decreased fall risk compared to the sham control; but, subjects in the resistance training program had a greater reduction in fall risk compared to those in the agility program (decreased fall risk by 57% and 47% respectively).

Programs designed primarily for agility and functional balance such as Tai Chi have also shown decreased fall risk compared to sham control (stretching class)[119], individualized balance training[227] , and education on fall prevention[172]. Song et al.[183] compared 12 weeks of Tai chi to a control group (n = 22 and 21 respectively) of older women diagnosed with OA. There were significant improvements in pain, perceived function, stiffness and abdominal muscle strength in the Tai chi group, but no differences in upper body strength, knee strength or flexibility.

Only one study attempted to investigate the independent effects of an education and exercise intervention. In this study[35], the investigators found that both education alone and exercise alone improved movement confidence and self-report function, but only exercise resulted in balance improvement. No control group was included in the study design; thus results of this study must be interpreted with caution.

2.5.2 **Questions arising from the literature**

The existing evidence is inconclusive as to the ideal type of exercise for decreasing fall risk in older adults. However, it makes intuitive sense that exercises aimed at improving the major fall risk factors should also affect fall incidence. This conjecture is supported from the recent prospective studies described in the previous section; that is, programs designed to improve functional balance and strength and are tailored to address individual impairments and disabilities result in reduced falls and fall risk as compared to sham stretching or education alone. However, there is still a wide expanse of unknowns such as: Is functional strengthening geared more toward daily activities better than the more regimented progressive resistance training? Do group programs provide a secondary benefit of socialization and improving falls-efficacy as compared to home programs? Is it physical gain which decrease fall risk or is it the education and learning of movement strategies and avoiding hazards that decreases fall risk? As well, there is little research that identifies the ideal duration, frequency or intensity of an exercise program. Some studies have found changes within 4 to 8 weeks[35, 180, 227], while others reported some improvement at 10 weeks[46], with greater improvements at 20 weeks[45]. Sattin et al.[172] found improvement at each 4 month increment of the intervention, but participants continued to show improvements in perceived function and falls-efficacy at 12 months. It is encouraging that a home program with only 4 visits from a physical therapist in the first 2 months resulted in decreased falls, however, this has not been duplicated in other studies[41].

2.5.3 **Does exercise reduce fall risk in older adults with hip OA?**

There is limited research on the effect of exercise on functional outcomes related to OA, and to date only one study has specifically addressed fall risk in this population[183]. The majority of studies evaluating the effect of exercise on functional outcomes related to OA include participants with knee OA, or a combination of all types of lower extremity arthritis. Two RCTs have included participants with hip OA (100 participants in total [96, 212]). In the van Baar et al. study[212] a 12-week program of individualized physiotherapy exercise prescription was compared to a control group who received education and medical management from their family physician. The intervention group also received this same educational information. Results showed a significant improvement for the intervention group in pain and observed functional ability via videotape, however adherence to the program was a concern. In Hopman-Rock et al.[96], 6 weeks of individualized exercise prescription combined with education was compared to no intervention. There was significant improvement in pain, quality of life, self-efficacy, quadriceps strength (one side only), knowledge, BMI and physical activity level for the exercisers vs. controls, but no differences in range of motion or functional tasks. Fransen et al.[76] concluded that data from two studies was not adequate to make any definite conclusions about the effect of exercise on hip OA. A previous review by van Baar[211] of exercise programs for hip and knee OA reported small to medium effect sizes for improvements in pain, self report function, walking ability and global assessment of improvement by participants as the result of exercise interventions; however, based on these data, conclusions could not be reached about the most beneficial type of exercise and only one study included hip OA.

An updated search of randomized controlled clinical trials for hip OA (2000-2007) revealed 4 more studies. The first of these papers evaluated the effect of the National Arthritis Foundation aquatic and land exercise programs on functional fitness and perceived ability to perform daily activities. There were only twenty-two participants with OA in this study and eight with RA (rheumatoid arthritis). No between group significant differences were found; however there was a trend for intervention groups to show improvement in functional measures as compared to controls after eight weeks of exercise[193]. The second study compared physical therapy treatment of manual therapy techniques to exercise therapy (nine treatment sessions of individualized instruction). One hundred and nine adults with hip OA were randomly assigned to one of the two intervention groups for 5 weeks; there was no control group. The manual therapy intervention resulted in perceived benefit in 81% compared to 50% of the exercise therapy group[95]. The third study evaluated the feasibility of implementing two exercise intervention programs for hip OA and knee OA. The results showed significant improvement in knowledge (knee OA program) and for pain in both programs and effect sizes were comparable to the previous RCTs[64]. The most recent study included participants with both hip and knee OA in an aquatic program for 6 weeks compared to a control group [93]. They found significant improvement in pain, perceived stiffness and function, quality of life and hip abductor strength, and six minute walk, however no significant differences in the timed up and go test, step test (balance/strength), quadriceps strength or self report activity level. Adherence to the program was very good and 84% of the sample of 71 men and women with a mean age 62 years continued with an aquatic program after the 6 weeks.

In conclusion, based on the current literature, there is limited evidence on the effect of exercise on improving symptoms and functional outcomes related to hip OA. The data suggest that there are beneficial effects in pain relief and possibly functional improvement. However, the exact type of exercise intervention for optimum results is not clear; and, although there appears to be some additional benefit of health education for knee OA, this has not been duplicated for hip OA.

2.5.4 **Aquatic Exercise**

2.5.4.1 *Definition, Benefits and Limitations*

Aquatic exercise is defined as "vertical exercise in the water with the participant submerged to chest or shoulder depth" [185 p.2]. One of the advantages of exercise in the water for individuals with joint pain is buoyancy, which diminishes gravitational loading on joints. The degree of loading depends on the person's body composition, the water's depth as well as the speed of movement (i.e. faster walking can increase the amount of joint loading[88 *p. 330*]). Water depth can have a substantial effect on joint loading; for example, gravitational loading can be reduced as much as 80% in chest depth water[185]. As a result, individuals with joint pain may find it more comfortable to exercise in water at chest depth or greater. Other important benefits of aquatic exercise include decreased risk of falling and sustaining injury, increased mobility due to diminished gravitational pull, the varying resistance of water with turbulent flow and drag force, the effect of hydrostatic pressure to decrease swelling and promote lymphatic return and increased sensory feedback[185 p.47, 200, 167]. The psychological benefits of aquatic exercise include improved self-efficacy, decreased depression and state anxiety, increased perceived function and intent to exercise in the future[2, 73, 85]. Limitations of aquatic exercise are decreased loading of bone which diminishes the stimulus to prevent bone resorption, allergies to chlorine and other chemicals, fear of water, and difficulty monitoring correct body mechanics.

2.5.4.2 *Aquatic exercise for hip OA*

Aquatic exercise is often recommended as a beneficial exercise program for people with arthritis due to the buoyancy support providing non-loaded movement. However, the research supporting the effect of aquatic exercise to improve functional ability, strength or decrease pain is limited as there are few randomized controlled trials with many studies lacking statistical power or with other methodological flaws which limit their conclusions. Only one (non systematic) critical review of the literature specifically related to aquatic exercise has been published[78]. In this review, two studies included adults with hip OA[82, 197] and two trials included general OA[2, 193]. Methodological concerns in these studies include inadequate power to compare groups[193], lack of randomization, lack of intention to treat analysis and limited description of adherence[2].

Although the quality of these studies was poor to moderate, there were some consistent trends in the data from this review as well as another study[23] that provide direction in developing testable hypotheses for future research on aquatic exercise for hip OA. The length of time of the intervention programs varied from 5 weeks to 20 weeks and frequency ranged from 2-3 times per week; but the effects of the interventions were consistent regardless of the frequency and duration. Improvements in physical function were found following 5 weeks as well as 20 weeks. It is difficult to compare the degree of change as different outcomes were used among the studies;

however in one study of a general OA population, adherence to the aquatic program played an important role. Belza et al.[23] found improvements in general well-being and physical function for adherers who attended at least 2/week for 16 weeks compared to control and non-adherers. Other studies had poor description of adherence and drop-outs. Some of the concerns regarding adherence to aquatic exercise are water temperature, inconvenience of changing into a bathing suit, access to the pool, skin allergies, muscle cramping and aggravation of pain[8, 93].

There is limited knowledge of the impact of aquatic exercise on psychological parameters such as self-efficacy, depression and quality of life. It is encouraging that one study found an improvement in self-efficacy for function and pain after 4 days of aquatic exercise, but the results must be interpreted carefully, as there was no control group [2]. Foley et al.[73] found improvement in arthritis self-efficacy in a gym based exercise program but not in the aquatic program. For improvement in physical parameters linked to fall risk, the addition of a structured aquatic program did not add any benefit in functional gains to a home exercise program[82]. There is only one study that measured balance in an OA population, and in this study there was a trend for lateral postural sway to improve after 6 weeks of aquatic exercise, however only 13 out of the 24 subjects had lower extremity OA, the rest were RA (rheumatoid arthritis), and it is not clear how many specifically had hip OA[194].

In conclusion, the research evaluating the effect of aquatic exercise on improving quality of life and physical function that may be linked to fall risk in an OA population is sparse and studies that have been done have several methodological flaws. Trends from these studies, however, suggest that aquatic exercise for at least 5 weeks, with 2 sessions per week, can result in functional gains; but there may be no difference than other forms of intervention such as gym-based exercise or home exercise. There are no studies that have specifically evaluated fall risk parameters in this population following aquatic exercise particularly in the areas of falls-efficacy, gait, functional ability and balance.

2.5.4.3 *Aquatic exercise to reduce fall risk in older adults*

Aquatic exercise has been recommended as a more appropriate exercise to decrease fall risk for individuals who are frail, severely kyphotic or suffer from pain or poor balance[75]. However, there is currently limited scientific evidence to justify recommending exercise in these populations.

The research evaluating the impact of aquatic exercise to decrease fall risk in a general healthy older adult population or other older adult populations is as limited as the research for hip OA with similar methodological concerns. Only 6 randomized clinical trials have been reported, and, only three had adequate statistical power to compare effects across treatment groups[65, 137, 218]. Watanabe et al.[218] measured the effect of aquatic and land exercise on state anxiety in healthy older adults and found no significant differences between groups, but there was no control group. McIlveen et al. [85] evaluated a population with low back or leg pain and also found no significant differences in range of motion, pain or strength between groups, but there was a trend for improvement in the aquatic intervention group. Devereux et al.[65] evaluated the effect of aquatic exercise on improving function, balance and fear of falls in women with osteopenia and found an improvement in functional balance as measured by a step test and self-report function, but there was no change in fear of falls. The other three studies are encouraging in that physical gains occurred both in cardio-vascular and endurance status for aquatic exercise[167, 199] as well as balance[180] . The Simmons et al. study[180] was unique in comparing 4 groups of adults over age 74 in order to delineate the effect of just being in the water (water sitters vs. water exercisers). Although the numbers in each group were small, there was a significant difference in balance change in water exercisers vs. sitters after 5 weeks, and although both land and water exercisers improved balance after the first week, the water exercisers continued to improve each subsequent week, whereas the land exercisers did not. In summary, the effect of aquatic exercise on improving fall risk factors in older adults is inconclusive. As well, there have been no studies that have considered combining an aquatic program with land-based education and practice of functional tasks to enhance the effect on improving function and quality of life.

SECTION III: EDUCATION TO ENHANCE FALLS-EFFICACY

2.6 Falls-efficacy related to fall risk and the effect of interventions

2.6.1 **Defining fear of falls, falls-efficacy and the link to fall risk**

Fear of falling has been recognized in the literature for over 20 years, initially described as the “post-fall syndrome” where elderly adults who have fallen experience fear and anxiety about future falls, which leads to activity restriction and loss of independence [144]. It is now recognized that fear of falling is not just limited to those who have had a fall; many older adults who have not fallen express fear of falls[181]. Fear of falling has been measured as a dichotomous entity (Yes/No) as well as within multi-item scales to determine level of fear[104]. Reservations with this approach for measuring fear of falling is that it is not theory driven: Fear may reflect a more general state of anxiety that is not specific to falls and some may either suppress or exaggerate fear due to concern of social stigma or to gain sympathy[148]. More recently, researchers have evaluated fear of falls within the context of self-efficacy theory[13], or one's belief in one's skills and abilities to successfully perform a task or behaviour[134]. Within this context, fear of falling is defined as "low perceived self-efficacy or confidence in avoiding falls"[209]. This has been referred to in the literature as both falls-efficacy[209] and balance confidence[148]. Higher levels of falls-efficacy relates to higher confidence in the ability to prevent a fall and thus, less fear in ability to perform day to day tasks.

Fear of falling is relevant to falls for several reasons. First it has been found to be an independent predisposing factor to reduce both physical status (strength, mobility, balance and physical activity involvement)[34, 37, 72, 77, 113, 148] and psychosocial status (social isolation, depression)[113, 134, 148]. With decreasing mobility and increased social isolation, fall risk factors accumulate. The evidence is clear that increased fear of falling results in restriction of both daily functional activity[72] and recreational activity[37]. As well, fear may interfere with other fall prevention strategies. For example, a fearful older adult may be less likely to participate in exercise and educational programs designed to decrease risk due to fear of getting to the class. Even if they do participate in the program, they may be less likely to challenge their ability to reach full potential in parameters such as balance and strength training. They also may have less motivation to be successful in reaching the exercise program's goals.

2.6.2 **The impact of chronic pain and arthritis on fear of falls and falls-efficacy**

There are two prospective studies[77, 145] that have evaluated the relationship of falls to fear of falls. Friedman et al.[77] found that the presence of falls at baseline was a strong predictor of developing fear of falling 20 months later (*OR = 1.75, CI 1.30 – 2.36*) and the presence of fear of falling was also a predictor of falling 20 months later (*OR = 1.79, CI 1.33 – 2.42*). This was a large sample of 2,212 community dwelling adults over the age of 65. In addition, perceived general health, age and taking 4 or more medications were significant predictors of developing fear of falling. Murphy et al. [145] followed 313 women over age 72 for one year. Significant predictors of developing fear of falling were age over 80 years, visual impairment, sedentary lifestyle, having a fall, and no available emotional support.

Results from cross-sectional analyses present some equivocal findings but also suggest that there are multi-faceted predisposing factors to fear of falling. Falls-efficacy and state-anxiety are correlated with performance on balance tests[43, 89, 113, 148]; however others have found no significant difference in balance between samples of fearful older adults and a non-fearful cohort matched for age and gender[34]. Other physical functional measures such as decreased walking speed[34, 113], use of a walking aid[98, 113] and muscle strength[113] have been associated with fear of falling. Muscle strength, particularly hip flexor strength has been significantly associated to fear of falls [34]. In this study, 62% of the variance explaining low levels of falls-efficacy was accounted for by decreased hip strength, lower activity levels and decreased perception of physical health. Age has been cited as related to fear of falling by some[77, 145] but not by others[98, 113]. Gender does not appear to affect fear of falling[98, 148], however, there are limited data for older males.

The presence of back, joint or muscle pain increased the likelihood of reported fear of falling two to four times in adults diagnosed with rheumatoid arthritis (60% of participants) [98]. This rate was almost double the findings from samples of healthy, community dwelling older adults[99, 113]. Jamison et al.[99] reported that the presence of more intense pain was significantly associated with increased fear in adults with arthritis. The relationship of chronic pain to fall risk includes sleep disturbances, decreased attention, social withdrawal, medication use, functional limitations, gait changes, presence of other chronic conditions, and limitation of activity[214].

2.6.3 **Education interventions to improve falls-efficacy**

Bandura [13] identified several sources or determinants of self-efficacy from which a model can be built to explain the impact of fall prevention educational programs on improving falls-efficacy. This model emphasizes that building self-efficacy and diminishing fear of an event (in this case falls) requires a process of education and knowledge building, confidence building in movements where falls may occur and finally to execute movement without falling. Three of the determinants of self-efficacy include: 1) enactive mastery experience, 2) verbal persuasion, and 3) physiological and affective states[13 p. 79-113]. Mastery experience can be developed by learning strategies to prevent falls and consistently applying these strategies to day to day tasks. This can be one of the most influential sources of efficacy information and by providing opportunities to discuss ways within a group setting to overcome obstacles and learn from failures, individuals develop confidence to prevent falls within a variety of contexts. Verbal persuasion can further strengthen one's beliefs that they are capable of success. Group facilitators can provide constructive feedback, information on potential losses for non-adherence and potential long term gains for adherence. Social persuasion from the other members of the group can also have a strong influence on sense of efficacy in preventing falls. The connection of physiological and affective states is an important component in building falls-efficacy when an exercise program is included within fall prevention programs. People may interpret physiological responses from exercise such as increased muscle soreness, joint pain, breathing harder and fatigue as signs of inefficacy, dysfunction or failure. If this state further arouses affective responses such as stress, anxiety or fear, the appraisal of falls-efficacy also diminishes. Consistent education and feedback on reasons for arousal states and a supportive environment may help individuals to remain motivated to continue with exercise.

Educational programs based on self-efficacy theory have been used for individuals with arthritis to successfully achieve improved sense of well-being, coping skills, diminished pain and perceived function[134]. Group educational programs designed to improve falls-efficacy by utilizing strategies based on self-efficacy theory have found positive effects on falls-efficacy[35, 201], intended future activity, improved social function and perceived mobility[201]. However, there is currently not enough empirical support to justify that educational programs to modify behavior alone can decrease fall risk[80]. Although educational programs have been shown to improve falls-efficacy, it doesn't translate into improved physical parameters such as balance and strength[27]. Thus, combining an exercise intervention with efficacy building education should result in the greatest improvement in fall risk. Although there is some evidence to support that multi-factorial interventions have a greater impact on fall risk than exercise alone[50,80], it is not clear which component of the multi-factorial approach adds the benefit to exercise: Is it the additional contact from other professionals, the knowledge provided, the social connection with others in similar circumstances or the strategies used to specifically enhance falls-efficacy? A study by Steinberg et al.[188] attempted to delineate this by a progressive research design of 4 groups, all receiving education, with subsequent groups having the addition of exercise, home assessment and then medical advice added sequentially. The addition of exercise for groups 2 to 4 resulted in significantly decreased fall risk compared to education alone, and they concluded there was no evidence that risk declined with the addition of further intervention beyond exercise. In another study, Martin Ginis et al.[135] compared a weight training and weight training plus education program on improving self-efficacy and performance of eight basic ADL activities in adults over age 68 years. The weight training and education group received behavioral training and written reinforcement of the link of the training exercises to activities of daily living (ADL). There was a significant improvement in self-efficacy for four of the ADL tasks in the weight training plus education group, but no significant difference in actual performance of these tasks. The addition of education to reinforce the importance of the exercise to ADL resulted in positive benefit in self-efficacy beyond what is achieved with exercise alone, however more study is needed to determine the long term consequences of this approach on performance of ADL and future exercise behavior.

In summary, it appears that education programs alone are insufficient to improve both physical and psychosocial fall risk factors. Combinations of exercise and education are promising in promoting long term behavioral change combined with physical improvement that may lead to greater adherence and ultimately fewer falls in the elderly, however more research is needed.

SUMMARY OF THE REVIEW OF LITERATURE

Osteoarthritis is the most common form of arthritis in adults over age 65 years. The consequences of pain, loss of strength, function, and diminished involvement in social and recreational activities puts them at risk of falls. Although there are associations found between lower extremity arthritis and increased fall risk, no studies have evaluated intervention programs that may help to decrease that risk. In particular, the literature specific to hip OA is lacking. Biomechanical studies suggest that hip motion and strength have a primary role in gait and balance; however there are so few randomized controlled trials of this population, firm conclusions that exercise is beneficial for hip OA cannot be drawn from systematic reviews.

There has been a substantial increase in research investigating fall prevention in the elderly in the last 10 years. There is evidence that prevention programs that include exercise, either individualized or in a group setting, decreases fall risk. Targeting individuals who are at greater risk, incorporating a balance component in the exercises and using a multi-factorial approach that includes education, appears to result in the greatest reduction in fall risk; however more evidence is needed to substantiate these data. The research evaluating the effect of aquatic exercise on balance or other markers of fall risk is sparse.

Although fear of falls clearly influences physical, recreational and social function, its role in fall risk is complicated and few studies have clearly defined interventions to address fear of falls. There is a growing body of research that exercise programs combining behavioral strategies to improve falls-efficacy and increase knowledge of the link between exercise and ability to function at home and in the community can have an impact on future exercise behavior and falls-efficacy. No-one has investigated this approach in an elderly population with fall risk.

CHAPTER 3

The history of falls and the association of the timed up and go test to falls and near-falls in older adults with hip osteoarthritis

ABSTRACT

Background: Falling accounts for a significant number of hospital and long-term care admissions in older adults. Many adults with the combination of advancing age and functional decline associated with lower extremity osteoarthritis (OA) are at an even greater risk. The primary purpose of this study was to describe fall and near-fall history, location, circumstances and injuries from falls in a community-dwelling population of adults over aged 65 with hip OA. A secondary purpose was to determine the association of the timed up and go test (TUG) with fall and near-fall history. **Method:** This was a retrospective observational study of 106 older men and women with hip pain for six months or longer, meeting a clinical criteria for the presence of hip OA at one or both hips. An interview for fall and near-fall history and administration of the TUG were administered on one occasion. **Results:** Forty-five percent of the sample had at least one fall in the past year, seventy-seven percent reported occasional or frequent near-falls. The majority of falls occurred during ambulation and ascending or descending steps. Forty percent experienced an injury from the fall. The TUG was not associated with history of falls, but was associated with near-falls. Higher TUG scores occurred for those who were older, less mobile, and with greater number of co-morbidities. **Conclusion:** A high percentage of older adults with hip OA experience falls and near-falls which may be attributed to gait impairments related to hip OA. The TUG could be a useful screening instrument to predict those who have frequent near-falls, and thus might be useful in predicting risk of future falls in this population.

Introduction and Purpose:

One out of three adults over the age of 65 and one out of two over the age of 80 years falls annually[4]. Falling accounts for 77% of all elderly injury-related hospital admissions and is the cause of 57% of injury related deaths among elderly females and 36% among males in Canada[170, 189]. In a review of 16 fall risk studies,[4] presence of arthritis was identified as having a higher mean relative risk of predicting future falls than age or cognitive status; however, few studies have identified the type, location and related impairments and disabilities that might increase the risk of falls in this population. As well, there are no studies describing incidence of falls, near-falls, or the type and circumstances of falls in individuals with lower extremity arthritis. Lower limb weakness, slower gait, decreased mobility and pain, all outcomes of hip OA, are also established risk factors for falls [44, 118, 214]. There is some evidence of increased fall risk in older adults with hip and knee arthritis [192]. However, others[7] found decreased fall risk for women with more severe radiographic changes of hip OA, but an increased risk for those with self-reported OA. This apparent paradox may suggest that those with more severe disease, due to more limited functional ability, may not put themselves at as great a risk compared to those with milder OA. Results from another study showing patients with new episodes of hip pain had increased occurrence of falls supports the notion of increased fall risk for those with milder or early signs of hip OA [149].

The timed up and go test (TUG)[160] is a simple timed test to quantify functional mobility. The test requires the participant to stand up from a chair, walk 3 meters and returning to a sitting position. The TUG has been associated with other tests of balance and functional mobility [29, 160]. Some studies support the predictive ability of the TUG to screen for older adults at risk for future falls[114, 116], although others debate the sensitivity of this instrument to classify fallers[204] and there remains no clear cut-off score to predict high risk fallers[177, 223]. The TUG has been found to be sensitive to functional change in patients following a total hip replacement[106] and a predictor of fall incidence six months following hip fracture surgery[114]; but there are no studies evaluating the association of the TUG to fall risk in older adults with hip OA.

OA is one of the leading causes of disability in the elderly and by 2020 it is projected that the number of persons with arthritis will increase by 57% due to the expected increased number of older adults [32 p. 9]. In Canada, long-term disability due to OA accounted for almost 80% of the nearly 3.5 billion total economic costs of arthritis in 1998[163]. Identifying the number of falls, the nature, circumstances and injuries resulting from falls is important in designing fall prevention programs for this population. The primary purpose of this study was to describe fall risk, history and nature of falls and near-falls in community living adults over age 65 with hip OA. There has been little research on the history of near-falls in the community dwelling elderly although some suggest it is an important predictor of future falls[202]. These descriptive data are important in order to develop intervention strategies to reduce fall risk and fall incidence in a population that may be at higher risk than the healthy community dwelling elderly. A secondary purpose was to determine the association of the TUG to fall and near-fall history in this population.

Methods:

Participants and Eligibility Criteria: Participants were recruited by newspaper advertisements and posters displayed in clinics, recreational facilities, senior residences and physician offices. Interested participants were first screened by a telephone interview in order to determine eligibility criteria and basic demographic information. The telephone screening (Appendix A) included questions on age, presence and duration of hip pain, participation in various types of activities including frequency and duration, presence of other medical conditions, mobility rating, use of walking aid, and the frequency of falls in the past year. Activity level was categorized as: 1) limited (perform activities of daily living, but not involved in regular exercise, minimal walking outdoors), 2) light (gets outside walking or involved in light activities at least twice per week, duration less than 30 minutes) and 3) moderate (involved in moderate activity at least 2/week for 30 minutes or longer). Self-perceived mobility was rated on a scale of 1 to 10, 1 was defined as being dependent in a wheelchair and 10 as having no mobility problems at all. Co-morbidities identified were added for a cumulative score. Exclusion criteria included individuals: 1) with a medical or neurological disorder that significantly affected day to day function, 2) currently involved in a regular group exercise program 2 times per week or greater that incorporated aquatic exercise or balance activities, 3) reporting pain in the hip for less than 6 months or having no hip pain present or 4) who had joint replacement surgery within the last 6 months.

If participants were eligible based on the telephone screen, they were asked to attend a physical screening exam conducted by a physical therapist which included: 1) an interview confirming the frequency of falls and near-falls within the past year, including details regarding the nature, circumstance and injury related to each fall recalled, 2) the Mini-Mental State Exam[74],

3) verification of presence of hip pathology using a clinical criteria, and 4) assessment of fall risk using the TUG test[160]. Prior to this screening test, participant consent was obtained. This study was approved by the institution's biomedical ethical review board (University of Saskatchewan Biomedical Ethics Review Board; see Appendix B for certificate of approval).

Falls and near-falls interview: A fall was defined as any event in which a person inadvertently or unintentionally comes to rest on the ground or another lower level such as a chair, toilet, or bed[205]. A near-fall was defined as a slip (sliding of the support leg), trip (impact of the swinging leg with an external object) or loss of balance where the person starts to fall but is able to stop or prevent the fall to the ground or other lower surface [168]. Participants were asked if they had a fall, and if so to recall the number of falls in the past year. Participants were also asked to describe where the fall occurred (indoors at home, outside at home, indoors in the community or outdoors in the community), the cause and circumstances related to the fall and if any injuries were sustained. Frequency of near-falls were categorized as frequent (occurring at least once per week or more), occasional (occurring less than once per week but more than a couple of times in the past year) or never. Interview data was recorded on the Falls and TUG screening form (Appendix C). There are no data indicating the accuracy of reporting near-falls. Recognizing that near-falls are more difficult to recall than actual falls, this categorization criteria was thought to be more accurate by estimating the frequency of near-falls rather than re-calling specific events.

Mini Mental State Exam: The Mini Mental State Exam is a reliable interviewer-administered test of 11 questions to screen for cognitive impairment [74]. It was used in this study to identify participants who may have more difficulty recalling fall-related events and other demographic information. The maximum score on this test is 30 and scores of 20 or less have been only found in adults with a diagnosis of cognitive dysfunction[74].

Determination of Hip OA: The classification system used to confirm hip pathology was based on the American College of Rheumatology (ACR) criteria to classify clinical presence of hip OA when radiographs are not available (Appendix D). As per the ACR recommendations, the measurement of both internal rotation and flexion of the hip was used with flexion restriction as a secondary criteria for determining presence of joint disease (87% and specificity of 75% [3, 143]). Where pain on hip motion was present, but movement restriction did not meet the criteria, reports from the most recent hip radiograph were used to confirm diagnosis. Health professionals are often in the situation needing to distinguish the presence of pain associated with joint disease as opposed to radiating pain in the hip region from the spine, bursa, or surrounding musculature. The presence of end range pain in internal rotation and flexion with a secondary restriction of abduction is a commonly reported capsular pattern of restriction for the hip joint [67 p 174]. The presence of hip pain for at least 6 months for most days, also rules out short-term pain conditions.

TUG: The TUG was used as a test for functional mobility and fall risk[160]. A standard chair with armrests was used for all tests. The participant was asked to stand up, using the armrests if necessary and walk past a line 3 meters away, turn around and come back and sit down in the chair. Participants were timed from the moment where their buttocks rose from the chair to when their buttocks touched the chair when returning to sitting. The instructions were to walk (not run) as quickly, but as safely as possible[177]. Participants had one practice trial, and the second trial was timed. If a walking aid was usually used inside the home, then the walking aid was used during the test. This test has been found to be reliable and sensitive to functional change in the older adult population (ICC = 0.99)[160] and older adults with hip dysfunction (ICC = 0.75) [106, 114].

Statistical Analysis:

The description of all fall events were categorized for mechanism or cause of fall, the activity the faller was doing at the time of the fall, the environmental location of the fall and any injuries that were incurred. Responses were reviewed by the researcher and categorized into common themes based on previous literature[94, 153]. Injuries from falls were categorized as 1) fracture, 2) other soft tissue or joint injury (not including simple abrasions or cuts, and 3) no injury. Seeking medical treatment or emergency room care for an injury was not used to categorize injury as it was felt that many fall-related injuries may not be reported to a medical practitioner.

Descriptive statistics and frequency data were generated for demographic information and the TUG scores. Descriptive statistics were calculated for the prevalence of fall and near-falls, and compared among three TUG score categories: < 10 seconds, 10 – 13.99 sec and 14 sec or >. These categories were based on the distribution of the TUG data (below 25th percentile, 25th to 75th percentile and greater than the 75th percentile) and other reported cut-off points for TUG scores[29]. A one-way analysis of variance was used to compare age, medication use, mobility rating and number of co-morbidities between the three TUG categories. Odds ratios were calculated to examine the association of the TUG test to fall and near-fall history. Odds ratios for being a faller vs. non-faller or a frequent near-faller vs. occasional or non near-faller were calculated for TUG categories of < 10 sec. compared to > 10 sec. and less than 14 sec. compared to > 14 sec., the lowest and highest quartiles. Odds ratios were calculated for other factors converted to dichotomous variables (activity level, age, location of hip pain and use of a walking aid). Receiver operator characteristic (ROC) curves were generated for the association of TUG scores to fall history and TUG scores to history of frequent near-falls with sensitivity on the y-axis and 1 – specificity on the x-axis. The area under the ROC curve reflects the degree of accuracy of the TUG in classifying fallers and frequent near-fallers. A value of 1.0 is an ideal test with 100% sensitivity and 100% specificity. A value of 0.5 represents 50% sensitivity and 50% specificity, a test with no discriminative value. Screening characteristics were determined for all cut-offs between 10 sec. and 14 sec. of the TUG.

Results:

Participants: One hundred and ninety-one participants were telephoned screened and 41 of these were excluded (only 5 as a result of being too active for the intervention study). One hundred and twenty-six of these participants agreed to attend a physical screen. The mean score on the Mini Mental State Exam was 28.2 (2.0) out of a possible score of 30. All participants scored 22 or greater on the Mini Mental State Exam, and only one participant scored less than 24. Twenty did not meet hip OA eligibility, resulting in a final sample of 106 eligible participants for the study (Figure 3.1). One hundred and five participants completed the TUG as one participant was assessed as not safe to complete the test. Of the 106 screened, 77 were female (73%) and 29 were male (27%). Fifteen participants (14%) had a previous total or partial hip arthroplasty more than 6 months ago. Seven individuals were on a waiting list for a total hip arthroplasty. Other descriptive data of the sample are reported in Tables 3.1 and 3.2.

Falls and near-falls: The frequency of falls and near-falls, fall mechanism, location and any injuries sustained is reported in Table 3.3. Forty-five % of the sample had at least one fall in the past year. A total of 59 falls were recalled from 48 respondents. A secondary analysis was done comparing frequency of falls in two age groups. Forty percent of the group under the age of 75 fell in the past year and 52% of those aged 75 and older fell in the past year. Trips were the primary cause of falls followed by slips and lost balance. Lost balance included a broad range of responses such as falling for no apparent reason or generally losing balance when standing on an unstable surface or in a static position. Ambulation (not on stairs or over curbs) was the most common activity where falls occurred, followed by ascending or descending stairs and reaching and getting up from a chair or bed. In the reaching category, 4 falls occurred when standing on a chair, ladder or step and reaching for an object. Ten percent of falls reported resulted in a fracture. The fractures that occurred included 1 distal radius, 1 spinal compression, 1 rib, 1 hip and 2 clavicle or shoulder girdle. Almost 80% of the sample reported frequent or occasional near-falls where they lost their balance, but they were able to recover before landing on the floor or other lower surface.

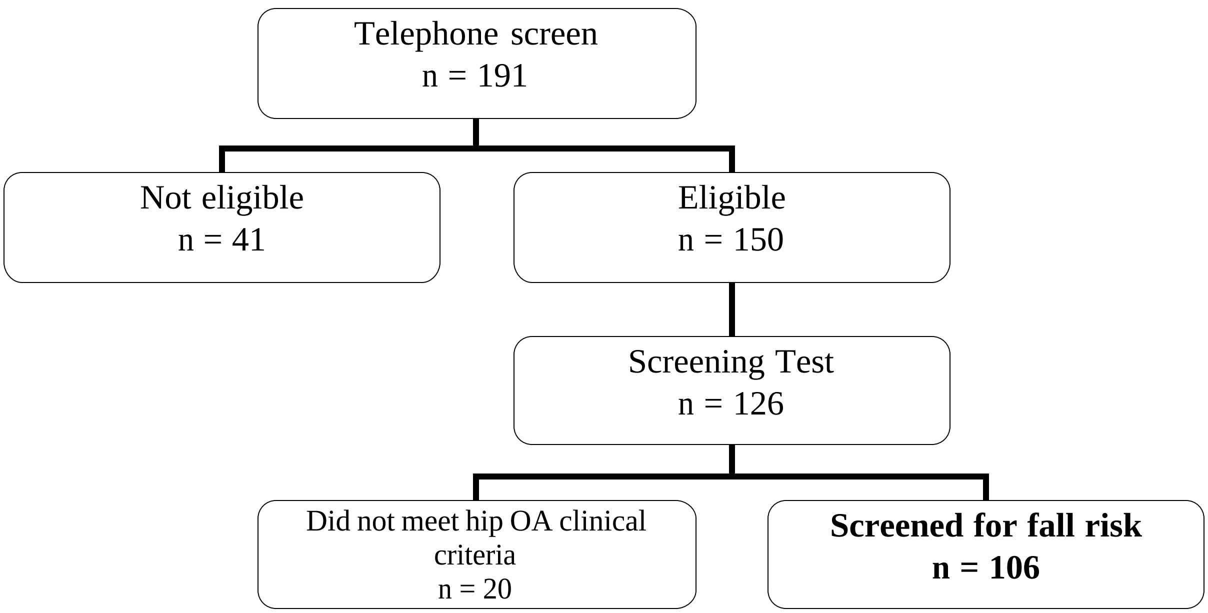


Figure 3.1. Flow chart of participants eligible for fall risk screening

Association of TUG scores to fall risk: As shown in Table 3.4, there were significant differences ($p<0.05$) for age, number of co-morbidities, number of prescription medications, and mobility rating, when comparing the highest quartile of the TUG scores (14 sec. or >) with the lowest (< 10 sec.).   Age and mobility rating were significantly different between the two middle quartiles (10 – 13.99 sec) and the lowest quartile (< 10 sec.). There were no significant differences in the number of fallers and the frequency of near-falls among the three TUG categories; but the percentage of frequent near-fallers increased as TUG scores increased as shown in Figure 3.2.

Table 3.1 Ambulatory and clinical characteristics of participants (n = 106)

Variable	Frequency	Percent
Exercise level †		
• Limited	42	39.6
• Light	44	41.5
• Moderate	20	18.9
Concurrent conditions		
• Osteoporosis	41	38.7
• Knee OA	21	19.8
• Arthritis in other joints	35	33.0
Use of walking aid	40	37.7
Type of walking aid		
• 1 cane	25	62.5
• Walker	7	17.5
• 2 canes	3	7.5
• Both walker and cane	5	12.5
Use of walking aid		
• Outdoors only	24	60.0
• Both in and outdoors	16	40.0
Lives alone*	29	39.7
Previous fracture**	28	33.7
Hip affected		
• Right	40	37.7
• Left	25	23.6
• Both	41	38.7

* n = 73, ** n = 83

† Exercise Categories: 1) Limited: perform activities of daily living, but not involved in regular exercise, minimal physical activity such as walking outdoors, 2) Light: some physical activity such as outdoor walking or involved in light sport or recreational activities at least twice per week[217], duration less than 30 minutes and 3) Moderate: involved in moderate sport or recreational activities[217] at least 2/week for 30 minutes or longer.

Table 3.2 Descriptive data for demographic and TUG scores

Variable	Mean (SD)	Range	N
Age	74.4 (6.2)	65 – 88	106
Total co-morbidities	2.2 (1.3)	0 – 7	106
Total prescription medications	3.0 (2.6)	0 – 12	81
Total non-prescription medications	2.5 (2.0)	0 – 8	81
Length of time with OA (yrs.)	8.1 (8.3)	0 – 50	73
Mobility rating	6.5 (1.8)	1 – 10	101
TUG score (sec.)	12.8 (5.3)	6.2 – 37.5	105

Table 3.3 Frequency of falls, near-falls, mechanism, location and injuries sustained from falls

Variable	Frequency	Percent
Participants reporting at least 1 fall in past year	48	45.3
Frequency of falls		
• 1 fall	37	77.1
• 2 or more falls	11	22.9
Location of fall*		
• In home or residence	29	49.2
• Outside the home or residence	10	17.0
• Indoors in the community	5	8.5
• Outdoors in the community	15	25.4
Mechanisms or causes of the fall*		
• Tripped (impact of swing leg on external object)	21	35.6
• Slipped (sliding of support leg)	16	27.1
• Lost balance	15	25.4
• Missed curb or step	4	6.8
• Muscle weakness/leg gave away	3	5.0
Activity at time of the fall*		
• Ambulating	33	55.9
• Ascending or descending stairs or step	13	22.0
• Reaching	7	11.9
• Getting up or down from chair or bed	6	10.2
Injuries sustained from falls reported*		
• Fracture	6	10.2
• No fracture, but other injuries beyond minor scratch or bruise	18	30.5
• No injury	35	59.3
Frequency of Near-falls**		
• Frequent (1 / week or more)	31	29.8
• Occasional (< 1 / week but more than once or twice in past year)	49	47.1
• Never	24	23.1

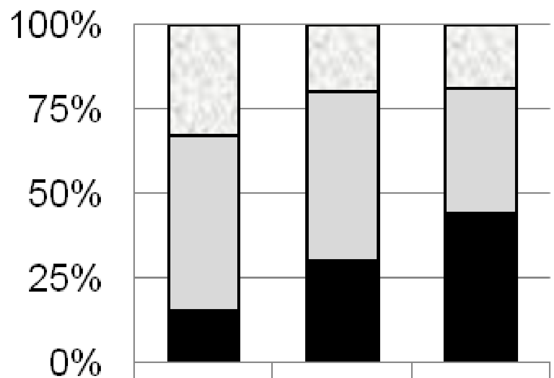
* Total of 59 falls recalled by 48 fallers; ** n = 104

Table 3.4 Mean values and standard deviations for age, mobility and other demographic factors comparing three TUG categories: < 10 seconds, 10 – 13.99 sec. and 14 or > sec.

Variable	< 10 sec. (n = 28)	10 – 13.99 sec. (n = 50)	14 or > sec. (n = 27)
Age (n = 105)	70.4 (4.2)	73.5 (5.5) *	79.7 (5.7) *†
Mobility rating (1-10; n = 100)	7.4 (1.8)	6.4 (1.7) *	5.5 (1.4) *
# prescription meds (n = 81)	1.5 (1.9)	2.8 (2.8)	4.0 (2.0) *
# co-morbidities (n = 105)	1.6 (0.9)	2.1 (1.1)	2.9 (1.6) * †
Length of time hip OA (yrs; n = 73)	5.8 (5.6)	7.6 (7.2)	10.4 (10.9)

* p < 0.05 comparing to < 10 sec.; † p < 0.05 comparing to 10 – 13.99 sec. category using Tukey's post-hoc analysis

Based on calculation of odds ratios (Table 3.5), participants were three times more likely to be a frequent near-faller if their TUG score was > 10 seconds or if they were over the age of 75. The odds ratio did not increase substantially using a higher cut-off for the TUG of 14 seconds for the association with a history of falls or near-falls. Because age was a potential confounder in determining the relationship of the TUG to fall and near-fall history, a post-hoc analysis was done comparing odds ratios in two groups: under age 75 and 75 years or older. The odds ratios associated with being a near-faller remained similar for both age groups: OR = 3.0 (CI 0.44 – 20.4) and OR = 2.5 (CI 0.24 – 25.7) for the younger and older group respectively. The association of TUG scores to fall history remained low and inconsistent for the two age subgroups, with no association found for TUG scores to fall history in either group. There were no other significant associations found for the other dependent variables (gender, use of walking aid, mobility level or hip pain bilateral vs. unilateral) to frequent near-falls, and there were no significant associations of TUG scores or any other factor to fall history (Table 3.5). Further analysis of ROC curves showed that the area under the curve for TUG score and fallers was 0.58 (95% CI 0.47 – 0.70). The area under the curve for frequent near-fallers for the TUG was 0.65 (95% CI 0.53 – 0.76). Thus, TUG was a more accurate test in predicting frequent near-fallers than fallers, but with an area under the curve of 0.65 it did not demonstrate a high level of accuracy. Sensitivity and specificity values for TUG categories from 10 sec. to 14 sec to classify fallers and frequent near-fallers are reported in Table 3.6. The cut-off of 10 seconds showed the highest degree of sensitivity for both fallers (73%) and frequent near-fallers (81%). The sensitivity or the ability to detect those at risk is important in falls screening. There was a forty-five percent increase in sensitivity for the 10 second cut-off as compared to the cut-off of 14 sec. A cut-off of 11 sec. improved specificity by 20% with only a small drop in sensitivity of 6% for classifying fallers; however this was not true for classifying frequent near-fallers as there was an equally high drop in sensitivity as specificity from a cut-off of 10 seconds to 11 seconds.



	T-1	T-2	T-3
None	33%	20%	19%
Occasional	52%	50%	37%
Frequent	15%	30%	44%

Key:
T-1: TUG score < 10 seconds
T-2: TUG score 10 seconds – 13.99 seconds
T-3: TUG score 14 seconds or >

Figure 3.2 The frequency of near-fallers for three TUG categories: < 10 seconds, 10 – 13.99 seconds and 14 seconds or >.

Table 3.5 Odds ratios and 95% confidence intervals for predicting fallers and frequent near-fallers

	Faller OR (95% CI)	Frequent near-faller OR (95% CI)
Uses walking aid vs. none	0.84 (0.4 – 1.8)	1.4 (0.6 – 3.3)
Age 75 + vs. < 75	1.6 (0.8 – 3.6)	**3.0 (1.3 – 7.3) ***
Hip pain bilateral vs. unilateral	0.9 (0.4 – 2.2)	0.5 (0.2 – 1.4)
Limited activity vs. light or moderate	0.9 (0.4 – 1.9)	2.2 (0.9 – 5.1)
Female vs. male	1.0 (0.4 – 2.3)	0.7 (0.3 – 1.9)
TUG score 10 sec or > vs. < 10 sec	1.0 (0.4 – 2.3)	**3.1 (1.0 – 9.9) ***
TUG score 14 sec. or > vs. < 14 sec.	1.4 (0.6 – 3.4)	2.4 (1.0 – 6.1)

*** p < 0.05**

Table 3.6 Test Characteristics of TUG for identifying fallers and frequent near-fallers

TUG cut-off score	**10 sec**	**11 sec**	**12 sec**	**13 sec**	**14 sec**
N (TUG)	77	56	38	30	27
Sensitivity Faller Specificity Faller	0.73 0.35	0.67 0.55	0.44 0.70	0.33 0.74	0.27 0.77
Sensitivity Near-faller Specificity Near-faller	0.81 0.36	0.68 0.51	0.55 0.70	0.45 0.77	0.36 0.79

Discussion:

The first purpose of this study was to describe the one year history and circumstances of falls in a population of older adults with hip pain due to osteoarthritis. The nature of falls and near-falls for individuals with hip OA has not been previously described despite evidence that the presence of lower extremity arthritis significantly increases fall risk[192].

I found that 45% of the participants screened reported at least one fall in the past year. This is higher than the commonly estimated prevalence of 30% or one out of 3 older adults over the age of 65 living in the community falling annually [4, 210]. Although there was a higher percentage of fallers aged 75 or older, there were 40% who experienced a fall in the past year under the age of

75. All participants were independently living in the community with no cognitive impairments; therefore the higher prevalence of fall history likely was not simply a factor of sample demographics. As well, 80% reported more than one occasion of a near-fall in the past year and 30% reported that near-falls occurred at least once per week.

Few studies have attempted to identify the number of near-falls reported by the elderly. In a small sample of community living elderly Ryan et al. found that 70% reported a near-fall in the past month[168]. Using the definition of a "stumble" as loss of balance regained before landing on the ground or another object, Teno et al.[202] found that adults who reported two or more stumbles were twice as likely to experience a subsequent fall. One of the reasons for the lack of further data on near-fall events is the difficulty of recall. I attempted to avoid the difficulty of recall by asking participants to estimate frequency of near-falls, rather than specific events. Other screening tools have utilized this approach[59]. Although it is not clear if this is a more accurate method of estimating near-falls rather than recalling specific events, it does provide an estimation of how often older adults lose their balance in daily activities, something not previously reported in the literature. Cummings et al.[58] found that older adults were more likely to under-report fall events (forget a fall that occurred) verses over-reporting (recalling a fall that had not occurred). As well, individuals who scored higher on MMSE were more likely to be accurate in their fall related history[58]. In this study, there were no signs of cognitive impairment based on scores of the MMSE or during the interview procedure. As well, Hale et al. reported a high level of accuracy (92%) in older adults recalling fall related events in the past year[87]. Although one could argue that recalling the frequency of near-fall events may be more difficult than an actual fall, 30% reported near-falls occurring as recent as one week or less.

The relatively higher frequency of falls and near-falls reported in this study may be a factor of the activities and circumstances related to the fall. For example, almost 80% reported falling during ambulation or while climbing or descending stairs. In contrast, other studies in older adults have found that approximately 50% of falls reported are related to ambulation activities[153, 210]. When walking, an individual must bear 81% of her/his body weight on a single limb for 60% of the gait cycle; this equates to a loading force through the hip greater than 4 times the body weight [133]. Individuals with hip pain and/or muscle weakness surrounding the hip will often compensate for the decreased ability to support load on one limb by shifting the center of body mass over the support limb in order to increase the efficiency of the abductor muscles [133 p 52].

This compensation results in an abnormal gait with a displacement of the center of gravity toward the side of the painful hip. As a result, balance may be jeopardized and risk of falling increased; the risk is particularly increased if combined with environmental obstacles, poor visual cues or decreased proprioception. This sequence of events is compounded further by age-related changes in gait: slower speed, decreased stride length, increased double support, decreased plantar flexion propulsion, and decreased hip extension[14, 226]. There is evidence that loss of hip extension range and strength may be biomechanical contributors to fall risk[51, 107].

Other activities reported where falls occurred included reaching and getting up from a chair or bed. These activities could also be directly associated with impairments related to having hip OA as it requires weight shifting on one lower extremity to reach and adequate strength in hip musculature to move from sitting to standing. It is interesting and somewhat alarming that 4 out of the 7 falls related to reaching for articles were due to standing on a chair, ladder or stepping from a chair to a ladder in order to reach a high object.

Tripping was the most common reason reported for falling, followed by slipping. Biomechanical studies suggest that the ability to prevent a fall in the event of a trip depends on where the center of gravity is located at the time of the trip. An anterior shift of the center of gravity due to flexed posturing or loss of hip extension is associated with falling when a trip is induced. Buckling of the limb, which can occur due to pain or muscle weakness, is also associated with a greater risk of falling[158, 159]. The accumulation of gait adaptations due to hip pain from OA, combined with aging could increase the risk of falling during locomotion in this population. Other mechanisms for falls reported such as slipping, missing a step, leg giving away or just losing balance could also be associated with the presence of pain, loss of range and weakness due to hip OA.

Most falls occurred in the participant's own home or residence or just outside their residence. This result is consistent with other studies of older adults and highlights the observation that most falls occur in very familiar surroundings and are not due to an unexpected environmental hazard. Ten percent of our sample sustained a serious injury as the result of the fall (fracture reported). Most other studies report injury rates in the range of 1.5 % [153] to 6 %[151]. Although there has been some evidence suggesting the incidence of fragility fracture is lower in individuals with OA due to increased bone density in bone surrounding OA joints; others have found that the incidence of fragility fracture is not decreased in older adults with OA [7, 103]. My data suggests that the annual incidence of fragility fracture due to falls is just as high, if not higher than other findings in the community dwelling elderly. This greater incidence could be due to the increased exposure to trauma from a higher number of falls occurring, although the sample in this study is not large enough to make any definite conclusions.

The second purpose of this study was to determine the usefulness of the TUG test to classify fallers and frequent near-fallers in older adults with hip OA. The TUG test is a commonly used screening test for mobility dysfunction and as a predictor for fall risk in the elderly. Although the test has been recommended as a sensitive measure to predict future falls post hip fracture surgery[114], others have cautioned its usefulness in predicting fall risk. Similar to my results, Thrane et al.[204] found the ability of TUG to classify fallers retrospectively was poor. I found that the TUG was not associated with a history of falls in men and women with hip OA, and its ability to classify fallers was poor. It appeared that the TUG was better at distinguishing mobility difficulties related to reports of frequent near-falls as opposed to fall history. The TUG had a stronger association to a history of frequent near-falls (once a week or more) than to actual falls in older adults with hip OA. This relationship held true for older adults whether they were aged 65 to 74 or aged 75 or older. If participants scored 10 seconds or greater on the TUG they were three times as likely to be a frequent near-faller. The highest sensitivity to predict frequent near-fallers was a cut-off of 10 seconds. This is lower than other TUG values recommended for predicting future fall risk such as 13.5 seconds and 16 seconds[114]. However, Whitney et al.[224] reports a cut-off score of 11 seconds resulting in sensitivity of 80% and specificity of 56% in classifying retrospective fall history. Because this was not a prospective study, conclusions about the best cut-off score to use for predicting future fall risk cannot be made; however using a higher value for the TUG (i.e. 14 seconds) to predict falls may miss many older adults with a moderate to high risk of falling.

If near-falls are a good predictor of future falling, then the TUG could be a useful indicator for risk of future falls. Similar to other studies, I found that the profile of older adults that score less than 10 seconds on the TUG are the healthy community living adult who are younger, taking fewer prescription medications and are more functionally independent[29, 160]. However, a lower score on the TUG did not translate to fewer retrospective reports of falls and therefore this test appears to have greater use in its ability to predict mobility loss and frequency of near-fall events rather than its ability to classify fallers vs. non-fallers.

Results of this study provide important information on falls and near-falls in a population rarely studied, older adults with hip OA; however my data has several limitations. First, the participants who responded may not be representative of the general population with hip OA and their fall history; that is it's possible that participants self-selected because they were interested in reducing fall risk. It was impossible to not inform participants of the intention of the study, and it was unlikely that there was a bias toward higher risk fallers volunteering. From the demographic data of age, number of co-morbidities, prescription medications and mobility level, this sample seemed reflective of the community living older adult. One of the participant exclusion criteria included higher activity levels, as this study was the initial screening for an exercise intervention study. However, only 5 participants were excluded based on the physical activity exclusion criteria. In addition, the percentage of participants classified as moderately active was 19%. This compares favorably to Jerome et al[101], who reported that less than 15% of a sample of 710 women aged 70-79 with self-reported functional deficits participated in moderate activity for 150 minutes or more per week. The 39% of this sample who reported zero minutes of moderate physical activity per week is also consistent with Canadian statistics for community dwelling elderly where 23% to 40% of older adults report limited activity[186]. Finally, the size of this sample was not sufficient to thoroughly test the ability of the TUG to classify fallers. Future study needs to do a prospective analysis of the ability of the TUG to predict falls and near-falls in older adults with hip OA.

In conclusion, approximately one out of two adults aged 65 and older with hip OA fall annually, more than reported in the healthy community living older adult population. Most of these falls occur during ambulation and when navigating steps and stairs, which may reflect impairments in gait often associated with hip OA. The TUG test was not an effective discriminator of previous fallers and non-fallers. However, TUG scores were related to near-falls incidence; thus it may be a useful tool in screening older adults for mobility difficulties associated with balance and future fall risk.

Relationship of Study 1 to Thesis:

This first study provided descriptive data of the sample population in this thesis. This provides the context for Studies 2 and 3, as the participants did have a high frequency of falls and near-falls supporting that this is a higher risk group in need of intervention. The nature, location and circumstances of falls help explain why falls occur and can be connected to fall risk factors identified in Studies 2 and 3. This first study also supports that the cut-off scores used for the TUG were appropriate for screening for fall risk in Studies 2 and 3.

CHAPTER 4

The relationship of physical and psychosocial factors to fall and near-fall history and the association of falls-efficacy to balance performance in older adults with hip osteoarthritis

Abstract

Purpose: The purpose of this study was to examine the relationship of physical and psychosocial factors to a history of falls and near-falls and to determine the role of falls-efficacy in predicting balance performance in older adults with hip OA. **Method:** This was a cross-sectional study of 79 older men and women with hip pain for six months or longer, meeting a clinical criteria for the presence of hip OA at one or both hips. A battery of fall risk tests including balance, mobility, function, strength, gait and falls-efficacy were conducted and relationships with fall risk factors and fall history were examined. **Results:** Frequent near-falls and greater distances on the 6 minute walk were significantly associated with fall history; with the strongest relationship being history of near-falls to falls. Lower falls-efficacy was associated with frequent near-falls. Individuals with lower falls-efficacy were 7 times more likely for frequent falls to be related to actual falls compared to those with higher falls-efficacy. Falls-efficacy for functional tasks predicted 7 to 11% of the variance on balance tests when other factors such as number of medications, age, use of a walking aid, health status and physical activity level were controlled. **Conclusion:** Frequency of near-falls and falls-efficacy may be important screening questions to include for assessing fall risk in older adults with hip OA. Lower levels of falls-efficacy increases the association of near-falls to falls and is an independent predictor of balance impairment in this population. Future study should determine the association of gait speed and use of walking aids with fall risk in older adults with hip OA.

Introduction and Purpose:

The data presented in Chapter 3 supported the conjecture that older adults with hip OA have a high risk of falls and near-falls; however, it is important to identify more specifically the factors within this population that increase the risk. Although there is evidence of diminished balance and strength related to hip OA,[192] it is not clear whether these physical impairments directly impact fall risk or if other psychosocial factors, such as falls-efficacy or the impact of arthritis on quality of life, have a role to play in this association. The relationship of falls-efficacy to performance of balance and functional tasks in this population is also not known.

There is limited research identifying risk factors in sub groups of community dwelling elderly. Determining the relationships of several physical and psychosocial parameters will assist in the understanding of impairments and disabilities that link to fall and fracture risk (Refer to Figure 1.1). Once these pathways are more clearly identified, prevention programs can be developed to address these risk factors.

The objectives of this study were to determine the: 1) relationship of physical and psychosocial factors that are associated with hip OA to history of falls and near-falls in this population, and 2) role of falls-efficacy in predicting balance performance. I hypothesized that: 1) factors associated with the presence of hip osteoarthritis such as low falls-efficacy, balance deficits, delayed reaction time and decreased strength would be associated with history of falls and near-falls and 2) higher levels of falls-efficacy for dual task function (combining walking with a cognitive or another manual task) , reactive balance and more challenging functional tasks would predict better performance on dual task TUG, reaction time, the Berg Balance Scale modified (BBSm) and the Modified Clinical Test of Sensory Interaction and Balance (MCTSIB) respectively.

Methods:

The initial recruitment and screening process is described in Chapter 3. After meeting inclusion criteria for hip OA, participants were screened for fall risk using an interview for fall history and the TUG (both described in Chapter 3). If participants had either a TUG score 10 seconds or greater **OR** a history of 1 or more falls in the past year, they were eligible to continue with the study. The flow chart of participants is shown in Appendix E. Of the 83 participants eligible for the study, 79 had baseline testing for physical and psychosocial fall risk factors. The baseline testing of fall risk for these 79 participants is presented in this chapter. The risk factors chosen were classified into five main constructs: balance, gait (broadly defined to include both endurance and components of gait such as step length), strength, falls-efficacy, and mobility/function. These constructs represent the primary intrinsic fall risk factors identified in the literature. Outcome measures were chosen based on measures specific and sensitive for the population under study and designed and adequately tested for psychometric properties in the older adult population[24, 52, 102, 147, 177]. Outcome measures were further divided into primary and secondary measures for each construct, with primary measures being those more frequently used in previous research with established associations to fall risk. Constructs and outcome measures are outlined in Table 4.1. References for psychometric properties for each test are cited in the description that follows.

Table 4.1 Outcome measures used for fall risk assessment

Construct	**Measurement Tools used**			
	Primary	*Secondary*		
Balance	BBSm	MCTSIB	Reaction time	
Gait	6 minute walk	MSL (forward, back and side)		
Lower body Strength	30 second chair stand	Hand - held dynamometer (hip extension, flexion, abduction, knee extension)		
Falls – efficacy	ABC	Falls-Efficacy Questionnaire $_{total}$	Components: Falls-Efficacy$_{dual}$ Falls-Efficacy$_{reactive}$ Falls-Efficacy$_{complex}$	
Mobility/ Function	TUG$_{standard}$ **TUG$_{cog}$** TUG$_{man}$	Hip ROM (total for affected extremity)	AIMS-2 Global health Global pain	PASE

List of abbreviations:
BBSm: Berg Balance Scale modified (includes last 9 items of the original scale)
MCTSIB: Modified clinical test of sensory interaction and balance
MSL: maximal step length
ABC: Activities Balance and Confidence Scale
TUG$_{standard}$: timed up and go test, standard walking
TUG$_{cog}$: timed up and go test, dual task cognitive
TUG$_{man}$: timed up and go test, dual task manual
ROM: Range of motion
AIMS-2: Arthritis impact measurement scale version 2
PASE: Physical Activity Scale for the Elderly

Outcome Measures

Each of the outcome measures and their psychometric properties are described below, followed by the testing procedure used in this study.

1) ***Balance:*** Because balance is complex with the contribution of sensory, central and neuromuscular systems, three tests were used to capture deficits in the three balance strategies (ankle, hip and stepping) in a variety of different environmental and functional circumstances. The primary balance measure was the Berg Balance Scale (BBS)[24], which consists of a series of daily tasks that progressively challenge balance. I used a slightly modified version of this test (BBSm) including only the last 9 tasks in the original scale as the first 5 tasks are simple tasks such as sitting without support that are not a problem for the community dwelling older adult [166]. The last 9 items included static standing with and without feet together, the forward reach test, picking up an object from the floor, turning upper body keeping feet stable, turning 180 degrees, alternate stepping, tandem and one leg standing. This scale has excellent inter and intra-rater reliability (ICC = 0.98 and 0.99) and high internal consistency (chronbach alpha = 0.96) [24] The BBS was correlated with other functional and balance tests and has been shown to predict falls in the elderly [115 25]. The Modified Clinical Test of Sensory Interaction and Balance (MCTSIB), originally developed by Shumway-Cook & Horak[178] and later modified[225] was used as a secondary balance measure. This instrument tests standing balance under four sensory conditions: eyes open stable surface, eyes closed stable surface, eyes open on compliant surface (foam) and eyes closed on compliant surface. Different from the BBS, the MCTSIB measures the impact of sensory systems on balance. Impairments often not detected in functional tasks such as the BBS, may become apparent in more challenging environments. The MCTSIB has been correlated with other tests of balance and studies have demonstrated comparable reliability and validity with footwear on and off and the feet placed in different positions [225, 229 178]. Reaction time (both upper and lower extremity) can distinguish between older adult fallers and non-fallers and has been associated with future fall risk[115, 222]. Lower extremity forward step reaction time was measured using a Lafayette digital timer as a secondary balance test. Intra-rater and inter-rater reliability for combined means for 5 trials of left and right step was confirmed in a sample of 18 older adults with and without lower extremity arthritis (ICC = 0.86, 0.81)[216].

2) ***Gait:*** Both endurance and step length were measured. The Six Minute Walk was used as a primary measure for walking speed and endurance. It is a functional walking test used in a variety of clinical and healthy populations, had high test re-test reliability (ICC = 0.95) and was correlated with other balance and function measures [187]. In addition to speed and endurance, stepping is an important component in the ability to recover balance and prevent falls. Up to 80% of a maximal step is required to recover balance and prevent a fall in the event of an external force unexpectantly displacing an individual's centre of gravity[203]. Maximal Step Length (MSL) was measured as a secondary test for gait in this study in three directions: laterally, forward and backward for both extremities. Reliability of MSL was confirmed in previous studies (test re-test ICC = 0.87 – 0.90) and has been correlated with other balance tests [139]. Inter and test re-test reliability for this test in a pilot study of 18 older adults was confirmed (ICC values ranged from 0.83 – 0.96) [216].
3) ***Strength:*** A functional lower body strength test was used in this study as the primary measure. The 30 second chair stand test is a component of the Senior Fitness Test and has been found to be a reliable and valid measure of lower body strength[102], and can discriminate between active and inactive older adults[140]. In addition, individual lower extremity muscle groups were measured using hand-held dynamometry (HHD) which is a simple, reliable method of measuring muscle strength in older adults[215]. I confirmed reliability and validity of this test in a pilot study of 18 older men and women (ICC values for test re-test ranging from 0.80 to 0.91 for hip and knee strength)[216]. Hip strength (flexion, extension and abduction) and knee extension strength has been associated with gait deficits and fall risk[14, 108].
4) ***Falls-Efficacy:*** The Activities and Balance Confidence (ABC) questionnaire has demonstrated excellent internal consistency (Cronbach's alpha = 0.96) and test re-test reliability over 2 weeks (r = 0.92)[161] and has been found to discriminate higher verses lower functional status[147]. It has been used in a variety of care settings and older adult populations, including the community dwelling elderly. However, the 16 items in the ABC do not capture the diverse range of incidents and activities that older adults may fear in day to day living. Therefore, a second questionnaire (Falls-Efficacy Questionnaire) was developed specifically for this study in order to measure efficacy related to functional tasks included in the evaluation and the subsequent intervention program described in Chapter 5. The variables

measured in the Falls-Efficacy Questionnaire included: 1) walking combined with dual task function, 2) balance under different sensory conditions, 3) ability to regain balance when displaced unexpectedly and 4) ability to do more complex functional tasks such as getting up from the floor after a fall. A pilot test using three older adults was used to verify readability of the questions. The questionnaire was administered again for all participants 2 weeks after baseline to evaluate consistency of the questionnaire. Test re-test reliability was determined based on comparing scores baseline to 2 weeks using the control group who did not receive any intervention. From the 17 control participants who completed the questionnaire twice, ICC values for absolute agreement were 0.79. A factor analysis was done to examine co-relationships among variables and to determine common groupings among the factors. Category 2 (balance under different sensory conditions) was dropped due to difficulty in question interpretation determined during the study. Principal component factor analysis confirmed three distinct factors: Dual Task Walking (questions 1.1 to 1.3), Reactive Balance (3.1 to 3.4) and Complex Tasks (4.1 to 4.13). Because of redundancy determined via pattern matrix, complex tasks were condensed to 8 questions (4.1,4.3,4.6,4.8,4.10-4.13). The internal consistency of the final questionnaire of 15 questions was high (Cronbach's alpha = 0.98). Internal consistency for each of the categories ranged from 0.93 to 0.97. (Questionnaire and results of factor analysis can be found in Appendix F).

5) ***Mobility/Function:*** The Timed Up and Go test, a well known screening test for fall risk[160] was tested under three conditions: TUG $_{standard}$, TUG $_{cog}$ and TUG $_{man}$ [177]. All three conditions measure the ability to stand up from a chair, walk 3 meters, return and sit down. The TUG $_{cog}$ and TUG $_{man}$ added the challenge of a cognitive subtraction task and a manual carrying task while performing the standard test. Thus, these tasks provide a measure of dual function, which has been found to negatively affect balance [179]. All three TUG tests demonstrate sensitivity and specificity in fall prediction, although the addition of the dual task function does not improve sensitivity over the standard test[177]. Based on results from this study, the TUG $_{cog}$ was chosen as the dual task function test as a primary fall risk measure.

Hip ROM was measured using a goniometer and standard protocol that has been shown to be reliable for measuring active and passive range[154]. A total hip ROM score for the affected hip was calculated by summing the degrees of motion in each of three planes: coronal, sagittal and transverse. Total degrees were then converted to z-scores. If both hips were affected, the hip with the lowest total range was used. The Arthritis Impact Measurement Scale (AIMS – 2) is a self-report questionnaire designed for a population with arthritis to measure the impact of their condition on daily function. The AIMS-2 can be scored in five (physical function, affect, symptom, social interaction and role) or three (physical, affect, symptom) domains. Reliability and validity of the tool have been documented[196] and a systematic review of 19 instruments to assess disability in daily care found the AIMS – 2 to be one of the most reliable and valid instruments recommended for use in the population with arthritis[196].

The Physical Activity Scale for the Elderly (PASE) has been validated and is a reliable tool used to measure activity levels in the community dwelling elderly [66]. It can distinguish between different mobility levels and several environmental factors that may impact level of mobility[49].

In addition to these baseline measures, a medial history and demographic questionnaire (Appendix G) was administered to determine location of hip pain, type of residence, a list of medications, and a check-list of medical conditions.

Procedures:

The primary fall risk factor testing was conducted by two physical therapists (PT) with over 20 years of clinical experience. Both PTs were blinded to group assignment (Study 3), pre-test scores and any demographic information. A third PT (primary investigator) assisted with questionnaire administration, data entry, safety spotting for balance tests, 6 minute walk, strength testing and counting errors for the TUG test. Two additional research assistants (undergraduate students) assisted with questionnaire administration, spotting for safety, the 6 minute walk, and the TUG test. All testers received an initial training session as well as a written testing protocol. The only tester not blinded to group assignment and demographic information was the primary investigator. All testers were blinded to pre-test scores during post testing.

Total testing time was approximately 2 hours. On arrival to the test centre (College of Kinesiology), participants first completed the ABC and Falls-Efficacy Questionnaire followed by the balance, strengthening and functional mobility testing with a rest break interspersed after approximately ½ hour with completion of the other questionnaires. A large room with adequate walking space and a hydraulic bed was used for all tests except for the 6 minute walk which was performed in a hallway or on a walking track. The protocol for each test follows:

BBSm and MCTSIB: Because the first two tasks of the BBSm and the MCTSIB overlap, these two tests were done simultaneously. The BBSm was conducted as per standard protocol [24] with the PT rating ability to perform each of 9 functional tasks on a scale of 1 to 4. The same stuffed toy was used for item #4, and a standard 12 inch step stool was used for item #7. The functional reach was performed with the right arm, and recorded in cm. The total possible score for the 9 items of the BBSm was 36. For the MCTSIB, shoes were kept on, and all tests were performed with feet together (heels and forefoot touching). If this was not possible due to biomechanical alignment, the forefoot was separated to a comfortable position and the distance was recorded. The instructions for the MCTSIB for all four sensory conditions were to "stand with arms crossed, feet together, for as long as you are able or until the tester said "Stop". One tester was at floor level to monitor foot position, the second tester was at one side, spotting for safety, and monitoring position of arms, eyes closed (condition 2 and 4). The test was stopped as soon as there was any lifting of either foot, movement of the feet, arms uncrossed, eyes open or manual assist required to prevent a fall. If the participant made 30 seconds on the first trial, they proceeded to the next condition. If not, they had two more trials for the same condition and a mean value was recorded. The total possible score for this test is 120 seconds.

Reaction Time: A Lafayette digital timer was used to measure forward lower extremity stepping response to an auditory cue. Two photo cells were taped to the floor approximately 12 inches apart. The photo cells automatically stopped the timer once the participant's foot stepped between the cells. The participant was told to step so that the bulk of the forefoot would land between the photo cells. One practice trial was given. The timer was initiated with an auditory cue (the tester commanded "Step!") and simultaneously pushed the start key. Participants stepped from a line marked at the average of their left and right 60% maximal step length (as measured by forward maximal step length test). At the command "Step," participants stepped as quickly as possible between the markers. Five trials were repeated consecutively for the right then left leg. A mean of 10 trials was used.

Maximal Step Length: Participants started with both feet (shoes on) in a 30.5 cm. square box with tape measures secured to an adhesive mat on the floor in four directions (forward, left, right, and back) For measuring step length, participants were instructed to take a maximal, but comfortable step, without losing balance or lifting the back or stabilizing foot. If the heel of the stabilizing foot lifted, the participant lost balance, or had difficulty returning to the initial position, the trial was repeated. Three trials were recorded for each leg in each direction (forward, left, right, back). Participants were allowed to hold their arms in any position they felt comfortable during the test. A spotter remained close to the participant for safety if any support was needed due to loss of balance. A mean of three trials was recorded for each of six directions. The mean for right and left extremities was used for lateral, forward and backward stepping.

Six minute walk: This test was conducted in a long hall or at the far end of a walking track. There was a chair at one end and a pylon placed at the other end of a 25 meter distance. Participants wore their usual walking shoes and if they normally used a walking aid to walk outdoors, the same walking aid was used during the test. Participants started at the chair and were instructed to walk as quickly as possible, but safely around the pylon and then return and touch the chair. They were told to walk at their own pace, and that they could stop and sit on the chair or stand and rest at any point during the test if needed. If the tester observed any signs of extreme fatigue, or other signs that might jeopardize safety, the test was stopped. There was no encouragement given and the instructor stayed positioned at the chair unless safety was a concern in which case the tester walked alongside, but did not offer encouragement. A one minute warning was given at the 5 minute mark. The distance walked in 6 minutes was measured with a meter wheel to the closest 5 meters[164].

HHD: Isometric strength using HHD was measured using the Lafayette Manual Muscle Tester, Model # 01163 (Lafayette Instrument Inc USA). The dynamometer was factory calibrated and purchased within the last 12 months prior to use in this study. It was "zeroed" as per factory instructions prior to each test. The strength tests used in this study were knee extension, hip abduction, hip flexion and hip extension. A standard protocol was used based on a similar study[215] with some minor modifications as described below. For each muscle group tested the limb was first moved to the set position. Instructions for the participant were to hold the position, trying to exert as much force as possible against the pad. The tester met the effort of the participant and did not break their hold. Cueing for the contraction was: "*push…hold, hold, hold, relax.*" This resulted in a hold of approximately 5 seconds which has been shown in other studies to be an adequate time period to generate maximal force[61]. Each participant performed 2 trials for each leg. The mean peak force achieved between 2 trials was used as the strength measure. The HHD pad was placed perpendicular to the limb for all test positions.

Hip flexion and knee extension were tested in the same position sitting on the edge of a plinth with the hips and knees bent at 90^0 and a stool used to place the feet at 90^0 of dorsiflexion. The participant was allowed to place their hands on the plinth for support, but was asked not to lean back. For hip flexion the dynamometer pad was placed three finger widths proximal to the top of the patella. The thigh was allowed to lift approximately 10^0 off the plinth during the contraction. For knee extension the dynamometer pad was placed anteriorly just proximal to the lateral and medial malleolus, and the participant was asked to straighten the knee to reach an angle of approximately 45 degrees before performing the isometric contraction. For hip abduction the participant laid supine on the plinth with both hips extended and one small pillow under the head. The dynamometer pad was placed three finger-widths above the lateral joint line of the knee. The participant was asked to push the leg out to the side keeping their heel on the plinth and toes pointing up, pushing from approximately 10° of abduction. Hip extension was tested with the participant standing facing the plinth with the hip in 0° extension. The plinth was raised to the participant's hip level so they could place their hands on it for support. The participant was told not to lean onto the plinth during the contraction. The dynamometer pad was placed 3 finger widths proximal to the posterior knee joint line. The command was to push the leg back keeping the foot off the ground by slightly bending the knee.

30 second chair stand: The same standard chair (17 inches from floor to seat) was used for all tests. Participants had shoes on, and were asked to cross their arms across their chest. If the chair moved during the test, the tester stabilized the chair. Each participant had one practice trial. Then on the word "go", the stopwatch was started and the participant was instructed to stand and sit as many times as possible until the tester said "Stop" after 30 seconds. There was no encouragement during the test. Only completed numbers of fully sitting back down on the chair were recorded.

TUG: The protocol for the standard TUG is described in Chapter 3. For the TUG_{cog}, a progression of three steps was used. First, the participant was asked to count backwards by ones starting at 70 and counting as far back as able to in 15 seconds, while sitting on the chair. This acquainted them to the cognitive task prior to the dual task demand. They were then asked to perform the standard TUG while counting backwards by ones, instructed to complete both tasks simultaneously the best that they could. If they stopped counting or walking, the tester cued them and encouraged them to continue. The number of errors, any deviation in gait (stumbled, stopped or lost balance) was recorded as well as the total time for the test. The test was repeated for counting back by twos and threes. If the participant was unable or had extreme difficulty counting backwards by threes in sitting, the test was stopped at this point. The total time for the second component of this test (counting backwards by 2s) was used for the analysis as several participants were unable to attempt the test counting backwards by 3s. For post-testing, participants started at the number 50 in order to avoid practice between tests. For the TUG_{man} a 70 cm high stool was placed beside the chair with a cup of water. The water was always poured to 2/3 of the cup using a marked line (6.6 cm. on a 10 cm. tall cup). Participants were instructed to perform the same TUG test, picking up the cup once they stood up, and walk past the line, return, place the cup back on the stool and sit down. No practice trial was given. If water was spilled, the cup dropped, or any deviations in gait were made, this was recorded as well as the total time for the test.

Hip ROM: All ranges were measured as active range of motion with passive overpressure to the endpoint of motion or to the point of pain if an endpoint could not be reached. A standard protocol was used[154]. Hip range of motion included flexion, extension, abduction, internal rotation and external rotation. For hip flexion the participant was supine on the plinth and asked to bend one hip and knee, pulling the knee towards the chest as far as possible. The tester applied overpressure posterior to the thigh, just below the knee. The goniometer fulcrum was centered over the lateral aspect of hip joint, with the greater trochanter as the reference. The proximal arm of the goniometer was parallel to the lateral midline of pelvis, and the distal arm parallel to the lateral midline of femur. Due to age, presence of hip pain and potential back strain, a modified position for hip extension was used. In supine, with the same goniometer reference points used as for hip flexion, the opposite hip was held in full flexion while the other hip was extended as far as possible. The angle of motion of the leg away from the parallel axis of the surface of the bed was recorded in degrees (0 degrees as full hip extension motion). With the proximal goniometer arm parallel to the anterior superior iliac spines (ASIS) in supine and the distal arm in line with the anterior midline of the femur, Hip abduction was measured as the angle from the imaginary perpendicular line bisecting the parallel line between the ASIS. Hip internal and external rotation was measured with the participant sitting over the edge of the plinth with a single towel roll under the distal end of the femur. The goniometer fulcrum was centered over the anterior aspect of the patella and the femur stabilized. The proximal arm was lined perpendicular to the floor and the distal arm aligned to the anterior midline of lower leg, using a point midline between the lateral and medial malleoli as a reference.

Other physical measures: Height was measured as stretch stature in cm. Weight was recorded using a standard scale in kg. Body mass index (BMI) was calculated as kg/m^2.

Questionnaires: The Aims-2, PASE, Falls-Efficacy questionnaire and ABC were all self-report questionnaires. If assistance was needed, a research assistant read or clarified questions as necessary.

Statistical Analyses:

Data cleaning was conducted prior to statistical analysis based on recommendations by Tabachnick and Fidell[198]. Univariate descriptive statistics (mean, SD, range, skewness and standard error) were first inspected for the fall risk variables. The following criteria were used to deal with missing data, outliers and deviations with normality. First, accuracy of data input was inspected, identifying implausible means, standard deviations and extreme outliers. Second, the amount and distribution of missing data was evaluated. There was only one variable (AIMS-2) where missing data accounted for more than 5% of the cases for that variable: There were no significant differences ($p < 0.05$) between missing cases and non-missing cases comparing other variables (age and TUG). Missing data was randomly distributed amongst variables. In order to maintain power, group means were substituted for missing values or when possible the case mean was used for variables where there were missing data points. Normalcy of the data for each variable was evaluated using pairwise plots for nonlinearity and heteroscedasticity and tests for skewness and kurtosis. For variables that significantly deviated from normalcy, transformations were performed and then the distribution was re-evaluated. If the transformation corrected the skewness or kurtosis to less than twice the value of the standard error, the transformation was retained. Extreme outliers (defined as > 3 inter quartile ranges (IQR) from the outer boundaries of the boxplot), were found for the BBSm (2 cases), MCTSIB (one case), PASE (1 case), and TUG_{man} (1 case). These were not determined to be due to recording error, but extreme scores. These deviant scores were converted to 1 unit above or below the next highest or lowest value in the distribution. This reduced the impact of the outlier on the data distribution, still conserving the placement in the distribution[198 p. 77]. The following variables were transformed: 6 min walk (refsqrt), BBSm (refsqrt), MCTSIB (refsqrt), $TUG_{standard}$, TUG_{man} and TUG_{cog} (log10), Falls-efficacy$_{dual}$ (sqrt), and AIMS-2 (log10). Z-scores for total ROM of the affected hip were used in the analysis and a total strength score[112] for the affected hip was also calculated using the total mean scores for hip flexion, extension, abduction and knee extension.

Hypothesis 1 (*factors associated with presence of hip arthritis would be associated with history of falls and near-falls*) was tested by first identifying the variables significantly correlated to fall and near-fall history using binary correlation coefficients. All of the baseline variables listed in Table 4.1 and including relevant demographic data such as age, gender, use of walking aid, BMI, number of co-morbidities, number of prescription medications, location of hip pain unilateral vs. bilateral, presence of other lower extremity arthritis, physical activity level and length of time with hip OA were correlated with falls and near-falls. Variables with significant bivariate correlation values ($p<0.20$, exploratory analysis) were then entered into two logistic regression analyses: The first equation determined the relationship of factors to a history of falls, and the second regression equation tested the relationship of factors to a history of frequent near-falls. The logistic regression model was fit by the "block" method, in which variables were entered one at a time based on correlation values (highest to lowest) and differences in the – 2 log-likelihood ratio test values were compared using a chi-square significance test ($p<0.05$)[110]. If the addition of the variable resulted in a significant difference in the - 2 log likelihood ratio test values, it was retained in the next model. If the variable did not add significance to the model, it was dropped. The most parsimonious model to explain the relationship of variables to fall and near-fall history was chosen based on goodness of fit as assessed by the – 2 log likelihood ratio test which is considered analogous to the F-test in multiple regression. Odds ratios (ExpB) were calculated to quantify the relationship of the fall risk factors studied to the likelihood of having fallen in the past year or the likelihood of having frequent near-falls.

Hypothesis 2 (*higher levels of falls-efficacy for dual task function, reactive balance and more challenging functional tasks such as getting up from the floor would predict better physical performance on dual task TUG, reaction time, the Berg Balance Scale and MCTSIB respectively*) was tested with seven hierarchical linear regression equations to answer the following: 1) Does confidence in dual task walking predict scores on TUG_{cog} and TUG_{man}, 2) Does confidence in reactive balance predict scores of reaction time, 3) Does confidence in complex tasks predict scores on a) Berg Balance and b) MCTSIB and 4) Does total efficacy score (ABC and Falls-Efficacy Questionnaire-total) predict scores on the Berg Balance Scale? In order to determine the impact of efficacy beyond the influence of other possible demographic factors such as age, mobility level, etc., a hierarchical regression model was used, first entering those factors that had significant correlations with the dependent variable.

Results:

Seventy-nine participants (71% females and 29% males) completed baseline testing. Frequency and descriptive data for other demographic information and baseline scores for variables measured are in Tables 4.2 and 4.3.

Table 4.2 Demographic data for 79 participants with clinical diagnosis of hip OA and at least 1 fall risk factor

Variable	Frequency	%
1 or more falls in the past year	39	49.4
Frequent near-falls (occurring 1/week or >)	23	29.1
Not engaged in moderate exercise 2/ week or > for at least 30 minutes	68	86.0
On a waiting list for total hip replacement	6	7.6
Osteoporosis	28	35.4
Arthritis in at least one other joint	26	32.9
Arthritis present both hip and knee	17	21.5
Hip Pain rating*		
• Mild	22	28.9
• Moderate	44	57.9
• Severe	10	13.2
Uses a walking aid	33	41.8
Lives in senior residence or apartment*	39	51.6
Lives in single dwelling home**	38	49.4
Lives alone***	28	40.6
History of fracture	27	34.2
Current use of non-steroidal anti-inflammatory medication	16	20.3
Hip affected		
• Right	29	36.7
• Left	19	24.1
• Both	31	39.2

* n = 76;** n = 77; *** n = 69

Table 4.3 Descriptive data for 79 participants tested at baseline

Variable	Mean (SD)	Range
Age (years)	74.4 (6.3)	65 – 88
Number of co-morbidities	2.1 (1.3)	0 – 5
Duration of hip pain (years)	7.6 (8.8)	0.5 – 50.0
Number of current prescription medications	3.0 (2.6)	0 – 12
BMI (kg/m^2)	29.8 (5.1)	22.9 – 47.4
Balance		
• Berg Balance Scale (modified / 36)*	30.3 (4.0)	19 – 36
• MCTSIB (/120 sec)*	95.0 (21.0)	23 – 120
• Lower extremity reaction time (sec)	0.89 (0.18)	0.2 – 1.45
Gait		
• Step length forward (cm)	21.9 (10.2)	4.2 – 54.0
• Step length sideways (cm)	28.7 9.7)	11.0 – 58.8
• Step length backward (cm)	17.6 (9.2)	0.0 – 44.5
• 6 minute walk distance (meters)	355.0 (106.5)	50.0 – 550.0
Lower body strength (hip flexion, extension, abduction and knee extension total for affected extremity)		
• Total leg strength (kg)	16.0 (7.0)	6.9 – 36.7
Falls – Efficacy		
• Dual Task (/100)	64.9 (24.9)	0.0 – 100.0
• Reactive (/100)	50.9 (26.0)	0.0 – 100.0
• Complex (/100)	62.8 (26.1)	12.5 – 100.0
• Total Efficacy Score (/100)	60.1 (24.0)	8.7 – 100.0
• ABC (/100)	68.4 (19.9)	15.6 – 99.4
Mobility/Function		
• TUG standard (sec.)	11.9 (4.3)	7.5 – 28.0
• TUG $_{cog}$ (counting backward by 2s, sec.)	15.0 (7.2)	6.3 – 49.9
• TUG $_{man}$ (carrying cup ¾ full of water, sec.)	12.1 (4.4)	6.8 – 28.2
• AIMS-2 (3 component model; 0 – 25)	10.5 (3.1)	5.6 – 22.7
• PASE total score	101.6 (47.3)	25.0 – 215.7
• Total hip range (z-score for affected extremity)	- 1.7 (3.0)	- 11.7 – 4.8

* Higher scores indicate better balance

<u>Relationship of demographic and baseline fall risk factors to fall history:</u>

Six variables had significant bivariate correlations ($p < 0.20$, exploratory) to a history of falls in the past year: 1) near-falls (categorized dichotomously as never or occasional vs. frequent) r = 0.26, 2) use of a walking aid r = - 0.17, 3) number of prescription medications r = - 0.17, 4) 6 minute walk, r = 0.17, 5) number of co-morbidities, r = 0.15 and 6) presence of arthritis in other joints, r = 0.15.

Results of the logistic regression analysis (Table 4.4) found that the best model associated with fall history included the variables history of frequent near-falls and the 6 minute walk. Using this model, 18% of the variance of fall history was explained. Participants who reported frequent near-falls (once a week or more) were 5 times more likely to report having had a fall in the past year. The relationship of the 6 minute walk to fall history was not the association expected, however. Individuals who walked a *greater* distance in this test were more likely to have had a fall in the past year. This was a weaker relationship than that of near-falls with falls, as the odds ratio was very close to 1.0. It is interesting to note that the relationship of use of walking aid also showed a similar negative relationship to fall history, with reported use of a walking aid (usually indicative of slower gait speed) associated with a less likely probability of a fall history, although this relationship was not significant.

Table 4.4 Logistic regression model explaining the association of risk factors to fall history

Variable entered	- 2 log-likelihood ratio	Nagelkerke R^2	Odds ratio (CI)	p-value
Model 1 Frequent near-faller	104.1	0.09	3.28 (1.16 – 9.24)	0.025
Model 2 Frequent near-faller Use of walking aid	101.5	0.13	3.49 (1.21 – 10.07) 0.46 (0.18 – 1.19)	0.021 0.111
Model 3 Frequent near-faller Number of prescription medications	102.3	0.12	3.17 (1.11 – 9.02) 0.88 (0.73 – 1.06)	0.031 0.188
Model 4* Frequent near-faller 6 minute walk (refsqrt)†	97.9	0.18	5.19 (1.61 – 16.72) 0.85 (0.74 – 0.97)	0.006 0.019
Model 5 Frequent near-faller 6 minute walk (refsqrt) Number of co-morbidities	97.4	0.19	5.33 (1.63 – 17.49) 0.84 (0.73 – 1.69) 1.14 (0.77 – 1.69)	0.006 0.016 0.524
Model 6 Frequent near-faller 6 minute walk (refsqrt) Presence of arthritis other joints	94.9	0.22	6.20 (1.84 – 20.87) 0.85 (0.74 – 0.98) 2.57 (0.85 – 7.77)	0.003 0.021 0.095

*** Model 4** significantly different than model 1 (χ^2 = 6.2, 1 df, $p < 0.05$), explaining highest percent of variance (18%); addition of other variables does not contribute significantly to the model
† Note that refsqrt signifies that higher scores means **less** distance walked

Relationship of demographic and fall risk factors to near-fall frequency

Thirteen variables were significantly ($p < 0.20$, exploratory) associated with history of frequent near-falls: BMI, reaction time, Falls-Efficacy (total score and 3 sub-scores), ABC, TUG_{cog} and $TUG_{standard}$, BBSm, MCTSIB, 6 minute walk, and the 30 second chair stand. Due to the high collinearity between the Falls-Efficacy sub scales, $Falls\text{-}Efficacy_{total}$ and the ABC ($r > 0.80$) and between TUG_{cog} and $TUG_{standard}$ ($r > 0.80$), $Falls\text{-}Efficacy_{total}$ was used to represent falls-efficacy and TUG_{cog} for a functional walking test. The correlation matrix for the 8 variables then entered into logistic regression with near-fall history are shown in Table 4.5. Converted scores were used in the regression analysis [6 minute walk, Berg Balance Scale, MCTSIB (refsqrt) and TUG_{cog} (log10)].

Table 4.5 Correlation matrix of demographic and baseline variables

Variable	Frequent near-fall	BMI	Reaction time	Fall-efficacy	Chair stand	6 min. walk	Berg	MCTSIB	TUG_{cog}
Frequent near-fall	X								
BMI	0.15	X							
Reaction time	0.17	- 0.09	X						
Fall-efficacy	- 0.30	- 0.23	- 0.31	X					
Chair stand	- 0.15	- 0.05	- 0.51	0.41	X				
6 min. walk	- 0.27	- 0.23	- 0.47	0.52	0.58	X			
Berg	- 0.22	- 0.11	- 0.53	0.56	0.72	0.62	X		
MCTSIB	- 0.19	- 0.16	- 0.36	0.42	0.34	0.39	0.50	X	
TUG_{cog}	0.18	0.04	0.62	- 0.29	- 0.60	- 0.50	- 0.62	- 0.19	X

Using the same model building principle, each of the 8 variables in Table 4.5 were entered one at a time into logistic regression analysis, first entering those variables with higher correlation values (Table 4.6).

Table 4.6 Logistic regression analysis of demographic and other fall risk variables associated to history of frequent near-falls.

Variable entered	- 2 log-likelihood ratio	Nagelkerke R^2	Odds ratio (CI)	p-value
Model 1* Falls-Efficacy-total	88.0	0.13	0.97 (0.95 – 0.99)	0.010
Model 2 Falls-Efficacy-total 6 minute walk (refsqrt)	86.8	0.15	0.98 (0.96 – 1.00) 1.09 (0.93 – 1.28)	0.08 0.271
Model 3 Falls-Efficacy-total Berg Balance Scale (refsqrt)	87.8	0.13	0.98 (0.95 – 1.00) 1.22 (0.54 – 2.76)	0.06 0.63
Model 4 Falls-Efficacy-total MCTSIB (refsqrt)	87.0	0.14	0.98 (0.95 – 1.00) 1.15 (0.88 – 1.49)	0.042 0.31
Model 5 Falls-Efficacy-total TUG_{cog} (log10)	86.5	0.15	0.98 (0.95 – 1.00) 6.87 (0.32 – 148.5)	0.029 0.22
Model 6 Falls-Efficacy-total Reaction time	87.4	0.14	0.97 (0.95 – 1.00) 3.37 (0.16 – 69.18)	0.022 0.43
Model 7 Falls-Efficacy-total Chair stand	88.0	0.13	0.97 (0.95 – 1.00) 0.98 (0.84 – 1.15)	0.022 0.82
Model 8 Falls-Efficacy-total BMI	87.5	0.13	0.97 (0.95 – 1.00) 1.04 (0.94 – 1.15)	0.017 0.47
* Model 1 was the only significant association to frequent near-falls, (χ^2 = 7.3, 1 df, $p < 0.05$); addition of other variables does not contribute significantly to the model				

The results showed higher falls-efficacy scores were minimally, but significantly associated with a lower risk of being a frequent near-faller. With lower falls-efficacy scores, approximately 13% of the variance of near-falls was explained and the model predicted frequent near-fallers 71% of the time.

Based on this finding, further exploratory analysis was conducted to determine the influence of falls-efficacy in the relationship of near-falls to falls. The potential effect of falls-efficacy as a confounder or effect modifier in the relationship of near-falls to falls was explored using the model depicted in Figure 4.1[21].

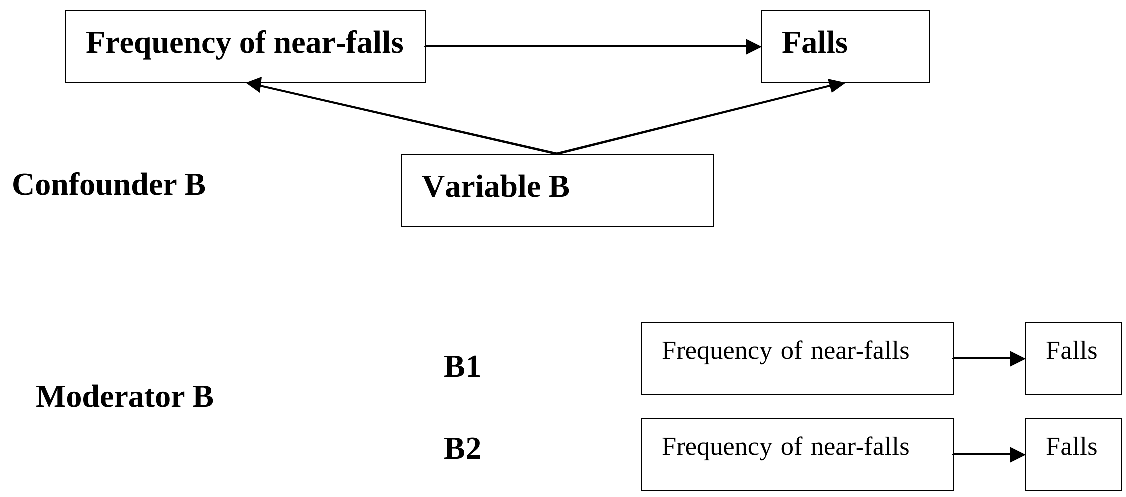


Figure 4.1 Analysis of the relationship of falls-efficacy (variable B) to history of falls and near-falls.

Falls-efficacy was not significantly associated with history of falling (OR = 0.99, CI 0.97 – 1.01, p = 0.54) illustrating it was not a confounder. However, after splitting the sample into dichotomous groups based on level of falls-efficacy (split at the median value for the Falls Efficacy Questionnaire, < 63.0 or 63.0), differences in the relationship of near-fall frequency to falls was observed suggesting that falls-efficacy is an effect modifier in the relationship of frequent near-falling to falls.

The odds ratios and confidence intervals for the different levels of the moderator variable are shown in Figure 4.2. When the sample was split into lower and higher levels of falls-efficacy, the relationship of near-falls to falls changed substantially. With lower levels of falls-efficacy, the odds of higher frequency of near-falls being associated with history of falls was 7 times more likely. I further explored this relationship by splitting the sample for the ABC scale, a different falls-efficacy or balance confidence scale. Results of these analyses were similar to the prior results with an OR of 8.2 (1.5 – 45.4) for the association of near-falls to falls for lower balance-confidence when ABC scores were split at the median of 70. In contrast, for the group with higher falls-efficacy, the relationship of near-falls to falls was diminished and became non-significant. As well, if comparing lower and higher falls-efficacy groups, there were significant differences in age, activity level, balance tests, 6 minute walk, AIMS-2, 30 second chair stands and reaction time ($p < 0.05$) using independent t-tests. Participants with lower falls-efficacy were older, less active with greater balance and mobility impairments. The influence of falls-efficacy on the relationship of near-falls to falls held true even when the logistic regression equation including both near-falls and the 6 minute walk was run again with the sample split into low and high falls efficacy groups. Near-falls remained strongly and significantly associated with falls with low falls-efficacy participants (OR = 8.4, CI 1.5 – 46.0), but the 6 minute walk was no longer significantly associated with fall history (OR = 0.81, CI 0.63 – 1.03).

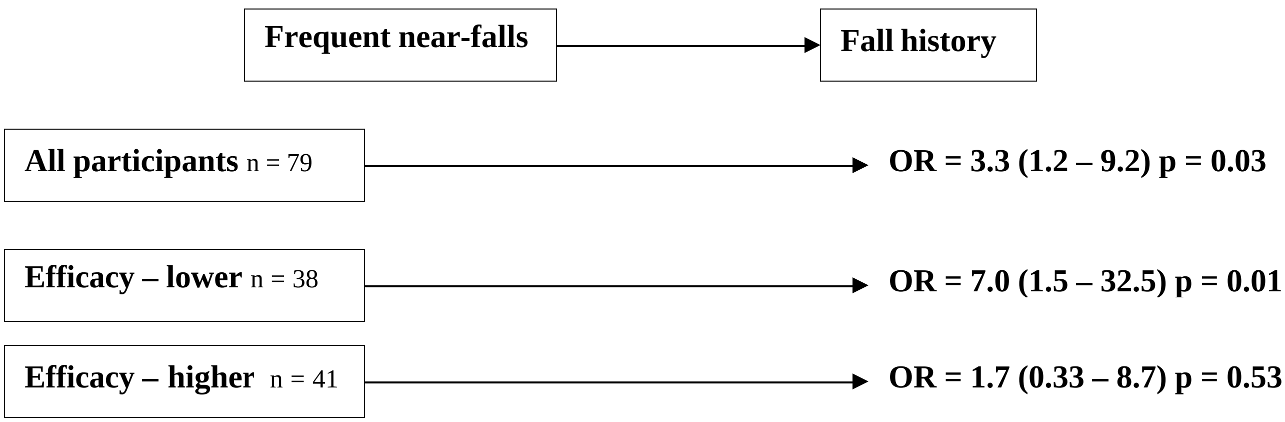


Figure 4.2 The effect of falls-efficacy as a moderator in the relationship of near-falls to falls

Falls-efficacy and performance on associated balance tests

Several hierarchical multiple regression equations were examined to evaluate the capacity of falls-efficacy scores in predicting performance in a similar balance task (refer to outcome summary in Table 4.1) within two hours after completing the falls-efficacy rating (Hypothesis 2). The following variables were first entered into each of the hierarchical regression equations in step 1, in order to determine the additional effect of falls-efficacy after controlling for these variables: Age, use of walking aid, number of prescription medications, total score on the AIMS-2 and total score of PASE. These variables were chosen based on significant correlations to the functional tests (Table 4.7).

The results of the regression models can be found in Tables 4.8 and 4.9. Table 4.8 portrays the results for the relationship of falls-efficacy in dual task performance with actual performance on the TUG_{cog} and TUG_{man} and the relationship of falls-efficacy in ability to react quickly to an external perturbation with lower extremity reaction time. Table 4.9 depicts the relationship of falls-efficacy in more complex functional tasks such as ability to avoid a fall under more challenging environmental and sensory deprived conditions with performance on the Berg Balance Scale and MCTSIB and the relationship of total falls-efficacy scores and the ABC with the Berg Balance Scale.

Table 4.7 Pearson r correlation values of demographic factors to balance and function tests

Variable	Age	Walking aid	# prescription medications	AIMS-2	PASE
BBSm	- 0.40*	- 0.39*	- 0.30*	- 0.35*	0.27*
MCTSIB	- 0.34*	- 0.20	- 0.40*	- 0.15*	0.24*
Reaction time	0.41*	0.38*	0.19	0.29*	- 0.27*
TUG_{cog}	0.35*	0.35*	0.12	0.29*	- 0.26*
TUG_{man}	0.36*	0.35*	0.17	0.25*	- 0.23*

$* p < 0.05$

Table 4.8. Hierarchical linear regression model summary for TUG_{cog}, TUG_{man} and reaction time

Independent variable › Dependent variable	R^2	R^2 Change	standardized ß (SE)	P
Dual-task efficacy (sqrt) › TUG_{cog} (log10)				
• Model 1	0.29	0.29		
o Age			0.31	0.004
o Walking aid			0.16	0.18
o # prescription medications			0.04	0.73
o AIMS-2			0.15	0.19
o PASE			-0.18	0.24
• Model 2	0.29	0.00		
o Age			0.30	0.01
o Walking aid			0.15	0.19
o # prescription medications			0.04	0.72
o AIMS-2			0.13	0.31
o PASE			- 0.17	0.12
o Dual task efficacy			0.05	0.70
Dual-task efficacy (sqrt) › TUG_{man}log10)				
• Model 1	0.27	0.27		
o Age			0.32	0.005
o Walking aid			0.18	0.14
o # prescription medications			0.05	0.63
o AIMS-2			0.12	0.27
o PASE			- 0.11	0.33
• Model 2	0.27	0.00		
o Age			0.31	0.009
o Walking aid			0.17	0.15
o # prescription medications			0.05	0.63
o AIMS-2			0.12	0.36
o PASE			- 0.11	0.33
o Dual task efficacy			0.03	0.83
Reactive efficacy › Reaction time				
• Model 1	0.29	0.29		
o Age			0.33	0.003
o Walking aid			0.18	0.13
o # prescription medications			0.02	0.84
o AIMS-2			0.18	0.11
o PASE			- 0.10	0.38
• Model 2	0.29	0.00		
o Age			0.34	0.003
o Walking aid			0.18	0.13
o # prescription medications			0.03	0.83
o AIMS-2			0.19	0.12
o PASE			- 0.10	0.38
o Reactive Efficacy			0.02	0.87

Table 4.9. Hierarchical linear regression model summary for Berg Balance Scale and MCTSIB

Independent variable › Dependent variable	R^2	R^2change	Standardized ß	P
Complex task efficacy › Berg Balance Scale (refsqrt)				
• Model 1	0.32	0.32		
o Age			0.30	0.005
o Walking aid			0.15	0.18
o # prescription medications			0.13	0.22
o AIMS-2			0.24	0.03
o PASE			- 0.08	0.50
• Model 2	0.44	0.11		
o Age			0.19	0.06
o Walking aid			0.09	0.39
o # prescription medications			0.14	0.16
o AIMS-2			0.05	0.69
o PASE			- 0.09	0.38
o Complex task efficacy			- 0.42	0.000
Complex task efficacy › MCTSIB (refsqrt)				
• Model 1	0.24	0.24		
o Age			0.33	0.004
o Walking aid			- 0.08	0.51
o # prescription medications			0.24	0.04
o AIMS-2			0.01	0.94
o PASE			- 0.22	0.06
• Model 2	0.31	0.07		
o Age			0.25	0.03
o Walking aid			- 0.13	0.28
o # prescription medications			0.25	0.03
o AIMS-2			- 0.14	0.26
o PASE			- 0.24	0.04
o Complex task efficacy			- 0.32	0.01
Efficacy-total › Berg Balance Scale (refsqrt)				
• Model 1	0.33	0.33		
o Age			0.30	0.005
o Walking aid			0.15	0.18
o # prescription medications			0.13	0.22
o AIMS-2			0.24	0.03
o PASE			- 0.08	0.50
• Model 2	0.43	0.10		
o Age			0.19	0.07
o Walking aid			0..09	0.38
o # prescription medications			0.12	0.21
o AIMS-2			0.04	0.73
o PASE			- 0.08	0.43
o Efficacy-total			- 0.41	0.001
ABC › Berg Balance Scale (refsqrt)				
• Model 1	0.33	0.33		
o Age			0.30	0.005
o Walking aid			0.15	0.18
o # prescription medications			0.13	0.22
o AIMS-2			0.24	0.03
o PASE			- 0.08	0.50
• Model 2	0.37	0.05		
o Age			0.27	0.009
o Walking aid			0.11	0.34
o # prescription medications			0.10	0.32
o AIMS-2			0.08	0.54
o PASE			- 0.06	0.55
o ABC			- 0.30	0.02

The falls-efficacy rating scales for dual task function and reactive balance did not add any significant variance in explaining results of the TUG_{cog}, TUG_{man} or reaction time respectively, after controlling for age, use of walking aid, number of prescription medications, and scores on the AIMS-2 and PASE (refer to Table 4.9). The single variable that explained most of the variance for these tests was age, based on the standardized beta values. However, for the Berg Balance Score and the MCTSIB, the variable that explained most of the variance was falls-efficacy as rated in the complex tasks category. The falls-efficacy total score and ABC also showed the strongest association to the Berg Balance score based on the standardized beta weights. Falls-efficacy of complex tasks as well as the total falls-efficacy score significantly improved the model and explained 11 and 10% additional variance beyond that already accounted for by age, number of medications, use of walking aid, PASE and AIMS-2. Falls-efficacy scores explained approximately 7% additional variance for the MCTSIB and significantly improved the model. The ABC scores also significantly improved the model, adding 5% additional variance.

Discussion:

In this study, I examined fall risk factors and the relationship of these factors to fall and near-fall history in a population of older men and women with a clinical diagnosis of hip OA living independently in the community. I found that participants who reported frequent loss of balance or near-falls and those who walked greater distances in the six minute walk were more likely to have fallen in the past year. Lower falls-efficacy was associated with a stronger relationship of near-falls to falls, with individuals with lower falls-efficacy seven times more likely to have experienced a fall if they reported frequent balance loss. The finding that falls-efficacy predicted outcomes on balance tests also supports the conjecture that falls-efficacy is an important contributor to balance performance and may further increase the risk of future falls and near-falls in the older adult with hip OA.

A history of near-falls was the only variable that showed a strong association to a history of falls. This association was not surprising, as a frequent loss of balance is more likely to result in an actual fall. Other studies also have observed an association of reports of near-falls to future falls[202]. A novel finding, however, was the moderating effect of falls-efficacy to the association of near-falls to falls. The explanation for this finding is not clear. It is possible that those with lower falls-efficacy experience more near-falls due to lower falls-efficacy; but, it is also possible that near-falls result in lower falls-efficacy. The older adult with hip OA and lower falls-efficacy might also be less able to recover a near-fall that may lead to an actual fall. This study was not designed to address these other possible causal relationships; nevertheless, based on previous research, populations with chronic pain do have higher levels of fear of falls[134].

The spiraling effect of fear of falls predicting falls and falls predicting further escalation of fear is well known[77]. It is possible that the association found in my study is unique to the hip OA older adult population. The mean score on the ABC was lower than mean scores reported in a sample of older women with low bone mass[122] and was similar to mean scores found for fearful older adults[148]. The impact of lower falls-efficacy may be greater on the risk of falls and near-falls in populations with mobility difficulties. Self-efficacy is potentially an important predictor of the overall health status for individuals with arthritis[134]. As falls-efficacy relates to self-efficacy theory, the same could hold true for the importance of falls-efficacy in predicting fall risk and future falls for individuals with hip OA. In this study I found that participants with lower falls-efficacy were older, less mobile with greater balance and functional impairments. Further research is needed to explain the confounding, moderating or mediating effect of falls-efficacy on future falls in this population. Screening for falls-efficacy may be important to identify those at higher risk.

Falls-efficacy was an independent predictor of balance both in the Berg Balance Scale and the Modified Clinical Test of Sensory Interaction and Balance. Even after accounting for factors such as age, activity level, number of prescription medications, use of a walking aid and scores on the Arthritis Impact Measurement Score (AIMS-2), falls-efficacy scores contributed 10% additional variance. Considering that falls-efficacy is associated with lower mobility and functional status, an additional independent contribution beyond these factors is clinically relevant. Other studies support the independent contribution of falls-efficacy. Liu-Ambrose et al.[122] found an independent effect of falls-efficacy as measured by the ABC scale on balance and gait speed in a sample of older women with low bone mass with 18% and 11% of the variance explained by falls-efficacy after controlling for age, activity level and other balance and visual impairment tests. Further, other studies have found relationships of falls-efficacy to balance and functional status as measured by functional reach, self paced walk, single leg stance, and a stepping test[113 148]. Falls-efficacy was also independently correlated with activities of daily living in a community-dwelling older adult population [208] and was a predictor of prospective decrease in activities of daily living independent of fall history in older adults admitted to acute care[56].

This was the first study to evaluate the association of selected falls-efficacy specific to related functional balance tests: dual task performance, stepping reactions to an auditory cue and balance under different environmental challenges such as no visual input and unstable support surfaces. It was not unexpected that the reactive falls-efficacy did not predict reaction time. Reaction time is a reflexive response to an unexpected perturbation, and individuals are not likely to feel that they have as much control over these movements as opposed to a self-initiated functional task. As well, for dual task falls-efficacy, the TUG_{cog} involved walking while counting backwards by 2s, which is not a common dual task in day to day living and thus, falls-efficacy rating related to this task might be more reflective of the unknown, verses lack of confidence. However falls-efficacy of functional movements, such as walking on rough ground, stepping up and down curbs, navigating when lighting is diminished, getting up and down from the floor, and walking to the bathroom at night, were independently associated with balance performance in tests that challenge balance under different environmental situations (MCTSIB) and with varying functional tasks (BBSm). Another study evaluated ADL specific self-efficacy as well as performance on related ADL tasks comparing two groups of older adults who either had a weight training program or a weight training program combined with education to enhance the link between the exercises and ability to perform ADL. They found that the exercise and education group improved in ADL self-efficacy, however it did not translate into greater improvement of actual ADL tasks[135]. Similarly, Liu-Ambrose et al. found that improvement in falls-efficacy following balance and strength training was not related to improvement in actual balance and strength performance[124]. Thus, it appears that falls-efficacy specific to day to day functional tasks is an important predictor of balance performance, but improvements in falls-efficacy is not enough to improve balance performance. Recognizing individuals at risk of poorer balance and functional performance through assessment of their falls-efficacy may be important for fall risk screening, particularly in groups where lower falls-efficacy is more prominent such as individuals with mobility restrictions. However, further research is needed to identify the interventions needed to improve both falls-efficacy and physical performance of ADL for those individuals at greater risk.

One finding from this study was contradictory to previous literature. Slower gait velocity, use of a walking aid and poorer walking endurance as measured by tests such as the six minute walk have all been associated with decreased mobility and increased fall risk in community-dwelling elderly[126]. I found that a greater distance walked in the 6 minute walk was positively associated with fall history; and the use of a walking aid was associated with a decreased risk of having had a fall in the last year, although this relationship was not significant. It could be that for populations that have conditions such as hip OA with mobility difficulties that the use of a walking aid as well as a slower gait pace actually decreases risk of falls. There is some support as a faster gait velocity has been found to increase the risk of tripping[158]. A second study also found that although slower gait velocity is associated with increased fear of falls, it is not related to fall history[131]. Walking slower may be a sign of being more cautious. For the older adult with lower extremity pain and decreased mobility, walking slower with a walking aid may improve the quality of gait and thus improve stability and diminish the risk of a fall. Because the 6 minute walk only measures distance walked and not *how* people walk, further study is warranted to investigate the quality of gait and the impact of walking aids and speed on fall risk in older adults with lower extremity arthritis and pain.

Although some studies have evaluated fall risk factors in populations with lower extremity arthritis[192, 220], no other studies have evaluated fall risk in a population specifically with hip pain. In this study, the sample consisted of 79 men and women over age 65 with hip pain and a clinical diagnosis of hip OA, and the presence of either a TUG score less than 10 seconds or a fall in the past year. Although this represented a sub-group of hip OA that may be at greater risk of falls, because of the high frequency of falls found in Study 1 (45%), this sample is representative of approximately 50% or more of the community-dwelling elderly with hip OA. There were lower mean and median scores for several functional tests where normative data are known. For the 6 minute walk and 30 sec chair stand, the majority of the sample was below the "normal range" (50th percentile) for the 70 to 74 age bracket.[164] For the Berg Balance Scale (if converted to original score/56), about 30% of this sample would be below the cut-off value for high fall risk[166]. However, the mean physical activity level was similar to what has been found in other samples of community-dwelling older adults as determined by PASE scores[217].

Limitations to the interpretation of the results of this study are the cross-sectional design comparing fall risk factors to a history of falls and near-falls. Although past falls predict future falls, causative conclusions cannot be made regarding the risk of future falls. Further prospective study is needed to determine the relationships of falls-efficacy, physical performance on balance and functional tests to future fall risk. Since the combination and degree of these factors present may be unique to the hip OA population, further study of individuals with hip pain as well as other chronic pain conditions is warranted.

In conclusion, older adults with hip OA present with several mobility and balance limitations that may partially explain the increased frequency of falls observed. Determining the frequency of near-falls may be an important screening question to include as there is a strong relationship of near-falls to fall history. Determining the level of falls-efficacy may also be an important screening tool for this population as lower levels of falls-efficacy increases the association of near-falls to falls and is an independent predictor of balance impairment. Finally, future study should determine the association of gait speed, gait quality and use of walking aids with fall risk in older adults with hip OA.

Relationship of Study 2 to Thesis:

Building on the results from Study 1, where a high frequency of falls and near-falls were reported in this population of older adults with hip OA, the question arose: What are the risk factors that contribute to this higher frequency? Study 2 attempted to answer this question by evaluating the relationship of a battery of primary and secondary fall risk factors to fall and near-fall history as well as explore the relationship of psychosocial factors to physical factors. I found that this sample did present with several mobility and balance impairments that would put them at higher risk of falling compared to other normative data in the literature. Frequency of near-falls and falls-efficacy may be important predictors of future falling in this population. The association of falls-efficacy to physical performance on fall risk tests was interesting and directs one to question if a change in falls-efficacy could also result in improved physical performance related to fall risk. Knowing the profile and potential relationship of fall risk factors present in this population leads to the next question explored in Study 3: What is the effect of an exercise intervention combined with efficacy enhancement on diminishing these fall risk factors? Does efficacy enhancement through education result in actual improvement in physical balance and mobility tests?

CHAPTER 5

The effect of aquatic exercise and education on improving indices of fall risk in older adults with hip osteoarthritis: a randomized controlled clinical trial

ABSTRACT

Purpose: The purpose of this study was to evaluate the effect of aquatic exercise and aquatic exercise combined with an education group program on fall risk factors in older adults with hip OA. **Methods:** Seventy-nine older adults with a clinical diagnosis of hip OA and at least 1 fall risk factor (TUG score 10 seconds or a history of falling in the past 12 months) were randomly assigned to one of three groups: Aquatic-Education, Aquatic or Control. The exercise and education interventions were 11 weeks in length. Fall risk outcomes included primary and secondary measures of balance, falls-efficacy, dual task function, strength, and mobility. **Results:** There was a significant between group difference for primary fall risk factors (full factorial MANCOVA; $p = 0.038$) where Aquatic-Education had improved falls-efficacy compared to Control and increased number of chair stands compared to both Aquatic and Control. There was no significant difference in secondary measures of hip strength, hip range, step length, reaction time and no difference in outcome of balance tests. Falls-efficacy specific to more complex functional tasks was significantly improved in Aquatic-Education compared to both Aquatic and Control. Rating of global health improvement was also significantly greater in Aquatic-Education compared to Control. **Conclusion:** Aquatic exercise on its own is not enough to result in improvement of fall risk factors in older adults with hip OA. The addition of land-based education to reinforce fall prevention strategies and the purpose of the exercise resulted in improvements in falls-efficacy and functional strength. Exercise programs for older adults already at risk for falls due to conditions such as arthritis need to consider the addition of education.

Introduction:

There have been several studies and reviews evaluating the impact of exercise programs on reducing falls and fall risk in the elderly population[50, 80, 219]. Although exercise has been found to improve some fall risk factors and reduce the frequency of future falls, it is still not clear the best type or frequency of exercise to reduce fall risk[80]. Educational programs on their own do not appear to decrease fall risk[80], however it is unknown what the impact is for different combinations of education and exercise for higher risk populations. Older adults with hip OA present with a collection of impairments as identified in Chapters 3 and 4 that put them at a higher risk of falls. As well, due to pain, limited mobility and greater fear of falls[214], they may be reluctant or unable to participate in standard fall prevention programs that incorporate land-based exercise. Despite limited evidence, aquatic exercise has been promoted as an effective exercise program for individuals with lower extremity OA to decrease pain, improve physical function and self-efficacy[2, 23, 78]. However, no studies have compared the effects of aquatic exercise alone and aquatic exercise combined with education on fall risk in the OA population. This combination of program may result in greater gains in physical status related to fall risk as well as improve falls-efficacy. The purpose of this study was to determine the effect of aquatic exercise and aquatic exercise combined with an education group program on fall risk factors in community dwelling older adults with hip OA. I hypothesized that: 1) Both aquatic exercise alone (Aquatic) and the combined aquatic and education program (Aquatic-Education) would improve primary and secondary **physical** fall risk factors in balance, gait, lower body strength, function and mobility compared to Control, 2) Aquatic-Education would result in greater improvement in **falls-efficacy** as compared to both Aquatic and Control, and 3) Aquatic-Education would show greater improvement in primary and secondary **physical** fall risk factors involving more complex balance and functional tasks (TUG_{cog}, 30 second chair stand, Berg Balance Scale, MCTSIB and reaction time) compared to Aquatic.

Methods:

The recruitment strategies, inclusion and exclusion criteria, and screening criteria have been described previously in Chapter 3 and Appendix A. Participants meeting eligibility criteria (aged 65 or older, presence of hip pain 6 months or longer, diagnosed with hip OA using a clinical classification, and presenting with 1 fall risk factor: TUG score 10 seconds or > or history of a fall in the past 12 months) were randomly assigned to one of three groups: Aquatic-Education, Aquatic or Control using the following random allocation method. First, following screening and prior to baseline testing, participants were stratified by the primary investigator according to: 1) history of a total hip replacement or other surgical hip repair and 2) TUG score 14 seconds or >. This stratification was done to ensure equal numbers across groups for these two factors likely to affect functional status. Once stratified, participants were randomly assigned by an individual not involved in the research project using a computer generated program to randomize numbers 1 to 3 for each stratified set (*Urbaniak G.C. & Plous S. The Research Randomizer; www.randomizer.org*). Participants were blinded to group assignment until after baseline testing, when given a sealed opaque envelope revealing their group assignment.

Details of baseline testing, outcomes used and the blinding of testers have been described previously in Chapter 4. Post-testing following intervention included the same outcome testing with the addition of a "general status" questionnaire including global improvement rating, and questioning regarding changes to health status, any additional interventions and repeat questioning regarding fall and near-fall history (Appendix H). Following baseline testing, participants started 11 weeks in one of the following groups described below:

Aquatic:

The aquatic exercise group met 2/week for 11 weeks at a community recreational facility with a pool designed for easy access for older adults (ramps and zero entry access, water temperature kept at approximately 30 degrees C.). The aquatic exercise session lasted 45 minutes with participants exercising in chest water depth. The goals of the exercise program were to improve mobility, strength and balance in a safe and supportive environment that allowed for optimum mobility with minimal joint pain (Refer to Appendix I for summary of the aquatic exercise program and goals). The instructors for the exercise session had training in aquatic exercise and were experienced fitness instructors. As well, a training session and a manual outlining the exercise protocol were provided for both instructors prior to the intervention. The research coordinator met on a weekly basis with instructors to ensure that the program goals were met. In addition, the instructors filled out weekly status reports, documenting attendance, any adverse effects reported, progressions made in the program and any modifications made.

Aquatic-Education:

This group had the same aquatic exercise program 2/week for 11 weeks, but held at a different time than the Aquatic group. In addition a 30 minute hour educational session preceded the aquatic class 1/week for 11 weeks. The educational session was held in the recreational facility where the pool was located using a multi-purpose room with mats, mirrors and space to walk as well as a common meeting space just outside of the pool area. The education sessions were conducted by a physical therapist with 20 years experience working with an elderly population. The outline for each educational session is in Appendix J. The goals of the education session were to 1) increase the transfer of exercises learned in the pool to ability to successfully perform activities of daily living on land, 2) increase intention to continue with exercise once the intervention was complete and 3) improve confidence in the ability to avoid a fall and recover from a fall at home and in the community. Participants in this group were given a manual with written information for each education session as well as an opportunity to set individual goals regarding exercise and fall prevention strategies. The group sessions utilized active learning strategies to encourage discussion. Attendance at education sessions was recorded as well as the same documentation as noted for Aquatic.

Control Group: This group was asked to continue with their usual activities and not begin an exercise program. They were told they would be offered either the Aquatic or Aquatic-Education class after 11 weeks. Adherence was encouraged by a phone call every 2 weeks.

All three groups were given a diary to take home to record falls, near-falls, any new medications, new conditions, therapy or illness. The diary was returned at post testing and reviewed with the participant when filling out the "general status" questionnaire.

Evaluation of Consistency of Aquatic Exercise Program Delivery:

In total three sets of 11 week exercise sessions were run (see Appendix K); the same instructor taught the first two sets and a second instructor taught the third set. Independent reviews of the standardization of the program were conducted by three individuals not directly involved in the program. They observed for consistency of delivery, progression of exercise, type, frequency and duration of exercise to address goals between the two aquatic sessions and one observer also evaluated consistency between the instructors. There were no discrepancies observed in delivery of the program.

Statistical analyses:

Power calculation: The primary balance measure, the Berg Balance Scale was used to determine sample size calculations. When the sample size is 25 per group there is an 80% chance of finding a significant difference in the Berg Balance Scale of 7 % (or 2 points) between groups at the 95% level of confidence, given a common standard deviation of 2.2.

Data Cleaning*:* Refer to Chapter 4 for the process used for missing data and data transformation. When possible drop-outs were re-tested at the time of leaving the study. Otherwise, for missing post-test data, last observation carried forward was used. Data was converted for the following variables as discussed in Chapter 4: BBSm (refsqrt), 6 min. walk (refsqrt), MCTSIB (refsqrt), and TUG_{cog} (log 10). AIMS-2 was not converted as post test scores did not require conversion. A total leg strength score was calculated for the affected lower extremity of each participant (total strength in kg. for hip flexion, extension, and abduction and knee extension). Z-scores for total range of the affected hip were calculated for hip range of motion. For both ROM and strength if both hips were affected by arthritis, the lowest strength or ROM score was used. Although converted data was used in all analyses, non-converted means are reported in all tables in order to avoid confusion in interpretation.

Outcome Measures*:* As noted in Chapter 4, some outcome measures were highly correlated with each other and therefore not all components of the test were used as outcome measures. Three components of the TUG were evaluated: $TUG_{standard}$, TUG_{manual} and TUG_{cog}. The latter two tests evaluate dual task function of performing the standard walking test while carrying a cup of water (TUG_{manual}) and counting backwards (TUG_{cog}). The $TUG_{standard}$ was used as a screening test and as a baseline measure to determine difference in time to complete after adding a dual task. The TUG_{cog} was chosen to represent the dual task construct as the TUG_{manual} was very easy for most participants to complete with little variation in time from the standard TUG score. Step length was measured in three directions (forward, lateral and backward). Step length was highly correlated for these three directions (r > 0.80) and for simplicity of one outcome measure for this test, the average of right and left $MSL_{forward}$ was used for a step length measure. In addition to the outcome measures outlined in Table 4.1, a post-test questionnaire was administered which asked about falls, near-falls, any change in medical status, and global health and pain rating (See Appendix H).

Inferential Analysis: Between group differences in outcome variables were examined using three general linear multivariate analyses (MANCOVAS) for the primary fall risk factors, secondary physical and secondary psychosocial fall risk factors, comparing between group post-test scores, using baseline values as co-variates. The ***first analysis*** included the primary outcomes identified in Table 4.1 in Chapter 4: BBSm, 6 minute walk, chair stands, ABC and TUG_{cog}. The ***second analysis*** tested the secondary physical fall risk factors: lower extremity reaction time, MCTSIB, $MSL_{forward}$, total hip strength of the affected extremity and total z-score for the affected hip range of motion. The ***third analysis*** tested the secondary psychosocial outcomes for Falls-$Efficacy_{tot}$, and AIMS-2 (impact of arthritis on symptoms, emotion and physical function). The use of MANCOVAs decreases the risk of Type I error as compared to performing multiple univariate tests. Only if the multivariate tests were significant using Roy's largest root, were univariate between subject tests examined for each outcome in the analysis. If univariate between group differences were significant, pairwise post-hoc tests using least significant differences (LSD) were performed to determine where the differences occurred. Physical activity level was monitored by PASE, administered before and after the intervention period to evaluate any differences between groups in activity level during intervention and control periods. Differences in global health and pain rating, and number of falls and near-falls were evaluated using Chi-square analysis for nominal level data (falls and near-falls) and Kruskal-Wallis test for ordinal data (global rating). A p-value of 0.05 was used for all tests and all analyses were conducted using SPSS version 14.0.

Results:

Participants:

Refer to Appendix E for a flow chart of study participants and Appendix K for the timeline of recruitment, testing and intervention. Eighteen participants dropped out before study completion, 5 from Aquatic-Education, 7 from Aquatic and 6 from Control. Reasons for dropping out deemed not related to the intervention included: scheduled for total hip replacement (2), scheduled for total knee replacement (2), acute illness or medical condition (4), personal reasons (2), flare of other joint pain reported due to activities and circumstances outside of the intervention (2) and deceased (1). Reasons for dropping out related to the intervention included: difficulty with transportation (2), mobility difficulties in and out of pool (1), decided to start another exercise program (1), and chlorine allergy (1). Only one moderate adverse effect occurred during the Aquatic intervention, which was a fall due to slipping on a wet surface while entering the pool. A flare of spinal pain occurred but did not result in withdrawal from the program. Further safety measures were instigated at the facility in order to avoid further incidents. Minor adverse effects such as muscle soreness or increased joint pain were reported rarely (4 – 5 times over the three sets of 11 weeks) and resolved quickly. There were no drop-outs reported due to adverse effects related to the exercise program. One participant dropped out due to difficulty changing and getting in and out of the pool, but did not report increased discomfort from the exercises. Comparison of baseline values for dropouts vs. completers found significant differences in fall history (28% vs. 56% had a history of falls respectively). There were significant ($p < 0.05$) differences between drop-outs and completers in several baseline fall risk factors: six minute walk, PASE, number of prescription medications, age, BBSm and the TUG, where drop-outs were older, less active with decreased performance in balance and functional tests. Based on these findings and the concern that eliminating drop-outs from the analysis may bias the results, intention to treat analysis was used as the primary analysis. A secondary analysis of primary fall risk factors for completers only was explored with results noted in the Discussion section. The mean percentage of class attendance for the Aquatic-Education Group was 74% and 65% for the Aquatic Group respectively; this increased to 81% and 82% when drop-outs were excluded. There were no significant differences ($p< 0.05$) in attendance between groups using an independent t-test.

Mean baseline values for various demographic factors for the three groups are reported in Table 5.1. Baseline or pre-test values for the primary and secondary fall risk factors for all three groups are reported in Tables 5.2 to 5.5. There was no significant difference in physical activity level between the three groups as measured by PASE at baseline (one-way ANOVA) or at post-test, using a general linear model univariate analysis of post-test PASE with pre-test scores as co-variates.

Table 5.1 Baseline demographic description for the three groups: Aquatic-Education, Aquatic and Control

Baseline Variable	Aquatic-Education n = 28	Aquatic n = 26	Control n = 25
A. Frequency Data	n (%)	n (%)	n (%)
Female	20 (71)	20 (77)	16 (64)
Reported fall in past year	14 (50)	16 (62)	9 (36)
Reported frequent near-falls in past year	9 (32)	8 (31)	6 (24)
Used a walking aid	10 (36)	9 (35)	14 (56)
Previous hip joint replacement	6 (21)	4 (15)	6 (24)
Unilateral hip involvement	18 (64)	16 (62)	14 (56)
B. Ratio Data	Mean (SD)	Mean (SD)	Mean (SD)
Age	73.2 (4.8)	74.4 (7.5)	75.8 (6.2)
Number of co-morbidities	2.3 (1.2)	1.9 (1.4)	2.2 (1.1)
Number of prescription medications	2.9 (2.6)	2.9 (2.5)	3.2 (2.8)
Length of hip pain (years)	7.5 (7.8)	8.6 (11.4)	6.6 (6.8)
BMI (kg/m^2)	29.2 (5.2)	30.4 (4.50	30.0 (5.7)
PASE score	96.6 (32.7)	106.9 (50.4)	101.4 (47.3)

***Outcome Measures*:**

Analysis 1: Primary Fall Risk Factors

Results of the MANCOVA was significant for the primary fall risk factors, (Full factorial multivariate test, F = 2.5 (5,68) p = 0.038). Subsequent univariate results and results of pairwise post-hoc comparisons can be found in Table 5.2. Change scores for each variable and percent change can be found in Table 5.3. There was a significant univariate difference between groups for the ABC where the Aquatic-Education group improved in balance confidence compared to the control group (12% difference compared to control) and in the 30 second chair stand where the Aquatic-Education group significantly improved in number of chair stands compared to both Aquatic and Control groups (a 20% improvement compared to 8% for Aquatic and Control). Similar trends were noted for dual task function as measured by TUG_{cog} and the 6 minute walk where the Aquatic-Education improved more than both Aquatic and Control, but these results were not significant.

Table 5.2 Pre- and post-test score values (not converted), effect sizes and results of post-hoc univariate tests for between group differences among Aquatic-Education, Aquatic and Control Groups for primary outcome measures (adjusted using pre-test values for BBSm, 6 minute walk, chair stands, ABC and TUG_{cog} as co-variates)

	Aquatic-Education	Aquatic	Control	Univariate Results			
Outcome Measure	Pre score (SD) Post score (SD)	Pre score (SD) Post Score (SD)	Pre score (SD) Post score (SD)	*F*-value (2,71)	*p*-value	Effect size (eta^2)	Observed power
BBSm (/36)	30.4 (3.8) 31.4 (3.2)	29.3 (5.2) 30.5 (5.1)	31.1 (2.7) 30.9 (3.8)	2.2	0.121	0.06	0.43
6 min. walk (meters)	355.2 (93.9) 398.5 (89.3)	357.4 (118.1) 371.9 (136.9)	352.3 (111.3) 352.6 (123.5)	2.3	0.110	0.06	0.45
Chair stands (# in 30 sec.)	7.6 (3.0) 9.1 (2.8)	6.9 (4.3) 7.5 (3.9)	7.5 (3.0) 8.1 (2.6)	4.1	0.022*	0.10	0.70
ABC (/100)	69.2 (19.9) 75.0 (15.2)	70.4 (21.9) 69.6 (24.4)	65.3 (18.1) 62.9 (20.8)	3.2	0.047*	0.08	0.60
TUG_{cog} (sec.)	14.9 (5.6) 12.6 (3.9)	15.8 (9.1) 15.1 (9.5)	14.3 (6.7) 14.5 (7.1)	2.6	0.084	0.07	0.50

***** $p < 0.05$, where post-hoc tests found Aquatic-Education significantly improved in number of chair stands greater than Aquatic ($p = 0.014$) and Control ($p = 0.023$), and Aquatic-Education significantly improved in ABC compared to Control ($p = 0.015$).

Table 5.3 Non-converted Change Scores, Standard Deviations and Percent Change for the Primary Fall Risk Variables for Aquatic-Education, Aquatic and Control Groups.

	Aquatic-Education		Aquatic		Control	
Outcome Measure	Change Score (SD)	% change	Change Score (SD)	% change	Change Score (SD)	% change
BBSm (/36)	1.0 (3.5)	3.3*	1.2 (2.3)	4.1*	- 0.2 (2.3)	- 0.6
6 min. walk (meters)	43.3 (63.8)	12.2*	14.5 (70.3)	4.1*	0.3 (70.7)	0.0
Chair stands (# in 30 sec.)	1.5 (2.0)	19.7*	0.6 (1.7)	8.7*	0.6 (1.7)	8.7*
ABC (/100)	5.8 (12.4)	8.4*	- 0.8 (21.1)	- 1.1	- 2.4 (10.7)	- 3.7
TUG_{cog} (sec.)	- 2.3 (5.1)	15.4*	- 0.7 (3.1)	4.4*	0.2 (4.3)	- 1.3

* signifies improvement

Analysis 2: Secondary Physical Fall Risk Factors:

Results for secondary physical fall risk factors are shown in Table 5.4. There was no significant difference for secondary physical fall risk factors (reaction time, MCTSIB, $MSL_{forward}$, total affected leg strength of the affected extremity and total hip ROM) comparing multivariate between group differences using MANCOVA (Full factorial multivariate test, $F = 1.3(5,68)$; $p = 0.26$). Since the MANCOVA was non significant, univariate tests were not reported.

Table 5.4 Pre and Post – test scores for secondary physical fall risk factors (non converted values except for z-scores hip ROM)

	Aquatic-Education	Aquatic	Control
Outcome Measure	Pre score (SD) Post score (SD)	Pre score (SD) Post Score (SD)	Pre score (SD) Post score (SD)
Reaction time (mean of 10 trials in sec.)	0.91 (0.18) 0.87 (0.13)	0.88 (0.22) 0.84 (0.21)	0.88 (0.15) 0.90 (0.15)
MCTSIB (sec.)	93.89 (20.67) 101. 33 (14.79)	92.94 (26.38) 104.36 (21.50)	98.30 (14.34) 106.85 (13.90)
$MSL_{forward}$ (cm.)	22.42 (10.57) 19.82 (11.17)	21.53 (13.73) 18.41 (13.12)	19.19 (8.27) 18.98 (7.67)
Affected Leg Strength (total hip abduction, flexion, extension and knee extension in kg.)	17.74 (7.18) 30.30 (14.50)	15.26 (7.30) 23.96 (14.27)	15.98 (6.98) 21.32 (10.27)
Affected Hip ROM Total z-score	- 1.54 (2.75) - 0.46 (4.06)	- 1.33 (2.86) - 0.88 (3.29)	- 2.17 (3.57) - 1.63 (3.38)

Note: no significant between group difference in the MANCOVA

Analysis 3: Secondary psychosocial fall risk factors

There was a significant between group difference for psychosocial factors, The Falls-Efficacy Questionnaire (total score) and the AIMS-2 (3 component model) as measured by MANCOVA (full factorial multivariate test F = 4.0 (2,74); p = 0.023). Results of univariate and post-hoc tests are in Table 5.5. Post-hoc tests results showed a significant difference between the Aquatic-Education and Control Group for Falls-Efficacy and a similar non significant trend for Aquatic-Education compared to Aquatic. There was no significant difference in Falls-Efficacy between Aquatic and Control.

Table 5.5 Pre- and post-test score values, effect sizes and results of post-hoc univariate tests for between group differences among Aquatic-Education, Aquatic and Control groups for secondary psychosocial outcome measures (adjusted using pre-test values for Efficacy_{tot} and AIMS-2 as co-variates)

	Aquatic-Education	Aquatic	Control	Univariate Results			
Outcome Measure	Pre score (SD) Post score (SD)	Pre score (SD) Post Score (SD)	Pre score (SD) Post score (SD)	*F*-value (2,74)	*p*-value	Effect size (eta^2)	Observed power
Efficacy_{tot} (/100)	62.22 (23.73) 70.26 (19.53)	60.64 (27.47) 62.77 (27.75)	57.03 (20.89) 56.00 (21.56)	4.0 *	0.023	0.10	0.70
AIMS-2† (physical, Symptoms, Emotion)	10.15 (2.37) 9.15 (2.70)	10.37 (3.21) 9.94 (4.30)	10.82 (3.26) 10.91 (3.04)	1.6	0.21	0.04	0.33

* post-hoc pairwise comparisons found significant differences between Aquatic-Education and Control (p = 0.007)
† lower score signifies better health status

Since there was a significant difference found for $\text{Falls-Eficacy}_{tot}$ further post-hoc analysis was done for the three sub-components of the questionnaire (Efficacy_{dual}, $\text{Efficacy}_{reactive}$ and $\text{Efficacy}_{complex}$). Three univariate general linear model analyses were conducted for each of the three components with post-test scores as the dependent variable, group assignment as the independent variable and pre-test scores entered as co-variates. The results of this comparison can be found in Table 5.6. There was a significant difference between groups for the

Efficacy$_{complex}$. Post-hoc test results indicated that Aquatic-Education had significantly higher Falls-Efficacy than both Aquatic and Control for more complex functional tasks related to falls such as getting up and down from the floor, walking on varying surfaces, navigating when light is diminished, and reaching for objects (Falls-Efficacy$_{complex}$). There was no significant between group difference for Efficacy$_{dual}$ and Efficacy$_{reactive.}$

Table 5.6. Pre- and post-test score values, effect sizes and results of univariate tests for general linear model comparison of post-test scores among Aquatic-Education, Aquatic and Control groups for falls-efficacy categories: dual task function, reactive balance and complex tasks, using baseline scores as co-variates.

	Aquatic-Education	Aquatic	Control	Univariate Results			
Outcome Measure	Pre score (SD) Post score (SD)	Pre score (SD) Post Score (SD)	Pre score (SD) Post score (SD)	*F*-value (2,75)	*p*-value	Effect size (eta^2)	Observed power
Efficacy$_{dual}$	67.02 (25.28) 69.64 (22.08)	65.13 (26.43) 63.85 (22.87)	62.27 (23.67) 58.40 (22.90)	1.86	0.163	0.05	0.38
Efficacy$_{reactive}$	52.95 (24.95) 59.64 (24.81)	52.60 (30.74) 58.75 (29.86)	46.90 (22.19) 46.40 (25.48)	1.88	0.159	0.05	0.38
Efficacy$_{complex}$	65.10 (26.56) 75.80 (18.13)	62.98 (29.52) 64.38 (29.26)	60.14 (22.49) 60.10 (24.81)	5.60*	0.005	0.13	0.84

*Aquatic-Education significantly improved compared to Aquatic (p=0.012) and compared to Control (p = 0.003)

Non-parametric tests:

There were no significant differences among the three groups for number of falls reported or number of frequent near-falls reported during the intervention period using Chi square analysis. (Number of falls reported = 8, 11 and 9 for Aquatic-Education, Aquatic and Control respectively; number reporting frequent near-falls = 1, 5 and 4 for Aquatic-Education, Aquatic and Control respectively). As shown in Table 5.8, there was a significant difference between the three groups in general health change rated on a 7 point scale from “very much worse” to “very much better”. Aquatic-Education had the highest ranking for this scale. A similar result but with higher ranks for both the exercise interventions compared to Control was found for rating of pain and discomfort following the intervention period where interventions saw an improvement or reduction in pain symptoms. Results of the post-hoc tests using a one-way ANOVA and Tamhane correction for unequal variances showed the Aquatic-Education group reported significantly higher general health compared to the Control group (mean difference of 1.44, p= 0.003).

Table 5.7 Results of Kruskal-Wallis test comparing health and pain rating scores between Aquatic-Education, Aquatic and Control groups

Outcome	Group	n	Mean rank	Chi-square (df)	p-value
General Health “how do you feel today compared to 3 months ago?”	Aquatic-Education Aquatic Control	25 21 19	40.52 33.48 22.58	10.41 (2)	0.005
Pain “how does your arthritis pain feel today as compared to 3 months ago?”	Aquatic-Education Aquatic Control	25 21 19	35.92 37.10 24.63	5.72 (2)	0.057

Post-hoc analysis of the relationship of falls-efficacy to functional improvement:

Because Aquatic-Education resulted in a significant improvement in chair stands as compared to Aquatic and Control, it was possible that falls-efficacy acted as an intervening causal variable for this physical improvement. In other words, the improvement in falls-efficacy might cause the improvement in number of chair stands observed. To evaluate this postulation separate linear regression models were run to determine the mediating effect of falls-efficacy change scores. Linear regression analyses answered three questions: a) Does the addition of an educational component affect improvement in falls-efficacy where group assignment was dummy coded as Aquatic or control (0) vs. Aquatic-Education (1)?, b) Does group assignment predict improvement in chair stands?, and c) If falls-efficacy improvement is controlled for, how does the association of group assignment to chair stand improvement change? Results of these analyses are shown in Figure 5.1. Perfect mediation exists if the independent variable has no effect on the dependent variable when the mediator is controlled[16]. There was not a strong mediation effect of falls-efficacy change scores on the relationship of group assignment to chair stand improvement. Not all relationships were significant, and there was only a modest decrease in size of beta coefficients for the effect of group assignment on chair stands when falls-efficacy change scores were controlled. Therefore, falls-efficacy was not a causal link in the improvement in chair stands observed for Aquatic-Education. To explore the role of falls-efficacy as an effect modifier in the improvement in primary fall risk outcome, high vs. low falls efficacy as measured at baseline (using median value of 63 for Falls-Efficacy as cut off) was entered as a second between group factor in the multivariate analysis for primary fall risk factors. In chapter 4, Falls-Efficacy was found to be an effect modifier in the relationship of near-falls to falls and was an independent predictor of balance. There was a significant multivariate effect of Group*Falls-Efficacy ($F = 2.9$ (5,66) $p = 0.019$); therefore, further exploratory independent t-tests were conducted with the sample split into low and high falls-efficacy groups. There was a significant difference in the percent improvement in the ABC in the Aquatic-Education Group where those with low-efficacy improved 16% in the ABC as opposed to only 3% improvement in those with high-efficacy ($p<.006$). There was no difference in change scores for Aquatic or Control groups. There was also no significant difference in change scores for chair stands, balance, 6 minute walk or TUG_{cog} when the sample was split into high and low efficacy, however the Berg Balance change score was close to significance for Aquatic-Education ($p = 0.052$) where lower falls-efficacy participants had a mean improvement of 2.5 points on the Berg Balance Scale compared to no change for higher efficacy participants (mean = - 0.19). Based on this analysis, level of falls-efficacy at entry was an effect modifier for the outcome of the ABC and to a lesser degree for balance. In other words, improvement in falls-efficacy and balance for the Aquatic-Education group was most advantageous for those who entered the program with lower falls-efficacy.

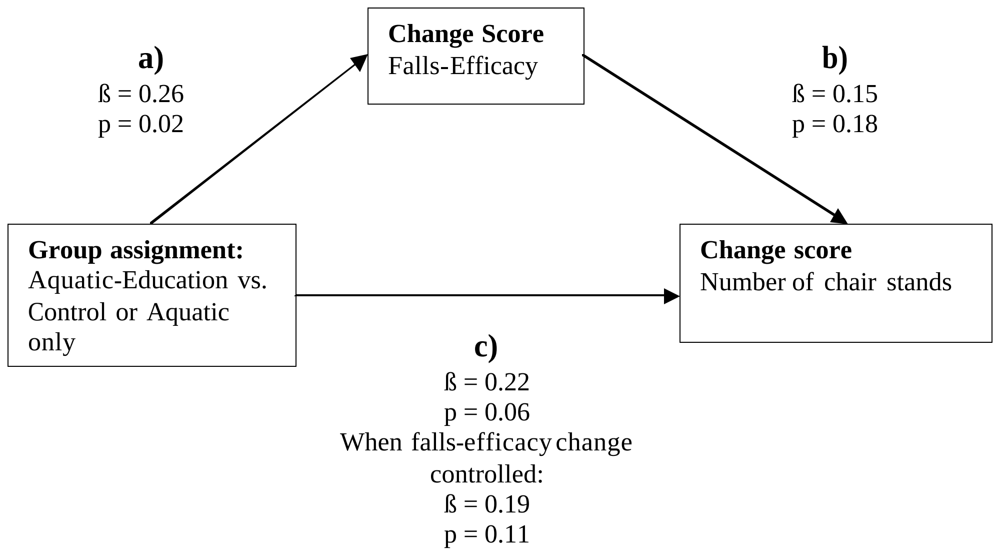


Figure 5.1 The role of improvement of falls-efficacy as a potential mediator in the improvement observed for chair stands in the Aquatic-Education group

Discussion:

In this study I compared the effect of an aquatic exercise program combined with an educational program designed to reinforce the purpose of exercise, improve knowledge of fall prevention and enhance falls-efficacy compared to aquatic exercise only and no exercise. I found that the combined program of Aquatic-Education resulted in significant improvement in falls-efficacy, lower body functional strength and perception of general health status compared to a Control group. Lower body functional strength and falls-efficacy of more complex functional tasks was also improved more in Aquatic-Education compared to Aquatic. There were no significant differences in any fall risk factors between Aquatic exercise only and the Control group. Neither intervention resulted in increased pain symptoms; in fact, there was a reduction in pain symptoms for both interventions, although not statistically different than the Control group.

The first hypothesis that both exercise programs would result in improvement in physical fall risk factors compared to no exercise was not supported. The only physical fall risk outcome that was significantly improved with an intervention compared to control was chair stands, but only for Aquatic-Education. This result suggests that aquatic exercise on its own for 11 weeks, twice per week does not improve fall risk factors in older adults with hip OA. The research evaluating fall risk in populations with arthritis or lower extremity pain is limited. McIlveen et al. [85] evaluated a population with low back or leg pain and also found no significant differences in range of motion, pain or strength between groups, but there was a trend for improvement in the aquatic intervention group. Studies evaluating the impact of aquatic exercise on fall risk factors for older adults with hip OA are sparse and equivocal. Green et al.[82] found no significant difference in muscle strength or range of motion for patients who received a home exercise program or a home exercise program combined with aquatic exercise 2/week for 6 weeks. On the other hand, Foley et al.[73] found an improvement in quadriceps strength, distance walked and physical function for both water and land-based exercise after 6 weeks for adults with hip or knee OA. An updated Cochrane review[17] found limited short term gains on function and quality of life with no evidence of effect on walking ability, pain or stiffness for aquatic exercise combining both hip and knee OA populations. There was no clear evidence that aquatic exercise can improve any of these factors over the short term for older adults with hip OA exclusively.

My study was unique in combining fall prevention education with aquatic exercise for the hip OA population. I found that the addition of a land-based educational program resulted in improvement in lower body functional strength as well as falls-efficacy, suggesting that the added enhancement of education does have an impact on improving both physical and psychological status related to falls. Although not all primary fall risk factors were significantly improved in the Aquatic-Education program, the finding of improvement in falls-efficacy, chair stands and general health status does support some benefit to this type of program delivery.

The second hypothesis that Aquatic-Education would result in the additional benefit of enhanced falls-efficacy was supported as significant improvements were found for the ABC compared to Control and for the functional tasks in the Falls-Efficacy Questionnaire compared to both Aquatic and Control groups. The educational program used in this study was developed based on Bandura’s self-efficacy theory[13]. This theory emphasizes that building self-efficacy and diminishing fear of an event (in this case falls) requires a process of education and knowledge building, confidence building in movements where falls may occur and finally to execute movement without falling. Three of the determinants of self-efficacy include: enactive mastery experience, verbal persuasion, and physiological and affective states[13 p. 79-113]. Mastery experience was developed by learning strategies to prevent falls and consistently applying these strategies to day to day tasks. Participants in the educational program were given information to assist them to develop individual goals to decrease fall risk factors at home and in the community. They also practiced some of these tasks in the class setting such as getting up from the floor, reaching and stepping over obstacles. Mastery experience can be one of the most influential sources of efficacy information in a group setting as individuals develop confidence to prevent falls within a variety of contexts as they listen and discuss with others how to overcome obstacles and learn from failures. Group facilitators can provide constructive feedback, information on potential losses for non-adherence and potential long term gains for adherence with social persuasion from the other members of the group adding further influence. Combining an educational program with exercise may also provide a connection between physiological and affective states. People may interpret physiological responses from exercise such as increased muscle soreness, joint pain, breathing harder and fatigue as signs of inefficacy, dysfunction or failure. If this state further arouses affective responses such as stress, anxiety or fear, the appraisal of falls-efficacy also might diminish. Consistent education and feedback on reasons for arousal states and a supportive environment may help individuals to remain motivated to continue with exercise and thus make physical gains in mobility tasks.

My results support Bandura's theory in that the addition of an educational program did result in improvement in falls-efficacy. The percent change in mean values ranged from approximately 10% for the ABC up to 15% for falls-efficacy of more complex tasks such as walking on rough ground and getting up from the floor for the Aquatic-Education Group compared to up to a 5% decline in falls-efficacy for the Control Group. Of interest, the individuals with the lowest falls-efficacy at baseline (score < 63), realized the greatest improvement. A cut-off score of 67 on the ABC has been considered a good predictor of fallers with 84% sensitivity and 88% specificity[115]. If individuals with lower falls-efficacy can make significant gains in their confidence with a combined exercise and education program, this may substantially reduce their risk of future falls. Also, participants who entered the Aquatic-Education group with lower falls-efficacy realized an average gain in functional balance of 2.5 points on the Berg Balance Scale compared to those with higher falls-efficacy. This equates to a 20% reduction in fall risk based on a baseline value in the 26 to 34 range[176]. Clinically this may be very important in designing the appropriate program for sub-groups of individuals at risk. My findings suggest that the addition of education to an exercise program is more important for those with low falls-efficacy.

The third hypothesis was partially supported in that Aquatic-Education improved in one of the functional tests, chair stands, greater than both Aquatic and Control. The question then is: Does the improvement in falls-efficacy related to the educational component cause the resultant improvement in chair stands? If this was the case, improvement in falls-efficacy would act as the mediating variable in the relationship of the intervention to improvement in chair stands. In this study, falls-efficacy improvement was not a mediating variable. This result is consistent with two earlier studies. Martin et al. [135] found the combination of a weight training and education program improved self-efficacy and perceived performance of eight basic ADL activities in adults over age 68 years compared to a weight training only group, but there was no significant difference in actual performance of these tasks. Results from another study found no correlation of an improvement in ABC after a 13 week agility or resistance training exercise to a comprehensive fall risk score, gait speed or physical activity level. Data from the findings in Chapter 4 as well as previous studies support independent relationships of falls-efficacy to function and balance tests[122,113,148]. Despite this relationship, it does not necessarily hold true that improvements in falls-efficacy will subsequently impact improvements in physical status. The relationship needs to be investigated further in larger prospective studies comparing low and high falls-efficacy groups.

The improvement observed in chair stands for Aquatic-Education has functional relevance to fall risk. Chair stands combines lower body strength, balance, mobility, endurance and motivation by evaluating the ability to get up and down from a chair as quickly as possible. Although there was a trend for other physical fall risk tests to show greater improvement in the Aquatic-Education Group compared to the other two groups, these were not significantly different. One of the problems with aquatic exercise is that it is difficult to mimic day to day tasks such as sit to stand. There is little carry-over in ability to do the task on land even though strengthening similar muscles used is practiced in the water. Aquatic exercise has been shown to not improve day to day function whereas land exercise did in a population of older women with osteoporosis[8]. Specificity in sport is defined as “optimal training…when an athlete’s training exercise is very similar to the task for which he/she is training” [22]. Similarly, for other exercise training, if the purpose is to improve functional independence and ability to move in daily tasks without losing balance, designing exercise to optimize functional specificity is imperative. In the Aquatic-Education Group, part of the education session focused on identifying and practicing functional tasks that the exercises in the water were designed to improve. The added knowledge of correct biomechanics in sit to stand movement and practice may have been the reason why the Aquatic-Education group significantly improved in this task compared to Aquatic. A recent study of older adults with disabilities including lower extremity arthritis found that a functional training program that focused on movement control was more advantageous to improve number of chair stands than a traditional strength training regime with elastic resistance, although there were gains in both interventions for lower body isometric strength as measured by hand-held dynamometry[112]. Because most falls occur during basic functional tasks (such as getting up from a chair, walking on level surfaces, and reaching to the floor), improving the ability to perform these tasks successfully should decrease the risk of falling. Results from meta-analyses support the theory that exercise programs to reduce the risk of falls should include functional balance components (daily tasks that challenge balance) [162] and be multi-dimensional in including education and environmental modifications to address the complexity of fall risk[50, 80, 219]. As well, the improvement in perception of general health in the Aquatic-Education group may further support motivation for participants to continue to exercise and set in motion fall prevention strategies. This could result in long term gains in balance, function and strength.

The sample used in this study consisted of older men and women with a clinical diagnosis of hip OA with at least one fall risk factor. It is possible that because they presented with some degree of fall risk either as a history of falls or a slower TUG test, that they already identified fall risk as a priority and were ready to accept education and active involvement in a group process; this may have impacted on the improvement seen in falls-efficacy. A second limitation of my study was that the control group continued with physical activity as usual with no social interaction. It is difficult to know if it was the social context of the education group that improved falls-efficacy or the content included in the program. In support of an effect beyond socialization, other studies have found no improvement in falls-efficacy or other fall risk factors with a sham control group that included social interaction [119,123]. I chose not to include a social context for the control group as previous experience found that this often results in discussion that begins to focus on knowledge building and sharing of educational information between group members. As well, the control group improved in their physical activity level as monitored by the PASE, suggesting that they were involved in some form of exercise as much as the other two groups; this may have confounded the relationship making it difficult to detect significant differences in change scores for physical fall risk factors. Other methodological limitations included one of the researchers assisting with testing not blinded, although all primary outcomes were evaluated by blinded evaluators, and a smaller sample size, resulting in diminished power to compare differences in sub-group analysis.

Of interest, in a secondary exploratory analysis of completers only, differences in primary fall risk variables remained significant even with the reduced sample size (excluding drop-outs and attended at least 50% of the exercise and educational classes; n = 23, 19 and 19 for Aquatic-Education, Aquatic and Control respectively). Not only did chair stands remain significantly different for Aquatic-Education compared to Aquatic and Control, but the improvement in the ABC was now significantly greater for Aquatic-Education compared to both Aquatic and Control. As well, the trend noted for the Berg Balance Scale was closer to significantly different for completers only (p = 0.059), with both Aquatic-Education and Aquatic resulting in a 4.5% improvement in balance compared to a 2.3% decline in balance in the control group. In a previous study of aquatic exercise for adults with OA[23], improvements in physical function were significantly greater in adherers vs. non-adherers. Adherence may impact the improvement in both physical and psycho-social fall risk factors with exercise and education intervention and warrants further investigation.

The addition of an educational program to a community exercise class increases participant time demands, costs of the program and health professional involvement. Other educational programs based on self-efficacy theory have been used for individuals with arthritis to successfully achieve improved sense of well-being, coping skills, diminished pain and perceived function[134]. Identifying those individuals with arthritis who are also at a higher risk of falling and targeting combined education and exercise programs may result in the greatest gain in both physical and psychosocial improvement. In conclusion, this study supports that aquatic exercise combined with an educational group program can improve falls-efficacy, functional strength and perception of health. Aquatic exercise on its own was not enough to improve fall risk factors for older adults with hip OA. This could be due to the limited ability to practice daily functional tasks in the water. The greatest gains in falls-efficacy occurred for those with low falls-efficacy prior to the program. Clinicians should consider targeting combined education and exercise programs for older adults with low falls-efficacy who are also at higher risk due to physical impairments such as lower extremity arthritis.

CHAPTER 6

GENERAL DISCUSSION AND CONCLUSIONS

The rationale for this dissertation was to investigate fall risk in a population that has received little attention in the literature, older adults with hip OA. This population warrants further investigation of fall risk as several impairments common to the condition would suggest higher risk such as lower extremity muscle weakness, balance deficits, gait deficits and joint pain. As well, the presence of a chronic pain condition that affects ability to engage in recreational, physical and social activities puts them at a higher risk of depression, social isolation and lower falls- efficacy. By choosing an intervention suitable to this population, aquatic exercise, combined with an educational program, it has carry-over to development of practical community programs that can continue into the future. In fact, this study resulted in the continuation of a community program designed for older adults with chronic pain or other fall risk concerns to exercise in a water environment with the supervision and educational support from a trained fitness specialist and a physical therapist.

The three studies outlined in this dissertation were designed to increase the knowledge of fall risk in this population and determine methods to address fall prevention. Depicted in Figure 6.1 is a summary of the findings from this study. The strengths of these studies included the evaluation of a population with chronic pain and mobility restriction that has received little attention in fall risk research, a comprehensive assessment of fall risk factors and evaluation of an educational program based on theoretical knowledge of efficacy enhancement strategies. Limitations included a sample that may have already been motivated to embrace fall prevention education, lack of long term follow-up and inadequate power to make definite conclusions on sub-group analysis.

Study 1 Population	**Study 2 Population**	**Study 3 Population**
Older adults with hip OA	Older adults with hip OA and a history of a fall or a TUG score > 10 seconds	Same as Study 2, randomized to Aquatic-Education, Aquatic or Control
Study 1 Results	**Study 2 Results**	**Study 3 Results**
High risk of falls and near-falls, primarily during ambulation activities The TUG identifies mobility limitations and those at risk of near-falls The best screen to identify fallers is not known	A high frequency of near-falls is strongly associated with falling, especially for those with lower falls-efficacy Falls-efficacy is an independent predictor of balance Walking slower may actually decrease risk of falls	Aquatic exercise combined with education improves physical function, perception of health and falls-efficacy This type of intervention is most advantageous for those with lower falls-efficacy Aquatic exercise on its own for 11 weeks is not enough to improve fall risk factors

Figure 6.1 Summary of findings for Studies 1 to 3

The findings from Study 1 identified a population with hip pain and arthritis that falls commonly, with frequent reports of near-falls. Injury sustained from a fall was just as high if not higher than what has been observed in other populations and most falls occurred in or around the home and during ambulation activities. These descriptive data reinforce the importance of identifying older adults with mobility impairments that put them at risk for falls. If clinicians recognize the presence of hip osteoarthritis and associated hip pain as a risk factor, screening tests such as recording history of falls and near-falls and simple tests such as the TUG can be implemented. Results from this study recommend a cut-off score of 10 seconds on the TUG should be used to identify individuals with mobility and balance impairments at risk of future falls. Clinicians working in rheumatology centers and clinics need to consider developing strategies for screening clients with lower extremity arthritis for fall risk.

In addition to screening tests such as the TUG, falls-efficacy appears to be an important factor to consider for fall risk screening in this population. Falls-efficacy has an influence on the relationship of near-falls to falls, with those having lower levels of falls-efficacy having a much higher association of frequent near-falls to actual falls. The reasons for this relationship are not clear; however knowledge that lower falls-efficacy is also an independent predictor of performance on balance tests is an important finding. This implies that it is not just physical factors such as strength and mobility that influence ability to balance and stop a fall; but that psychosocial factors play a significant role. This finding may be unique for individuals with hip OA, further research needs to be done to investigate the impact of falls-efficacy in other older adult populations. It reinforces the need to consider other factors when screening for fall risk beyond physical tests of mobility and balance. Easy to administer questionnaires such as the ABC could be useful in identifying those individuals with lower falls-efficacy who may benefit with an intervention designed to improve efficacy. I also found that rating confidence of other tasks not included in the ABC such as getting up and down from the floor, walking and reaching tasks in more challenging situations was also useful in identifying those at higher risk of poorer balance performance. Understanding the underlying mechanisms of what causes lower falls-efficacy would also add further insight in ways to prevent it from spiraling into social isolation, decreased physical activity and thus further increased risk of falls.

The encouraging finding in this study was that an intervention could improve falls-efficacy as well as functional strength and perception of health. Although other physical fall risk factors such as balance and mobility did not significantly change, the positive findings along with good adherence and no adverse effects support further investigation of this type of combined exercise and education programming for older adults with hip OA. As well, future study needs to consider the impact of this type of programming for other older adult populations. Of concern, however, is the finding that aquatic exercise on its own 2/week for 11 weeks does not offer any significant benefit in reducing fall risk. Clinicians and exercise specialists need to keep this in mind when designing programs for older adults at higher risk of falls. Aquatic exercise does have the benefit of reduced gravitational loading for painful joints and can provide a motivating and calming atmosphere that many older adults enjoy. However, it may be important to enhance these exercise programs with an educational component that facilitates them to make the connection of how exercises in the water can help them improve day to day function on land. In this study, the additional education for 11 weeks of ½ hour sessions in a group setting resulted in improvement in falls-efficacy. It is possible that a less intensive intervention may result in similar gains. As well, it may be useful to initially screen for falls-efficacy prior to admission in the program and target those with lower falls-efficacy for more enhanced education in conjunction with the exercise program than those with higher levels of falls-efficacy. Although other types of exercise programs have observed improved falls-efficacy with exercise on its own in a land setting, it is possible that results of this study may apply to exercise beyond aquatic. Individuals with lower falls-efficacy in other exercise programs such as an agility/balance program or Tai Chi may need some additional educational enhancement to optimize gains in physical performance and confidence. Figure 6.2 outlines a theoretical model to direct future research of screening and fall prevention for this population. This model was developed using Figure 2.2, the summary of fall risk factors linked to hip OA, and integrating the findings from this study.

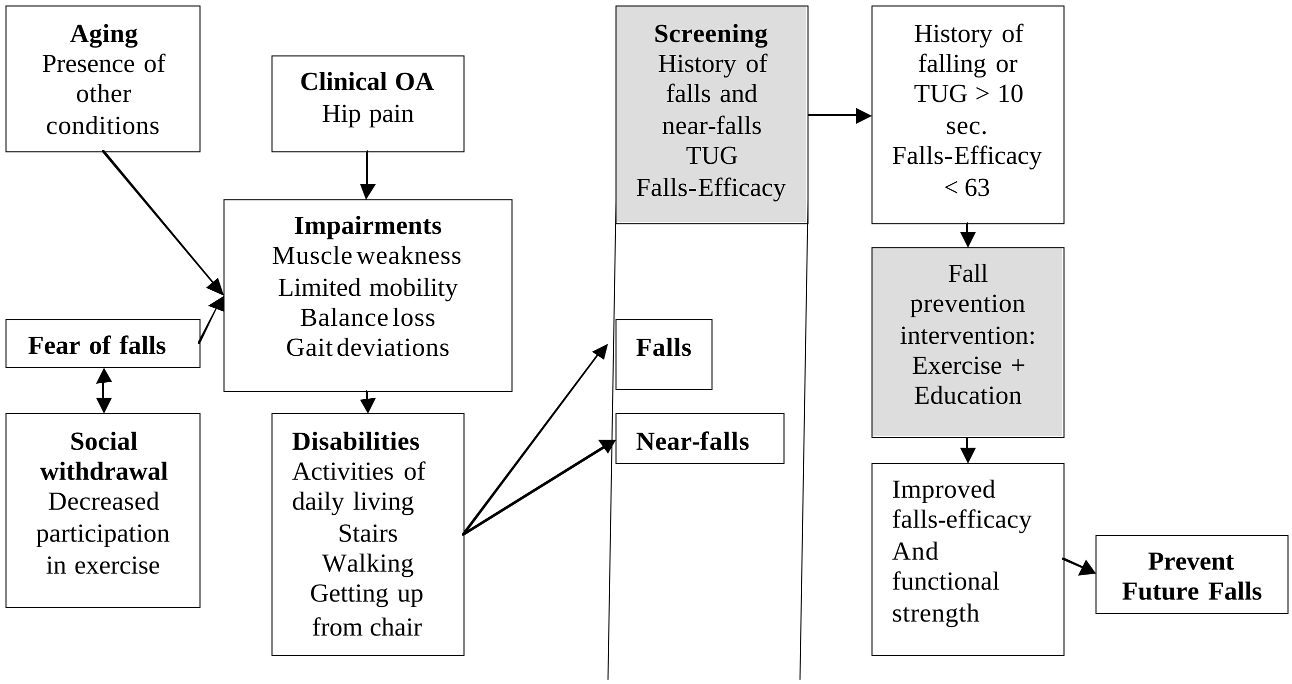


Figure 6.2 The relationship of fall risk, falls-efficacy and exercise-educational programs for fall screening and fall prevention in older adults with hip OA

In this research project I was not able to prove or quantify all of the relationships depicted above. The following questions arose from this study that should help to direct **future research** in this area:

1) How reliable is older adult recall of near-fall related events?
2) What is the relationship of gait parameters in the hip OA population to fall risk?
3) Are there other physical screening tests besides the TUG that may be more sensitive to determine fall risk in this population?
4) What is the role of falls-efficacy in improvement of fall risk factors and what other factors influence falls-efficacy?
5) Does the interaction of low falls-efficacy and frequent near-falls result in greater number of future falls?
6) What is the effect of an exercise and education intervention on a sample of older adults with low falls-efficacy?
7) What are the long term effects of the Aquatic-Education program on falls-efficacy and functional improvement?
8) Do these results carry over to other older adult populations with chronic conditions known to affect fall risk such as rheumatoid arthritis, knee or foot arthritis, back pain or osteoporosis?
9) What is the impact of adherence on changes in physical fall risk factors and falls-efficacy following exercise and education interventions?
10) Is a key component in successful fall prevention exercise programs the learning of movement control and “how” to safely and efficiently perform basic daily tasks?

Clinical Implications:

Health professionals and exercise specialists need to know where to target efforts in preventing falls for the elderly population. This becomes more crucial as we face an increase in the number of older adults, particularly in the number of older-old adults over the age of 80 that will be living independently in the community. Findings from this study support targeting programs that include both exercise and fall prevention education to older adults that present with at least one fall risk factor and lower falls-efficacy. Exercise on its own may be sufficient for those at lower levels of fall risk. Populations with lower extremity pain such as hip osteoarthritis are at greater risk and providing exercise in an aquatic environment combined with education is necessary to improve functional strength and falls-efficacy. Further research is needed to establish the best combination of programming to improve other factors such as balance and gait.

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Appendix A. Telephone Screening Questionnaire

Introduction: In order to find out if you are eligible for a screening test for this study, there are several questions that I need to ask you. Is it all right if I ask you some questions over the phone?

1. First, I need to get some contact information.

   Name:________________________________
   Address:______________________________
   Postal Code:___________________________
   Telephone:____________________________
   e-mail:________________________________(if applicable)

   Is this in Saskatoon or at least within 30 minutes driving distance? YES NO

2. Are you able to transport yourself to and from the testing site and to and from the intervention site?
   YES NO

3. Are you willing to commit to two testing times and 11 weeks of one of two interventions 2/week or a control period of 11 weeks that involves completing a diary and contact by telephone with a researcher?
   YES NO

4. Are you willing to be randomly assigned to one of three groups?
   YES NO

5. What is your age?________________________

6. Have you been diagnosed with osteoarthritis of 1 or both hips?
   YES NO

   If NO, do you have hip pain? YES NO
   If YES, How long have you had the pain?____________Yrs _________months

   If YES, who diagnosed you?
   Dr. Ortho surgeon Rheumatologist PT Other

   Name of Health Professional:______________________
   Name of Clinic:___________________________
   Have you had x-rays of the hip? YES NO
   If YES, where?____________________ Approximately when?________

7. Do you participate in any of the following regular community activities:

Activity	Yes	How Often	No
Walking			
Social Dancing			
Swimming or aquatic exercise			
Weight Training			
Aerobic Class			
Bowling			
Road Cycling			
Ski			
Hike			
Squash			
Tennis			
Tai Chi			
Skating			
Gardening			
Other Falls Prevention Program			
Any other activities not mentioned?			

8. On a scale of 1 to 10, can you rate your overall mobility, 1 being dependent on a wheelchair, and 10 having no mobility problems.

   1 2 3 4 5 6 7 8 9 10

9. Are you currently receiving physical therapy treatment for your hip?
   YES NO

   If YES, describe type of treatment, how often and for how long______________________________
   ____

   Are you currently receiving chiropractic, acupuncture or other treatment for your hip? YES NO

   If YES, describe type of treatment, how often and for how long______________________________
   ____

10. Do you know of any surgery you have booked within the next 6 months?
    YES NO

    If YES, describe____

    Are you on a waiting list for total joint replacement for your hip?
    YES NO

11. Do you have any of the following conditions?

Uncontrolled hypertension	YES	NO	
Recent heart attack	YES	NO	Describe_____________
Recent stroke	YES	NO	Describe_____________
Congestive heart failure	YES	NO	
Recent lung or blood clot	YES	NO	Describe_____________
Respiratory infection, i.e. pneumonia	YES	NO	Describe_____________
Joint injury, i.e. sprain	YES	NO	Describe_____________
Recent fracture	YES	NO	Describe_____________
Osteoporosis	YES	NO	Describe_____________
Chest pain/angina	YES	NO	Describe_____________
Vision or Hearing Problems	YES	NO	Describe_____________
Any other health problems	YES	NO	Describe_____________

12. Do you use a walking aid? YES NO
    If YES, how often? ALWAYS OCCASSIONALLY RARELY

13. Have you had a fall in the past year? (Described as any body part landing on the ground not due to fainting or a black-out)
    YES NO

    If YES, describe when, where it occurred and the circumstances leading to the fall? ____________
    ____
    ____

14. Do you have any other questions about the study?
15. Book screening appointment if they meet eligibility:

    DATE:______________
    TIME:______________

    REMIND THEM TO: Wear their usual walking shoes, bring walking aid if they usually use one and list of medications, or bring in current medications. Give location, parking instructions. You will phone to remind them the day before.

16. If not eligible for further screening, thank them for their interest, and inform them that the information from this telephone interview will be destroyed.

Appendix B. Ethics Approval Certificate

University of Saskatchewan
Biomedical Research Ethics Board (Bio-REB)

01-Oct-2005

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	Bio #
Robert A. Faulkner	Kinesiology	05-158

INSTITUTION (S) WHERE RESEARCH WILL BE CARRIED OUT

College of Kinesiology
105 Gymnasium Place
Saskatoon SK S7N 5C2

SUB-INVESTIGATOR(S)

Cathy Arnold
Nancy Gyurcsik

SPONSORING AGENCIES

PHYSIOTHERAPY FOUNDATION OF CANADA

TITLE:

The Effect of Aquatic Exercise and Aquatic Exercise Combined with Education and Efficacy Enhancement on Improving Indices of Fall Risk in Older Adults with Hip Osteoarthritis: A Randomized Controlled Clinical Trial

ORIGINAL APPROVAL DATE	CURRENT EXPIRY DATE	APPROVAL OF
01-Oct-2005	01-Oct-2006	Revised Researcher's Summary (19 Sept 05) Information for Participants (19 Sept 05) Poster Advertisement Physician Office/Clinic Recruitment Advertisement Telephone Interview Script (16 Sept 05) Demographic and Medical History Questionnaire Arthritis Impact Measurement Scale Physical Activity Scale for the Elderly Activity-Specific Balance Confidence Scale Physical Activity Staging

CERTIFICATION

The University of Saskatchewan Biomedical Research Ethics Board has reviewed the above-named research project at a full-board meeting (any research classified as minimal risk is reviewed through the expedited review process). The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research project, and for ensuring that the authorized research is carried out according to governing law. This Approval is valid for the above time period provided there is no change in experimental protocol or in the consent process.

ONGOING REVIEW REQUIREMENTS/REB ATTESTATION

In order to receive annual renewal, a status report must be submitted to the Chair for Committee consideration within one month of the current expiry date each year the study remains open, and upon study completion. Please refer to the following website for further instructions: http://www.usask.ca/research/ethics.shtml. In respect to clinical trials, the University of Saskatchewan Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations and carries out its functions in a manner consistent with Good Clinical Practices. This approval and the views of this REB have been documented in writing.

Please send all correspondence to:

Ethics Office, VP Research, University of Saskatchewan
Room 305 Kirk Hall
117 Science Place
Saskatoon, SK S7N5C8
Phone: (306) 966-4053 Fax: (306) 966-2069

APPROVED.

Michel Desautels, Ph.D., Chair
University of Saskatchewan
Biomedical Research Ethics Board (Bio-REB)

Appendix C. Falls and TUG Screen Recording Form

FALLS (document review from telephone survey)

Have you had a fall in the past year where any part of your body unexpectedly contacted the ground or other lower surface (ie. stairs, chair)?

YES NO

If YES, explain circumstances of the fall and any injuries sustained.

___

___

___

2. NEAR-FALLS

Have you had any near-falls in the past year where you slipped, tripped or lost your balance, but did not fall?

YES NO

If YES, occasionally, (less than 1/week) or frequently (1/week or more):

___

If YES, explain circumstances and any injuries sustained.

___

___

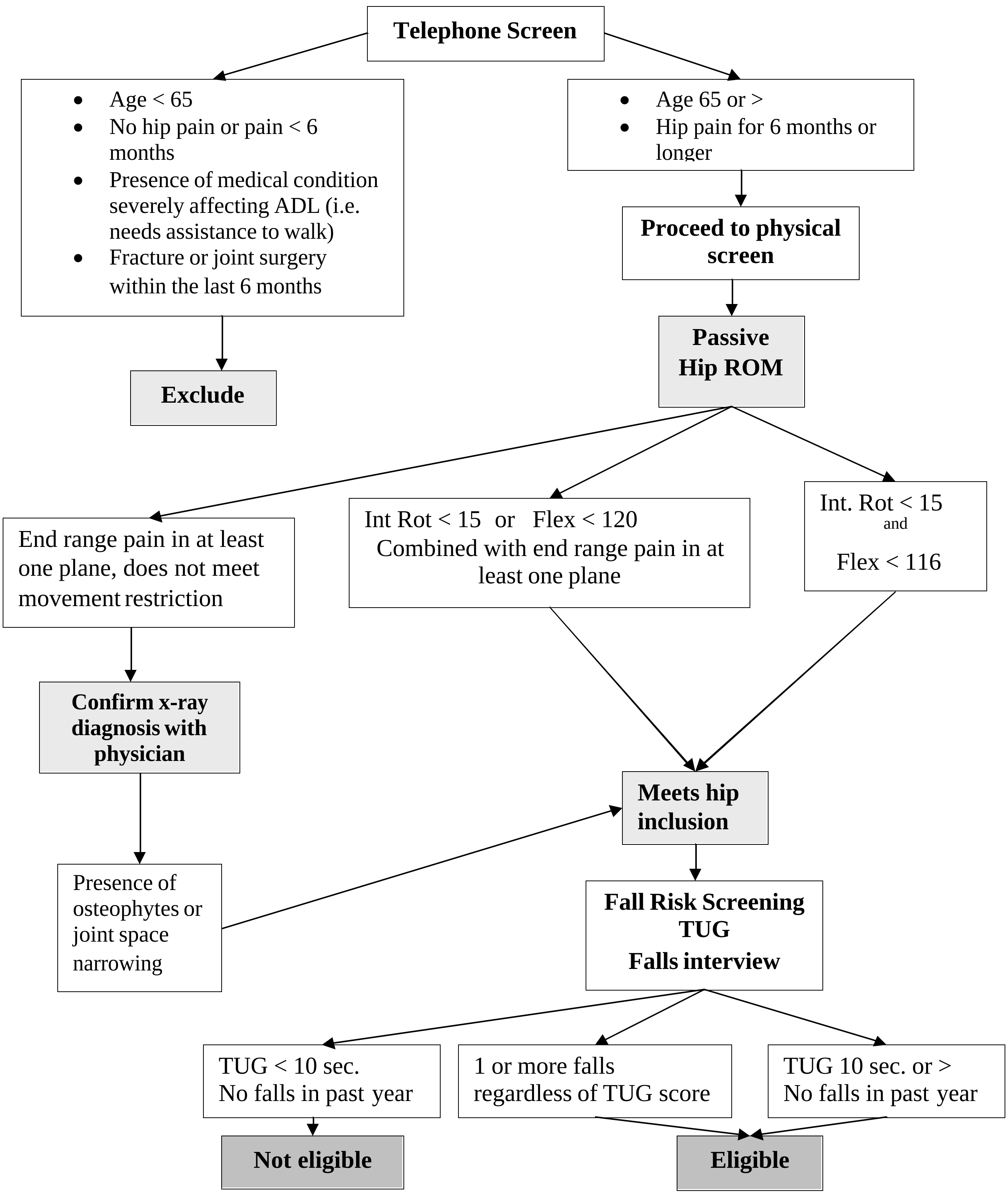
___

TUG Test

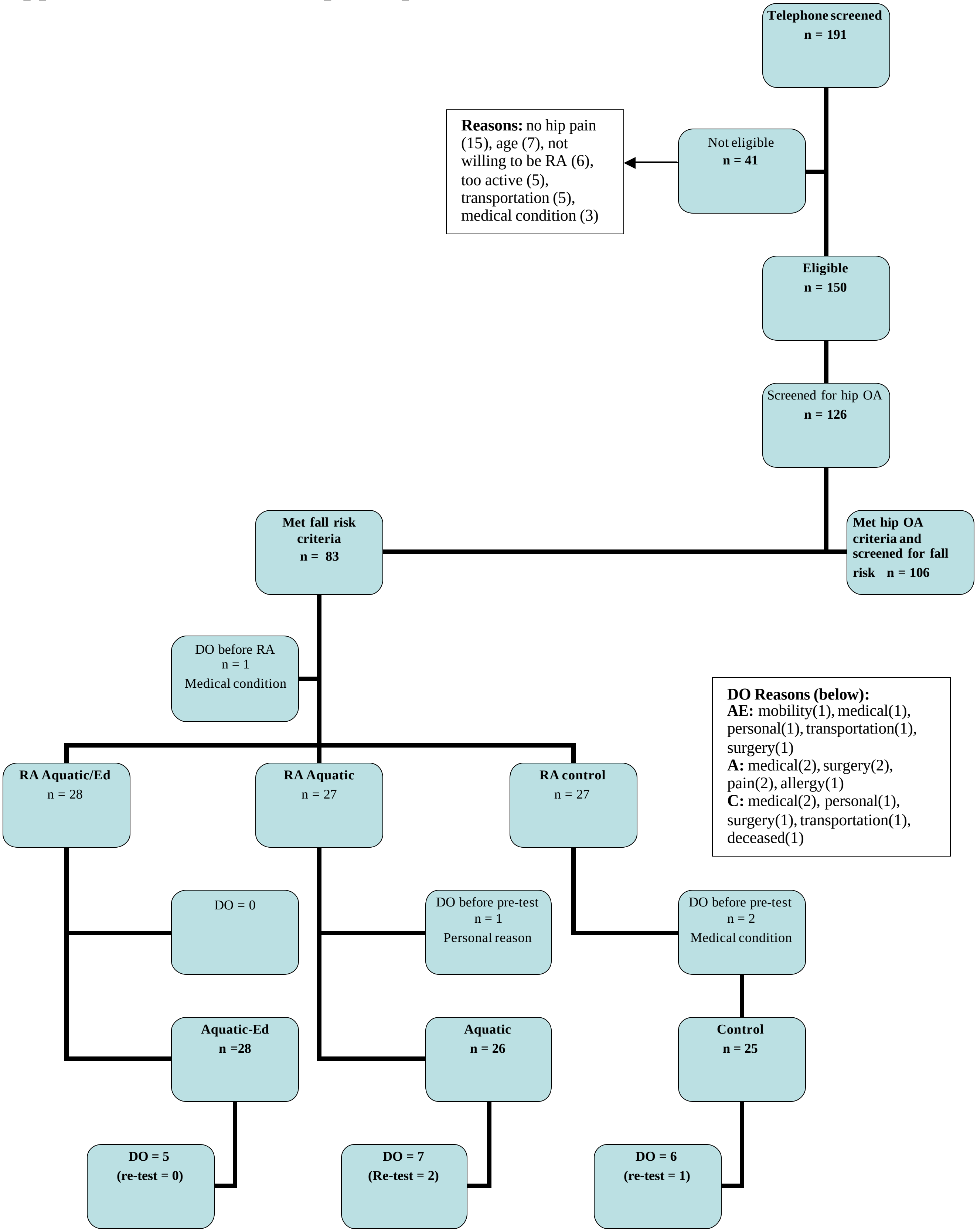
Practice Trial	YES	NO	ASSISTANCE
Walking Aid	YES	NO	

Time ___________ sec.

Appendix D: Screening Criteria to Classify Clinical Diagnosis of Hip OA and Fall Risk



Appendix E. Flow chart of participants



Appendix F. Falls-Efficacy Questionnaire and Results of Factor Analysis

* Note: questions in *italics* were deleted questions from the final version. Not to scale, converted to portrait for ease of viewing. Each question rated on a scale from 0 to 100

Answer the following questions by circling the corresponding number that best represents how confident you are in performing the following tasks:

1. **How confident are you that you could***:*	**No confidence**	**Complete confidence**
1.1 Walk at a steady pace without losing your balance while talking to a friend	0%................................100%	
1.2 Walk at a steady pace without losing your balance while counting backwards by twos (e.g.,90,88,86)	0%................................100%	
1.3 Walk at a steady pace without losing your balance while carrying a glass of water	0%................................100%	
2. How confident are you that you could:*		
2.1 Stand with eyes closed on a hard surface, like a tile floor, without losing your balance	0%................................100%	
2.2 Stand with eyes closed on a soft surface, like foam, without losing your balance	0%................................100%	
3. How confident are you that you could:		
3.1 Recover your standing position if pushed or bumped by surprise from behind	0%................................100%	
3.2 Recover your standing position if pushed or bumped by surprise on the RIGHT side of your body	0%................................100%	
3.3 Recover your standing position if pushed or bumped by surprise on the LEFT side of your body	0%................................100%	
3.4 Recover your standing position if pushed or bumped by surprise from the front	0%................................100%	

4. How confident are you that you could:	**No Confidence**	**Complete Confidence**
4.1 Walk outside <u>with assistance</u> on rough or uneven ground when good lighting is available without osing your balance	0%..................................	100%
*4.2 Walk outside <u>with NO assistance</u> on rough or uneven ground when good lighting is available without losing your balance**	0%..................................	100%
4.3 Walk outside <u>with assistance</u> on rough or uneven ground when good lighting is NOT available without losing your balance	0%..................................	100%
*4.4 Walk outside <u>with NO assistance</u> on rough or uneven ground when good lighting is NOT available without losing your balance**	0%..................................	100%
*4.5 Walk to the bathroom with NO assistance at night without losing your balance**	0%..................................	100%
4.6 Reach forward to tie your shoe while sitting on a chair without losing your balance	0%..................................	100%
4.7 *From standing, reach down and pick up a light object, like a sock from the floor, with a chair or table close by without losing your balance**	0%..................................	100%
4.8 From standing, reach down and pick up a light object, like a sock from the floor, with NO support close by without losing your balance	0%..................................	100%
*4.9 Stand on one leg while putting on a pair of pants without losing your balance**	0%..................................	100%
4.10 Move from standing to lying on the floor using a chair or couch for support without losing your balance	0%..................................	100%
4.11 Move from lying on the floor to standing using a chair or couch for support without losing your balance	0%..................................	100%
4.12 Move from lying on the floor to sitting on a chair or couch close by without losing your balance	0%..................................	100%
4.13 Move from lying on the floor to standing with NO chair or couch for support without losing your balance	0%..................................	100%

Results of Factor Analysis:

The Falls-Efficacy Questionnaire was designed specifically for this study in order to evaluate confidence in completing tasks specific to the goals and outcomes of the program. Factor analysis of the questionnaire was used to test the validity of the ideas generated for each component and to determine how items should be grouped together in subscales and which items should be dropped.[90] Twenty items were entered into the correlation matrix with an analysis n = 78. Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.93. Principal component extraction was used with an unrotated factor solution. Based on the theory of three primary categories, Falls-Efficacy$_{dual}$, Falls-Efficacy$_{reactive}$ and Falls-Efficacy$_{complex}$, three factors were forced. Eighty-one % of the total variance was explained by the first three components. Eigenvalues were > 1.0 for the first 2 components. Reproduced and residual correlation matrices were examined. There were 38 (20%) non-redundant residuals with absolute values > 0.05. The pattern matrix was to assist in determining which components could be dropped. Correlations > 0.30 that were not distributed equally across factors were kept. The final questionnaire resulted in dropping 5 questions from Fall-Efficacy$_{complex}$. The other two factors were kept in the original format. The internal consistency values of the final questionnaire were as follows: Falls-Efficacy$_{total}$ = 0.98, Falls-Efficacy$_{dual}$ = 0.93, Falls-Effficacy$_{reactive}$ = 0.97, Falls-Efficacy$_{complex}$ = 0.93.

Appendix G. Demographic and Medical History Questionnaire

Screening #________
Initials____________
SUBJ #___________

Name:________________________ Address:______________________________
Age:_____________ PC ______________________________
City ______________________________
Name of Family Physician:___________________ Clinic:_______________________
Which of the following best describes your place of residence? (check off all that apply)
______House ______Apartment or condo ______Senior residence ______Other
______live alone ______live with another adult

For the following questions, please fill in the blanks or circle your response

1. Do you have pain in your legs? YES NO

2. If YES, where is the pain? HIPS KNEES FEET OTHER:____

3. Which leg is affected? RIGHT LEFT BOTH

4. How long have you had pain? _________Years ___________months

5. Do you use a walking aid? YES NO

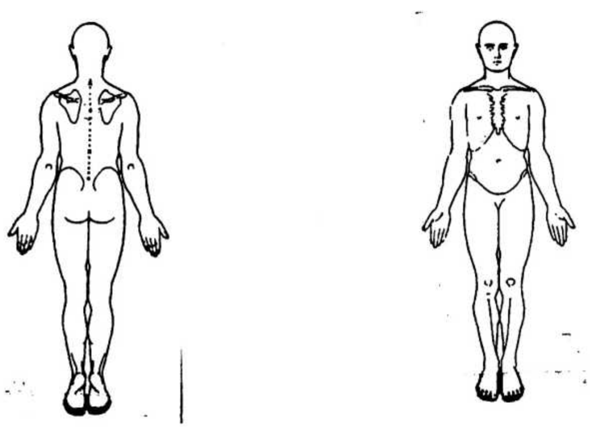
If YES, what type of aid? CANE WHEELED WALKER OTHER:_____

Where do you use your aid? INDOORS ONLY OUTDOORS ONLY BOTH

6. How would you rate your current pain?

MILD MODERATE SEVERE

7. Shade in the area on the body chart below where you feel your pain on most days:



7. Have you ever been diagnosed as having any of the following conditions?
(check off all that apply)

	Approximate year of onset
Heart Attack	______________
Transient Ischemic Attach	______________
Angina (chest pain)	______________
High blood pressure	______________
Stroke	______________
Peripheral Vascular Disease	______________
Diabetes	______________
Neuropathies (problems with sensation)	______________
Respiratory Disease	______________
Parkinson's Disease	______________
Multiple Sclerosis	______________
Polio/Post Polio Syndrome	______________
Epilepsy/Seizure	______________
Other neurological conditions:	______________
Osteoporosis	______________
Fractures (describe)	______________
Rheumatoid Arthritis	______________
Other arthritic conditions:	______________
Uncorrected Visual problems:	______________
Inner ear problems/ear infections	______________
Depression	______________
Extreme fear of Water	______________

Skin conditions: ______________________

Rashes/open wounds ______________________

Cancer ______________________

Joint Replacement ______________________

Cognitive condition ______________________

Any other health problems ______________________

8. Do you currently experience any of the following symptoms?

Chest pain or discomfort

Extreme fatigue

Nausea or vomiting

Short of breath

Dizziness or light-headedness

Fainting

Swelling of hands or feet

Muscle cramping

Muscle weakness

9. Do you require eyeglasses? YES NO

10. Do you require a hearing aid? YES NO

11. Have you required emergency medical care or hospitalization in the past 2 years?

YES NO If YES, explain why______________________________

12. List all medications that you currently take: (including over the counter medications)

Type of medication For what reason

______________________ ______________________

Appendix H. Post-test General Information Questionnaire

POST TEST GENERAL INFO

Initials__________________
SUBJ #____________
POST
Date:______________

1. FALLS

Have you had a fall in the past 3 months where any part of your body unexpectedly contacted the ground or other lower surface (ie. stairs, chair)?

YES NO

If YES, explain circumstances of the fall and any injuries sustained.

____

____

2. NEAR-FALLS

Have you had any near-falls in the past 3 months where you slipped, tripped or lost your balance, but did not fall?

YES NO

If YES, occasionally, (less than 1/week) or frequently (1/week or more):

____

If YES, explain circumstances and any injuries sustained.

____

3. Rate your current pain:

MILD MODERATE SEVERE

4. List any new medications you have started since the last time you were assessed?

NAME REASON

____

____

____

5. List any new conditions, injuries or treatments you have started since the last time you were assessed

____

____

____

6. On a scale of 1 to 10, rate your overall mobility, 1 being dependent in a wheelchair, and 10 having no mobility problems.

1 2 3 4 5 6 7 8 9 10

7. In terms of your general health (i.e. energy, strength, ability to do things), how do you feel today compared to 3 months ago (since you were last assessed) :

VERY MUCH WORSE

WORSE

SOMEWHAT WORSE

SAME

SOMEWHAT BETTER

BETTER

VERY MUCH BETTER

8. In terms of your arthritis pain or hip discomfort, how do you feel compared to 3 months ago (since you were last assessed):

VERY MUCH WORSE

WORSE

SOMEWHAT WORSE

SAME

SOMEWHAT BETTER

BETTER

VERY MUCH BETTER

Appendix I. Summary of Aquatic Exercise Programs and Goals

Osteoarthritis Aquatic Exercise Program:

**** Note: The following are excerpts from a larger manual outlining the program, which is available upon request from the author**

Objectives of the Aquatic Exercise Program

- ❖ Provide a supportive, safe environment that allows for optimal movement with minimal joint pain
- ❖ Improve mobility, strength and balance
- ❖ Improve confidence in ability to move during day to day tasks
- ❖ Improve quality of life
- ❖ Instill motivation to continue exercise
- ❖ Provide an opportunity for socializing and group support

<u>Structure</u>:		**<u>Time</u>:**
1	**Warm Up**	**5 minutes**

< Walking
< Activity for social interaction
< Posture check

Goals:

< Increase heart rate, warm-up for large muscle groups.
< Reinforce normal gait and posture.
< Increase motivation and social interaction.

2	**Stretching/General Mobility**	**10 minutes**

< Neck
< Shoulders
< Trunk/Hip
< Lower extremity

Goals

< To maintain functional mobility of the major joints/muscles
< Increase the extensibility of tight muscles ie. scalenes, trapezius, pectoralis major, quadriceps, calves, hamstrings.
< Reinforce correct posture of the neck and shoulders.

3 Strengthening **10 minutes**

Trunk/Lower Extremities

< Quadriceps
< Hip flexors/extensors
< Hip Abductors/Adductors
< Ankle

Trunk/Upper Extremities **10 minutes**

< Shoulder external rotation/Scapular retraction
< Shoulder abduction/adduction
< Triceps
< Abdominals
< Trunk

Goals:

< To improve the strength of functionally important muscle groups, such as those required for daily activities like sit to stand or maintaining balance in standing.
< To maintain balance between antagonistic muscle groups.
< To prevent flexed posture.
< Target muscle groups at common fracture sites: hip, spine, forearm

4 Balance **5 minutes**

< Variation in gait patterns
< One leg and tandem stand
< Use of turbulence to challenge

Goals:

< Improve static and dynamic balance.
< Decrease the risk of falls.
< Improve confidence in balance.

5 Posture Correction/Cool Down **5 minutes**

Goals:

< Reinforce proper posture.
< Gentle activity and stretching to cool down for the end of the session.

Appendix J. Outline of content for Education Classes*

*** This is an excerpt from the manual "*Osteoarthritis and Fall Risk Study Education Booklet: Myself, My Home and My Community, Preventing Falls, Working Together*". Author: Cathy M. Arnold**

Goals of the Program:

1. **Increase the transfer of exercises learned in the pool to ability to successfully perform activities of daily living (ADL) on land**
2. **Increase intention to continue with exercise once the intervention is complete**
3. **Improve confidence in the ability to avoid a fall and recover from a fall at home and in the community**
4. **Increase knowledge of fall risk factors**
5. **Develop individual goals to address risk factors and determine fall prevention strategies**

Outline:

Session 1:

- Introduction
- Summary of Falls/Fall Risk Factors
- Identify individual risk concerns
- Set individual goals to address concerns

Session 2:

- Review goals from last week
- Summarize proper body mechanics for exercise and the ADL targeted with the exercises in the pool
- Generate list of activities from participants that they would expect to improve with the exercise program

Session 3:

- Review list of ADL generated by participants as a group
- Participants record any improvements they have already observed
- Practice session 1: good biomechanics in movement, sit to stand, sit and reach

Session 4:

- Falls in the home
- How to decrease risk in the home – poster find the safety hazards
- What are some environmental risks specific to your home or community – generate list
- Take home environmental checklist

Session 5:

- Review environmental checklist
- Recovery from a fall - what do I do?
- What are my fears about falling
- Review ways to cope if you fall
- Specific ADL addressed in exercises to help with decreasing home fall risk, recovery after a fall
- Practice session: if I fall, getting up and down from the floor

Session 6:

- Review fears of falls and cycle – what can I do to address destructive fear?
- Review practicing recovery from a fall
- Falls in the community – how gait changes affect falls,
- Specific ADL addressed in exercises that help with improving gait
- Importance of walking practice, proper use of aids
- Practice session: walking, simple obstacle course

Session 7:

- Review goals from Day 1: what have I accomplished?
- Review ADL list – how have I improved in ADL
- Instructor reinforces specific exercises and ADL
- Practice session: dual task walking, quick stepping

Session 8:

- Review attention and alertness – dual task activities
- Practice Session – advanced obstacle course, biomechanics in standing function, sensory challenge

Session 9:

- Review ADL list – how have I improved, identify any progressions from exercise that will improve new ADL or enhance ones already identified
- Importance of continuation of exercise in maintaining, and improving ADL and decreasing fall risk

Session 10:

- New list of ADL activities
- How do I keep up with regular exercise?
- List difficulties in maintaining exercise, what type of exercise fits my lifestyle?
- Goal setting – exercise continuation
- Practice session – walk around facility

Session 11:

- Wrap-up
- Individual reflection
- Group reflection

Appendix K. Timeline for Recruiting, Testing and Intervention

Continuous Recruitment Sept 2005 – Sept 2006	Session 1 Baseline Testing Dec. 2005 n = 30	Session 1 Intervention and Control Jan - March 2006	Session 1 Post-testing March 2006
	Session 2 Baseline Testing March 2006 n = 34	Session 2 *Intervention and Control April – June 2006	Session 2 Post-testing July 2006
	Session 3 Baseline Testing Sept 2006 n = 15	Session 3 *Intervention and Control Oct. – Dec. 2006	Session 3 Post-testing Dec. 2006

*** Participants in control groups from sessions 1 and 2 were offered the opportunity to participate in one of the interventions in sessions 2 or 3.**

Appendix L. Publications arising from this thesis

1. Arnold CM & Faulkner RA [2007]: The history of falls and the association of the timed up and go test to falls and near-falls in older adults with hip osteoarthritis. *BMC Geriatrics* 7 (17) http://www.biomedcentral.com/1471-2318/7/17. (attached)