

Minimal Chair Height Standing Test Performance is Independently Associated  
with Falls in a Population of Canadian Older Adults

By

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B.Sc., York University, 2010

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

In the School of Exercise Science, Physical and Health Education

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Dr. Catherine Gaul (School of Exercise Science, Physical and Health Education)  
**Supervisor**

Dr. Patti-Jean Naylor (School of Exercise Science, Physical and Health  
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**Departmental Member**

## **ABSTRACT**

### **Supervisory Committee:**

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**Departmental Member**

**OBJECTIVES:** To assess whether the Minimal Chair Height Standing (MCHS) test, could effectively identify “fallers” in a population of Canadian older adults, and to compare its effectiveness with the commonly used Sit-to-Stand (STS) test.

**DESIGN:** Cross-sectional with counter-balanced assignment of testing order.

**SETTING:** Community centres, independent-living and assisted-living facilities.

**PARTICIPANTS:** 167 older adults (mean age=83.6yrs), able to walk independently.

**MEASUREMENTS:** Participants were interviewed for medical conditions, physical activity, cognitive status (Mini Mental State Examination), mobility and independence (Independent Activities of Daily Living). Height, weight and shank length were measured. Fall history was self-reported and recorded retrospectively. The main outcome measures were MCHS and STS scores.

**RESULTS:** MCHS performance was significantly worse for fallers (37.7cm, 95% CI: 35.5-40.0cm) than non-fallers (30.3cm, 95% CI: 28.1-32.5cm). Fallers showed significantly slower times in the STS. For participants with cardiac disease and/or stroke, MCHS scores discriminated between fallers and non-fallers ( $p=.001$ ), but the STS did not ( $p=.233$ ). For participants with knee

replacements, MCHS discriminated between fallers and non-fallers ( $p=.044$ ) but the STS did not ( $p=.076$ ).

CONCLUSIONS: The MCHS was found to be simple, practical and feasible for use with the elderly. The current study demonstrates its effectiveness as a fall-risk screening instrument for use with Canadian older adults. Further studies should be undertaken to determine its predictive validity.

## Table of Contents

Supervisory Committee.....	ii
Abstract.....	iii
Table of Contents.....	v
Abbreviations .....	vii
List of Figures .....	viii
List of Tables .....	ix
Acknowledgments.....	x
Dedication.....	xi
Chapter 1: Introduction .....	1
1.1 Purpose of the Experiment .....	3
1.2 Research Questions .....	4
1.3 Hypothesis.....	4
1.4 Delimitations .....	4
1.5 Limitations .....	4
Chapter 2: Review of Literature .....	6
2.1 Introduction.....	6
2.2 The Association between Muscle Weakness and Risk of Falling .....	7
2.2.1 Sit-to-Stand Test .....	8
2.3 Fall-Risk Assessment Tools .....	9
2.3.1 Physiological Profile Assessment.....	11
2.3.2 Berg Balance Scale .....	13
2.2.3 Additional Fall-Risk Screening Instruments.....	16
2.2.4 Minimal Chair Height Standing Ability .....	19
2.4 Summary of the Literature .....	21
Chapter 3: Methods .....	22
3.1 Experimental Design.....	22
3.2 Participants.....	23
3.2.1 Sample Size .....	23
3.2.2 Inclusion Criteria.....	23
3.2.3 Recruitment .....	24
3.3 Data Collection .....	24
3.3.1 Baseline Assessment .....	25
3.3.2 Anthropometric Assessment.....	25
3.3.3 Incidence of Falls .....	26
3.3.4 Measurement of Minimal Chair Height Standing Ability.....	26
3.3.5 Measurement of STS Performance .....	29
3.4 Statistical Analysis .....	29
Chapter 4: Results .....	32
4.1 Participant Characteristics .....	32
4.2 Minimal Chair Height Standing Ability, Age, BMI, and Gender .....	33
4.3 Minimal Chair Height Standing Ability and Falls .....	33
4.4 Minimal Chair Height Standing Ability and Sit-to-Stand (functional strength) .....	35
4.5 Inability to Perform the MCHS Test .....	35

4.5.1 Performance on the MCHS Test, Age, BMI and IADL.....	35
4.5.2 Performance on the MCHS Test and Falling History.....	38
4.5.3 Performance on the MCHS Test, Mobility and Physical Activity Level.....	38
4.5.4 Performance on the MCHS Test and Medical Conditions.....	38
4.6 MCHS vs. STS for Participants with Medical Conditions.....	39
4.6.1 Cardiac Disease and/or Stroke.....	39
4.6.2 Knee Replacements.....	40
4.6.3 Hip Replacements.....	40
4.6.4 Lower Limb Arthritis.....	42
4.7 Test Order Effects.....	42
Chapter 5: Discussion.....	43
5.1 Population Characteristics.....	43
5.1.1 Age.....	43
5.1.2 Gender.....	45
5.1.3 Body Weight.....	45
5.1.4 Fall History.....	46
5.1.5 Cultural Influences on Lifestyle.....	47
5.2 MCHS Test as a Fall Risk Screening Instrument.....	49
5.2.1 Feasibility for Use with the Elderly.....	50
5.2.2 Simplicity and Practicality.....	52
5.2.3 Guidelines for Fall-Risk Assessment.....	54
5.2.3.1 Very High Risk of falling.....	54
5.2.3.2. High Risk of Falling.....	55
5.2.3.3 Low Risk of Falling.....	55
5.3 Implications for Physical Activity Programs.....	56
5.3.1 Walking.....	56
5.3.2 Resistance-Training.....	57
5.3.3 Squatting.....	59
5.4 Limitations.....	60
5.5 Conclusions.....	61
References.....	63
Appendix A1: Poster Advertisement.....	70
Appendix A2: Invitation to Participate.....	71
Appendix A3: Participant Consent Form.....	74
Appendix A4: Baseline Questionnaire.....	78
Appendix A5: Instrumental Activities of Daily Living.....	80
Appendix A6: Mini Mental State Examination.....	81
Appendix A7: Fall History Questionnaire.....	82
Appendix A8: MCHS Testing Procedure.....	84
Appendix A9: STS Testing Procedure.....	85
Appendix B: Data for Participants with Randomized Test Order.....	86
Appendix C: Certificate of Approval- Human Research Ethics Board.....	87

**Abbreviations**

<u>1RM:</u>	1 Repetition Maximum
<u>BBS:</u>	Berg Balance Scale
<u>BMI:</u>	Body Mass Index
<u>FR</u>	Functional Reach
<u>IADL:</u>	Instrumental Activities of Daily Living
<u>MCHS:</u>	Minimal Chair Height Standing Ability Test
<u>MMSE:</u>	Mini-Mental State Examination
<u>PA:</u>	Physical Activity
<u>PPA:</u>	Physiological Profile
<u>STS:</u>	Sit-to-Stand Test
<u>TB:</u>	Tinetti Balance
<u>TUG:</u>	Timed-Up-and-Go

**List of Figures**

Figure 1 Starting position for measurement of MCHS performance.....	27
Figure 2 MCHS testing chair (left) STS testing chair (right) .....	28
Figure 3. Differences in MCHS scores of Canadian versus Taiwanese participants for individuals classified as fallers and non-fallers.....	48
Figure 4. MCHS scores and Adjusted MCHS scores for a population of fallers and a population of non-fallers.....	53

## List of Tables

Table 1 Berg Balance Scale Sub-tests .....	14
Table 2 Psychometric Properties of Studies Evaluating the BBS as a Predictor of Fall Risk in Elderly Populations.....	15
Table 3 Summary of Data Collection Protocol .....	22
Table 4 Age, Anthropometric Characteristics, ADL Limitations, and Cognitive Status of the Study Population (n=167) .....	33
Table 5 MCHS, STS, Age, and BMI means for the Faller and Non-faller Groups .....	34
Table 6 Age, BMI, Mobility and IADL Limitations, Participation in Physical Activity, and Prevalence of Medical Conditions for Participants in the Poor Performance, Moderate Performance and Strong Performance Groups ..	37
Table 7. MCHS and STS for Faller and Non-faller Groups of Participants with History of Cardiac Disease and/or Stroke .....	40
Table 8. MCHS and STS for Faller and Non-faller Groups of Participants Who Have Had Knee Replacement Surgery .....	40
Table 9 MCHS and STS for the Faller and Non-faller Groups of Participants Who Have Had Hip Replacement Surgery .....	42
Table 10 MCHS and STS for the Faller and Non-faller Groups of Participants Who's Testing Order was Randomized. ....	42

## **Acknowledgments**

First and foremost, I would like to offer my most sincere gratitude to my supervisor, Dr. Kathy Gaul who has guided and supported me from the very beginning of this journey. It has been an honour to have had the chance to work with and learn from such a great researcher and individual.

I would like to thank Dr. Patti-Jean Naylor who has always supported and guided me throughout my academic career at the University of Victoria. I am very grateful to have had the chance to work and learn from you as an undergraduate and graduate student. Thanks to all the members of my committee who have given their time and made sacrifices to help me complete this thesis on time.

I am grateful to our undergraduate research assistants who have volunteered their time to assist me with data collection: Kathleen Leahy and Raquel Solmer. Thank you so much for your hard work, patience and dedication to the project.

Thank you to all the recreation managers, directors and program coordinators of the facilities involved with this research. Thank you for your flexibility and willingness to be a part of this project. Last but not least, I am most sincerely grateful to all the participant volunteers that were involved in this study. Truthfully, this research would not have been possible without you!

**Dedication**

This thesis is dedicated to my parents, to Matt and to my three wonderful sisters for loving and supporting me unconditionally.

## **Chapter 1: Introduction**

One in three persons over 65 years of age and 40% of those over 80 years of age will fall at least once a year (Murphy, Olson, Protas, & Overby, 2003). The major problem that arises with falling is the risk of a skeletal fracture, and this risk grows exponentially as individuals age and bone mass weakens (Melton, 1996). The area of the human body that is most susceptible to fractures is the hip (Zehnacker & Bemis-Dougherty, 2007; Cummings & Melton, 2002). Hip fractures exert a vast impact on public health, as they are often associated with increased morbidity, mortality, loss of function and high economic costs (Lirani-Galvao, & Lazaretti-Castro, 2010).

In Canada, the annual economic costs of hip fractures are \$1.1 billion (Nikitovic, Wodchis, Krahn, & Cadarette, 2012) and are expected to rise to \$2.4 billion by the year 2041 because of the ageing population (Wiktorowicz, Goeree, Papaioannou, Adachi, & Papadimitropoulos, 2001). Furthermore, the psychological implications of falls can be devastating: The prevalence of post-fall anxiety syndrome and function-impairing fear of falling affects 73% of fallers (Perell et al., 2001). The damaging consequences that this fear of falling has on individuals can result in further costs, due to nursing home placement and often prolonged, rehabilitation (Perell et al., 2001).

In addition to the physical risks and the threat to the healthcare system, fall-related injuries can have deteriorating effects in the psychological health, quality of life and general well-being of older individuals (Cwikel, Fried, Biderman, & Galinsky, 1998). Thus, developing strategies to effectively predict falls among

the elderly should remain a priority for both health-care practitioners and researchers (Bongue et al., 2011; Cwikel et al., 1998).

Attempts have been made to identify risk factors for falling (Lord & Menz, 2003). A key challenge that arises when trying to identifying fall risk factors, is that falls are not random events; they typically occur, among other reasons, because of physiological impairments, such as impaired balance, muscular weakness, and slowed reaction time (Carter, Kannus, & Khan, 2001; Muir, Berg, Chesworth, & Speechley, 2008).

Additionally, a substantial number of fall-risk screening tools such as the Physiological Profile Assessment (PPA) (Lord & Menz, 2003), Berg Balance Scale (BBS) (Berg, Wood-Doplinee, Williams, & Gayton, 1989), Timed Up and Go (TUG) (Podsiadlo, & Richardson, 1991), and Functional Reach (FR) (Duncan, Weiner, Chandler, & Studenski, 1990). However, most of these tools have not yet been included as routine assessments by physicians or other health professionals (Bongue et al., 2011). The lengthy administration time, need of cumbersome equipment, and inability to be applied within various settings are some of the reasons these tests have been underutilized in health-care settings (Bongue et al., 2011). The lack of validation of these assessment tools is another reason for their underuse. In a recent systematic review of published studies Scott et al., (2007) assessed the validity and reliability of fall-risk assessment tools for use among older adults. The authors found that no single tool exists that can be applied reliably across different settings to accurately predict risk of falling (Scott, Votova, Scanlan, & Close, 2007).

Successfully identifying older adults with a high risk of falling can be complicated, time consuming and not feasible in daily medical practice. Health care professionals need a simple and pragmatic clinical approach to identify older adults with high risk to falls (Bongue et al., 2011).

The MCHS test was introduced at the Australian Physiotherapy Association Conference in May, 2002 (Schurr, Ho, Sherrington, Pamphlet, & Gale) and differs from other screening tools primarily by its simplicity, both in the equipment necessary and in the administration time. This test, which measures the lowest chair height from which a person can stand, is a functional test similar to deep squatting and requires a combination of joint flexibility, strength, and balance (Kwan, Lin, Chen, Close, & Lord, 2011). If the findings demonstrate that decreased MCHS performance is an important risk factor for falls in older people, the test could have significant applications in clinical settings and could potentially benefit a large portion of the elderly population that needs to be identified and directed towards fall-prevention programs.

### **1.1 Purpose of the Experiment**

1. The primary objective of this study was to assess whether the use of a recently developed fall-risk screening instrument (MCHS) could effectively discriminate between a population of older adult fallers and a population of older adult non-fallers.
2. The secondary objective was to determine whether MCHS performance was positively associated with Sit-to-Stand (STS) performance. The STS

is a test that is commonly used as a measure functional strength in older adults (Bohannon, 2002).

## **1.2 Research Questions**

1. Can MCHS performance discriminate between a population of “fallers” and a population of “non-fallers”?
2. Is MCHS performance positively correlated to STS performance?

## **1.3 Hypothesis**

1. MCHS scores (cm) can be used to discriminate between “fallers” and “non-fallers”
2. MCHS performance (cm) is positively correlated with STS performance (seconds).

## **1.4 Delimitations**

The study was delimited to individuals who were 65 years or older, living in the Greater Victoria area. The population was limited to ambulant community residents (with or without walking aids).

## **1.5 Limitations**

1. The incidence of falls was self-reported and recorded retrospectively. After having completed a baseline demographic questionnaire (see Appendix 4), participants were asked the following question: “In the past 1 year, have you fallen? If yes, how many times?” (Kwan et al., 2011, p.1082). Although problems have been noted with this self-report method of collecting data on falls (Bogle Thorbahn & Newton, 1996), the interviewer was instructed to ask very detailed questions regarding the setting (i.e. shower, bedroom, kitchen) and situation (i.e.

cleaning, getting dressed) in which the fall occurred with the intent to improve recall capabilities.

2. Participants might have overestimated the number of falls reported due to social desirability bias. To account for this limitation, the phrase “We all fall from time to time...” was mentioned by the interviewer before commencing the questionnaire (Cwikel et al., 1998, p.163). Interviewers were instructed to clearly define “a fall” as: ‘when you suddenly find yourself on the ground, without intending to get there, after you were in either a lying, sitting or standing position’ (Cwikel et al., 1998, p.163). A copy of the Falls History Questionnaire can be found on Appendix 7.

3. The cross sectional study design is an inherent limitation to this study. In order to examine the predictive validity of the MCHS, participants would have had to be followed longitudinally for at least a one year period, and the prevalence of falls collected over this one year period. However, this longitudinal assessment is not possible within the context of this Masters project.

4. The baseline questionnaire used to collect information about participants’ demographic information was not validated. Data obtained from this questionnaire were used to report information about participant’s age, gender and medical conditions. A copy of this questionnaire can be found on Appendix 4.

## **Chapter 2: Review of Literature**

### **2.1 Introduction**

Falls have devastating consequences for older adults in terms of morbidity, mortality, and loss of independence. Falling is the leading cause of severe injury, such as hip fractures, in the elderly population (Lord & Menz, 2003). Additionally, falling and the fear of falling impose great psychological stress in the lives of those affected (Murphy et al., 2003).

An important goal of falls' research is to develop a reliable and valid clinical measure that is simple, pragmatic and can accurately identify older adults at higher risks. Another important goal of falls' research is identifying the variables that are associated with increases in the prevalence of falling.

Numerous risk factors have been associated with a high risk of falling; these risk factors are generally categorized into extrinsic and intrinsic factors. Extrinsic factors include environmental hazards or hazardous activities such as slippery surfaces, obstacles and poor lighting (Perell et al., 2001). Intrinsic factors include patient-related factors such as advanced age, impaired balance and impaired gait (Perell et al., 2001). One of the variables that has been consistently and independently associated with a high risk for falls is muscle weakness (Shimada et al., 2011; Olivetti et al., 2007; Liu-Ambrose et al., 2004).

The following literature review seeks to underline the importance of having a fall-risk tool that can be easily implemented in health-care settings. The first section of the review evaluates prevailing research describing the association between muscle weakness and falling and describes existing methods that are

used to test this association. The final section summarizes relevant information regarding existing fall-risk assessment tools; it evaluates their validity, reliability and feasibility for use in clinical practice.

## **2.2 The Association between Muscle Weakness and Risk of Falling**

The ageing process has been associated with decreases in muscle strength and increases in the risk of falling (Carter et al., 2001). This association exists because muscle strength is essential to being able to perform activities on a day-to-day basis. Any functional activity (i.e. sitting up from a chair, picking up groceries, getting in the shower) can occur only if the muscles are capable of generating the force critical for that activity (Perry, Carville, Smith, Rutherford, & Newham, 2007). The closer an individual's strength is to that critical value, the more difficult it is to perform and control the activity (Perry et al., 2007).

Many researchers have attempted to quantify measures of muscle strength in older people. This is usually done by measuring muscle groups in isolation either concentrically or isometrically (Lord, McLean, & Stathers, 1992; de Rekeneire, et al., 2003; Takazawa, Arisawa, Honda, Shibata, & Saito, 2003; Robinson, Gordon, Wallentine, & Visio, 2004; Daubney, & Culham, 1999; Skelton, Kennedy, & Rutherford, 2002; Melzer, Benjuya, & Kaplanski, 2004). The problem with this way of measuring strength is that muscles do not work in isolation; in order to better understand the mechanisms by which older people fall in a real world setting, muscle strength needs to be measured functionally.

Functional strength was addressed in a study conducted by Perry et al. in 2007. The study investigated the differences in leg extension power, isometric,

concentric and eccentric strength of the knee and ankle muscles between a group of older “fallers” and a group of older “non-fallers”. Fallers were defined as those having had at least one unexplained fall over the past twelve months. It was found that the strength measurements from each individual muscle group (either concentric, isometric or eccentric) did not show significant differences between “fallers” and “non-fallers”. However, for all muscles combined the fallers were consistently weaker than the non-fallers. Most importantly, measurements of leg power were lower in the fallers than the non-fallers. As this was the most functional of the tests performed, the authors concluded that a measure of functional strength may be the most informative in terms of understanding the mechanisms underlying falls in this population (Perry et al., 2007)

### **2.2.1 Sit-to-Stand Test**

Although there are many functional strength tests, the sit-to-stand test is used most often with older individuals (Bohannon, 2002). Rather than measuring muscle groups in isolation, the STS measures the efficiency with which a person utilizes a vast array of muscle groups (primarily knee extensors and hip extensors). The test involves measuring the fastest time it takes to stand from a seated position five times (Bohannon, 1995).

In a study conducted by Lord et al., (2002) the authors sought to prove that the STS was more than a specific measure of lower limb strength and therefore could be used to assess a person’s balance and mobility. In their study, 669 community-dwelling men and women aged 75 – 93 years underwent

quantitative tests of strength, vision, peripheral sensation, reaction time, balance, health status, and STS performance.

It was found that STS performance was significantly associated with a range of sensorimotor, balance, and psychological factors. Specifically, the authors demonstrated that nine measures (visual contrast sensitivity, lower limb proprioception, tactile sensitivity, simple foot reaction time, postural sway, body weight, reported pain, anxiety, and vitality) in addition to knee extension, knee flexion, and ankle dorsiflexion strength were significant and independent predictors of STS performance.

These results suggests that, when compared to measuring strength of isolated muscle groups, STS performance is a more appropriate measure of strength when evaluating an older population at a high risk for falls (Lord, Murray, Chapman, Munro, & Tiedemann, 2002). This is the reason why this study assessed STS performance and evaluated whether STS performance is positively associated with MCHS ability.

Test-retest reliability and intra-class reliability of the STS have been shown to be high by Jones et al., (1999) and Lord et al., (2002) respectively. In addition, the STS has been shown to possess convergent, construct and discriminant validity (Bohannon, 2002)

### **2.3 Fall-Risk Assessment Tools**

Because of the extreme cost of falling to the Canadian health care system, a vast amount of research has been dedicated to developing a screening test that can be used in clinical settings to identify people at a high risk of falling. The

purpose of these screening tools is to identify patients at risk of falling, and direct them to fall-prevention programs when necessary.

Assessment of fall-risk usually involves either the use of multifactorial assessment tools, which cover a wide range of fall-risk factors, or functional mobility assessments, which focus on the physiological and functional domains of postural stability including strength, balance, gait and reaction times (Scott et al., 2007). This review will focus on evaluating the most commonly used functional assessment screening tools in clinical practice and health-care settings: The Physiological Profile Assessment (PPA) (Lord & Menz, 2003), Berg Balance Scale (BBS) (Berg et al., 1989), Timed Up and Go (TUG) (Podsiadlo, & Richardson, 1991), and Functional Reach (FR) (Duncan et al., 1990),

In order to compare the effectiveness of each test, the sensitivity, specificity, reliability, and practicality of each test will be evaluated. Both the sensitivity and specificity of a test are measures of its predictive validity. The sensitivity of a test is defined as the proportion of individuals that are “fallers” whom the screening test labels positive (Day, 1985). The specificity of a test refers to the probability that a person who is a “non-faller” will have a negative test. Perell et al., (2001) have recommended the establishment of ‘high’ predictive values for fall-risk assessment tools as those that have sensitivity measures above 80% and specificity above 75%. The reliability is the aspect of a test concerned with whether it produces consistent and dependable results (Stratford, 1989) . The practicality of a test refers to its administration time, equipment needed, and simplicity for use in various health-care settings.

### **2.3.1 Physiological Profile Assessment**

Balance deficiencies have been shown to be associated with increases in fall risk in older people (Aoyama, Suzuki, Onishi, & Kuzuya, 2011). However, falls among elderly persons have a multifactorial etiology; thus attributing a degree of falls' risk to one specific factor (balance) is problematic (Bogle Thorbahn & Newton, 1996). In response to this problem, Lord & Menz (2003) have taken a "physiological" approach to evaluating falls' risk factors.

According to Lord & Menz (2003) the physiological factors that are the primary contributors to stability are: Vestibular function, reaction time, vision, peripheral sensation and muscle force. The functioning of each of these factors declines with age, and impairments in each factor are associated with increased risk of falling (Lord & Menz, 2003). Based on this knowledge, the Physiological Profile Assessment (PPA) was created to assess fall-risk in the elderly, a test that is commonly used by physical therapists and researchers (Liu-Ambrose et al., 2004). The PPA is based on an individual's performance in 9 different tests: Visual field dependence, visual acuity, contrast sensitivity, knee flexion, knee extension, ankle dorsiflexion, tactile sensitivity, vibration sense, and proprioception.

The PPA has 2 versions: a comprehensive (or long) version and a screening (or short) version. The long version takes up to 45 minutes per person to administer. While the short version takes 10 to 15 minutes to administer and it is more suitable for settings in which time constraints are an issue (clinical settings) (Lord & Menz, 2003). For both the short and long forms, a Web-based

computer software program has been developed to assess an individual's performance in relation to a normative database (Lord & Menz, 2003).

A disadvantage to using the PPA is that it requires specialized equipment to be conducted. Visual acuity is measured by using a letter chart. Tactile sensitivity is measured with a Semmes-Weinstein–type pressure aesthesiometer. Vibration sense is measured using an electronic device that generates a 200-Hz vibration of varying intensity. Muscle force is measured using a string gauge attached to the subject's leg. Reaction time is assessed using a hand-held electronic timer and postural sway is measured using a sway meter (Lord & Menz, 2003). An additional disadvantage to using the PPA is that the equipment and computer program are costly; the price for the comprehensive and screening versions of the PPA are US\$6,000 and US\$3,000 respectively (Lord & Menz, 2003).

As a fall-risk assessment tool, the PPA has been shown to have high validity. In a 1-year prospective study of 95 residents of an intermediate care hostel, the PPA measurements were used to correctly classify subjects into a “fallers” group with an accuracy of 79% (Lord, Clark, & Webster, 1991). In a similar 1-year prospective study, involving 414 community dwelling women, the PPA was used to correctly classify subjects as “fallers” with an accuracy of 75% (Lord, Ward, Williams, & Anstey, 1994). The vision, muscle force, reaction time, and balance tests have all been shown to have high test-retest reliability, and the sensory tests have shown moderate test-retest reliability (Lord & Menz, 2003).

Overall, the PPA measurement is a valid instrument to assess risk of falls in older people. However, administration of the test requires specialized equipment and computer processing which is time-consuming and costly. Consequently, the PPA might not be feasible for use in clinical settings. Other simple assessment measures which do not require much equipment or computer analysis might be more practical for settings, such as a physician's office, in which time constrains, are an issue.

### **2.3.2 Berg Balance Scale**

One of the most commonly used assessment tools in health-care settings is the Berg Balance Scale (BBS). The BBS was developed as a clinical measure of functional balance specifically for older people (Berg et al., 1989). The scale takes approximately 20 minutes to complete, and requires minimal equipment (chair, stopwatch, ruler, and step) (Neuls et al., 2011). The BBS assesses balance through direct observation of a patients' performance on 14 different tasks (Table 1). Each one of the 14 tasks is subjectively scored on a scale of 0 to 4, for a total possible score of 56, indicating no identified balance difficulties (Muir et al., 2008). Previous studies have used the cutoff value of 45 as the value used to distinguish people with an increased risk of falling from people with a low risk of falling (Muir et al., 2008).

**Table 1 Berg Balance Scale Sub-tests**

<b>Item</b>	<b>Description</b>
1	Sitting to standing
2	Standing unsupported
3	Sitting unsupported
4	Standing to sitting
5	Transfers
6	Standing with eyes closed
7	Standing with feet together
8	Reaching forward with an outstretched arm
9	Retrieving object from floor
10	Turning to look behind
11	Turning 360°
12	Placing alternate foot on stool
13	Standing with foot in front of the other foot
14	Standing on one foot

Neuls et al., (2011) conducted a systematic review of the literature that evaluated the ability of the BBS to predict falls in the elderly. A total of nine studies met the inclusion criteria: Five of these studies addressed elderly populations without known pathologies, and the remaining four studies investigated . elderly participants with neurological disorders. The results of the review are shown in Table 2. Across the nine studies, the BBS showed specificity levels ranging from 55% to 100% and sensitivity levels ranging from 25% to 92%.

Based on these results the authors concluded that BBS alone was not able to predict fall risk. They suggested that the BBS be used in conjunction with other tests to better help guide a clinician's recommendation for fall-risk interventions (Neuls et al., 2011).

**Table 2 Psychometric Properties of Studies Evaluating the BBS as a Predictor of Fall Risk in Elderly Populations**

<b>Study</b>	<b>Sample Size</b>	<b>Sensitivity</b>	<b>Specificity</b>
Ashburn et al. (2008)	122	85% (95% CI:73-93)	PPV 95% CI: 55%; (43-65) NPV 95% CI: 83%; (68-91)
Bogle-Thorbahn and Newton (1996)	66	BBS and initial fall frequency: 53%	BBS and initial fall frequency: 96%
Chiu et al. (2003)	78	BBS and 6 month f/u fall frequency: 53% (95% CI): 88.2% (63.5-98.2)	BBS and 6 month f/u fall frequency: 92% (95% CI): 76.5% (50.1-93.0)
Dibble and Lange (2006)	45	41% cutoff score of 46	100% acutoff score of 46
Lajoie and Gallagher (2004)	125	82.5%	93%
Landers et al. (2008)	49	68.0% acutoff score of 45	87.5% acutoff score of 45
Mackintosh et al. (2006)	55	92%	65%
Muir et al. (2008)	187	(95% CI): 25% (16-36)	(95% CI): 53% (43-63)
Shumway-Cook et al. (1997)	44	77%	86%

---

CI: Confidence Interval BBS: Berg Balance Scale PPV: Positive Predictive Palue  
NPV: Negative Predictive Value f/u: Follow-up  
Retrieved from (Neuls et al., 2011)

In conclusion, even though the BBS is widely used in clinical settings, it can be time-consuming for the practitioner to perform and can be burdensome to

the patient since it requires the performance of 14 different tasks. Based on evidence from the literature, the scale shows strong reliability and specificity but poor sensitivity for identifying people with increased risk of falling (Bogle Thorbahn & Newton, 1996). The issue is that the BBS was developed in 1989 as a measure of functional balance (Berg et al.), and it is now being used as a predictor of fall-risk; balance impairments are not a sufficient cause of falls and therefore are not present in all people who have fallen or who will fall (Muir et al., 2008). Thus, in order to quantify an older adult's chances of falls, the scale should be used in combination with other risk-assessment tools.

### **2.2.3 Additional Fall-Risk Screening Instruments**

In addition to the BBS and PPA, numerous screening tools such as the Timed Up and Go (TUG), Functional Reach (FR), Tinetti balance (TB), and Tandem Stance (TS) are available for evaluating fall risk in older people. These various instruments have been developed for use in different populations: hospitals, residential care facilities, community-dwelling older adults (Gates, Smith, Fisher, & Lamb, 2008). These instruments also vary in complexity (from a single clinical test to scales involving 14 or more assessments). Since it is time-consuming to use all of these measures for each individual, researchers have attempted to identify the test that is most effective at predicting falls.

In a systematic review conducted in 2008, Gates et al., sought to assess and summarize the evidence available concerning the accuracy of screening tests at predicting fallers in community-dwelling populations. Twenty-five studies were eligible and included in the review. Studies were included if the participants

were older people in residential care environments, living independently with no specific diagnoses (i.e. stroke, Parkinson's disease). Most importantly, studies were included in the review if they used a prospective design; this was done so that predictive validity could be assessed.

In general, the screening tests assessed in the studies had higher specificity than sensitivity, indicating that a higher proportion of non-fallers than fallers were correctly identified (Gates et al., 2008). Specificity of at least 80 percent was reported 22 times, compared with only 8 reports of sensitivity of 80 percent or more. Only two tests had any result for which sensitivity and specificity both exceeded 80 percent (Murphy, Olson, Protas, & Overby, 2003; Lundin-Olsson, Nyberg, & Gustafson, 2000), although a larger study of one of these tests did not confirm this result (Gates et al., 2008).

The review included four studies that assessed the Timed Up and Go (TUG). In the TUG, subjects are asked to stand up from a standard chair with a seat height between 40 and 50 cm, walk a 3-m distance at a normal pace, turn, walk back to the chair, and sit down (Podsiadlo & Richardson, 1991). All four studies that were evaluated in the review, utilized different methods to conduct the TUG. Hence it was not possible to perform a meta-analysis with the data obtained from these four studies (Gates et al., 2008).

The systematic review also included two studies that evaluated the Functional Reach (FR) test. When performing the FR test, individuals are positioned next to a wall with one arm raised, fingers extended, and a yardstick mounted on the wall at shoulder height. The distance in centimeters that a

subject is able to reach forward from an initial upright posture to the maximal anterior leaning posture is measured (Duncan et al., 1990). A study conducted by Murphy et al., (2003) found relatively high values for sensitivity and specificity (0.73 and 0.88, respectively), although the confidence intervals (CI) were wide because of this study's small size. A larger study conducted by Lin et al., (2004) suggested that the FR had almost no discriminatory ability between fallers and non-fallers.

Another frequently used test of functional performance is the Tandem Stance (TS). When performing the TS, participants are asked to stand heel-to-toe for up to 60 seconds (Cho, Scarpace, & Alexander, 2004). In a prospective cohort study, Stel et al., (2003) found the test's ability to identify fallers as "poor". Additionally, Murphy et al., (2003) found poor sensitivity (55%) but good specificity (94%) for the TS. The intra-rater and inter-rater reliability of the TUG, FR, TB and TS within two weeks have been found to be excellent by Lin et al., (2004) with a range of 0.93 to 0.99.

Overall, Gates et al., (2008) were not able to confidently identify any screening test that was effective at identifying fallers. The authors found that most tests had only been evaluated by one study, and where multiple studies existed, such as for the TUG, the methodologies in the studies varied. Moreover, many studies had small sample sizes which did not allow them to estimate sensitivity and specificity with sufficient precision. The authors concluded that further high-quality studies are needed in order to determine which screening instrument is best at identifying older adults at high risk of falling (Gates et al.,

2008). Similar findings were obtained by Perell et al., in 2001. After reviewing the literature, the authors concluded that confidently selecting an appropriate screening instrument is problematical due to the lack of consistency in methodology of the studies published.

#### **2.2.4 Minimal Chair Height Standing Ability**

This test, which measures the lowest height chair from which a person can stand, is a functional test similar to deep squatting and requires a combination of joint flexibility, strength, and balance (Kwan et al., 2011). Deep squatting has been shown to be beneficial as an everyday exercise for maintaining lower limb strength, coordination, and balance in older people (Kwan et al., 2011; Lord et al., 2005). The MCHS was introduced at the Australian Physiotherapy Association Conference in May, 2002 (Schurr et al.) and differs from other screening tools primarily by its simplicity; both in the minimal equipment and quick administration time required in conducting the test.

Olivetti et al., (2007) have used the MCHS test as a primary outcome measure to evaluate strength and mobility in a study designed to assess the effectiveness of a weight-bearing strengthening program in older adults undergoing rehabilitation. The authors found that participants who took part in a weight-bearing strength-training program were able to stand from chair heights that were 5cm lower than participants in a non-weight bearing strength training group.

Kwan et al., (2011) were the first researchers to evaluate the effectiveness of the test in discriminating between fallers and non-fallers in a population of

older Taiwanese Individuals. An interesting aspect of Taiwanese culture is that the practice of squatting for toileting, home chores, gardening, and playing with children is very common, even in the elderly, making the MHCS an appropriate test for this population (Kwan et al., 2011).

The study consisted of 280 participants (160 men, 120 women) aged 65 to 91. Initially, participants were asked to rise from a backless 47-cm-high chair with their arms crossed and held close to the chest. The chair was then lowered by 3- to 5-cm until the participant could not stand from the seated position. The final seat height a participant was able to stand up from was recorded and testing procedure concluded. Additional outcomes measured were the PPA, visual acuity, depth perception, proprioception, knee extension strength, reaction time, postural sway, and standing balance. This was done to determine which of these measures were most strongly associated with MCHS performance.

Kwan et al., (2011) found the intra-rater reliability of the test to be high (0.83), while the inter-rater reliability for the MCHS test had previously been reported to be 0.9 (Schurr et al., 2002). Out of the 280 participants, 81 had fallen in the previous year and were therefore classified as “fallers”. The authors found that fallers had significantly higher MCHS scores, independent of age and BMI. Most importantly, poor performance in the MCHS test was significantly associated with falls even after adjusting for PPA fall-risk scores.

MCHS performance was also significantly associated with lower limb strength, standing balance and leaning balance, suggesting that these 3 factors are important in the maintenance of this functional measure. Lastly, the authors

found that MCHS ability and falls was significantly associated with the frequency in which the participants squatted each day.

These findings demonstrate that the MCHS served an effective instrument to measure fall risk in older Taiwanese people. The use of the MCHS test could have significant applications in clinical settings where there is a need for a fall-screening test that is reliable, valid and quick to administer. The MCHS is a recently developed assessment tool and prospective studies are needed to determine the predictive validity (specificity and sensitivity) of the test. Further research is also needed to determine whether the test is able to discriminate between fallers and non-fallers in other cultural groups where deep squatting is not a common every-day activity. This particular study will seek to assess whether MCHS ability can discriminate between fallers and non-fallers in an older Canadian population.

## **2.4 Summary of the Literature**

A reliable and valid clinical measure can increase a physician's ability to predict who is at risk for falls. Some of the screening tools mentioned in the literature are quite detailed and can be burdensome for an older patient. Some can be time consuming for the practitioner to perform, taking up to 45 minutes to complete. Numerous quick and reliable screening tools have been developed, although studies have failed to provide quality validity measures to support their use. In conclusion, no fall-risk screening instrument exists that has been consistently shown to be valid, reliable, and practical for use in clinical practice.

## Chapter 3: Methods

Data were collected over 8 weeks between May 7, 2012 and July 7, 2012 in Victoria, British Columbia. The University of Victoria Human Ethics Research Committee provided approval for this study to be conducted (see Appendix C)

### 3.1 Experimental Design

A descriptive, cross-sectional research design was implemented in order to evaluate the effectiveness of the MCHS and STS tests in discriminating between a population of older adult fallers and a population of older adult non-fallers. As shown in Table 3, for each participant recruited (n=167), data were collected over a single 45 minute time frame.

**Table 3 Summary of Data Collection Protocol**

Time (minutes)	Data Collected
0-10	<ul style="list-style-type: none"> <li>• Informed Consent</li> </ul>
10-20	Non-Standardized Questionnaires <ul style="list-style-type: none"> <li>• Baseline Questionnaire: Age, List of Medical Conditions.</li> </ul> Standardized Questionnaires <ul style="list-style-type: none"> <li>• EPIC Physical Activity Questionnaire*</li> <li>• IADL<sup>∞</sup></li> <li>• MMSE<sup>^</sup></li> <li>• Fall History Questionnaire</li> </ul>
20-30	Anthropometric Assessment: <ul style="list-style-type: none"> <li>• Height and body weight</li> <li>• Shank Length</li> </ul>
30-45	Physical Performance Tests <ul style="list-style-type: none"> <li>• MCHS</li> <li>• 3 minutes rest</li> <li>• STS</li> </ul>

\*European Prospective Investigation into Cancer and Nutrition Physical Activity Questionnaire

∞ Instrumental Activities of Daily Living Questionnaire

^Mini-Mental State Examination

A sub-sample of the study participants (n=46) was chosen to determine whether the order in which participants performed the MCHS and STS affected performance in these tests. Twenty-one individuals from this sample (mean age  $\pm$  SD,  $83.5 \pm 7.9$ ; 17 women) were randomly assigned to begin testing performing the MCHS. While 24 individuals (mean age  $\pm$  SD,  $81.5 \pm 9.5$ ; 18 women) were randomly assigned to begin testing performing the STS. Demographic information of participants in this sub-sample of the population is available in Appendix B.

## **3.2 Participants**

### **3.2.1 Sample Size**

The number of participants required to complete the study was calculated using G\*Power 3.1.3 for Windows. The calculation was conducted using a one-tailed hypothesis, a medium effect size of 0.52, and an error probability of 0.05. The effect size of 0.52 was obtained based on the results from a previous study that demonstrated significant differences between the MCHS scores of “fallers” as compared to “non-fallers” (Kwan et al., 2011). Based on this calculation, a sample size of 162 was obtained as the required sample size.

### **3.2.2 Inclusion Criteria**

Participants were eligible to participate in the study if they were 65 years or older, living in the greater Victoria area, and were able to walk independently (with or without walking aids). A total of 168 individuals (120 female, 48 male) met this inclusion criteria. Participants were informed of the purpose of the study and signed an informed consent form (Appendix A3).

### **3.2.3 Recruitment**

Participant recruitment was conducted by poster advertisements (Appendix A1), written invitations (Appendix A2) and in person. Written invitations were sent by electronic mail to activity and recreation directors of 10 independent living facilities and 5 assisted living facilities across Victoria, BC. Written invitations were also sent by electronic mail to program directors of 2 senior community centers and 1 recreation center. These invitations provided facility directors with basic information about the study, and were used to set up meetings at the respective facilities to clearly describe the details of the project.

Meetings were set up with recreation managers from 5 independent living facilities, 2 assisted living facilities, 2 senior community centres and 1 recreation centre. All 10 managers gave permission to conduct research in their building, and provided specific dates for data collection to take place.

Participant volunteers were recruited through poster advertisements placed across these facilities, as well as in person through presentations and information sessions held at the settings mentioned above. Sign-up timesheets for the day/s of the data collection were provided to those individuals who showed interest in participating. On the day of data collection, the investigators were provided with a small room or private area in the facility where data collection took place.

### **3.3 Data Collection**

On the day of data collection, participants were supplied with printed copies of the consent form (Appendix A3). An explanation and familiarization of

the study was provided, and any questions or concerns addressed fully. This was followed by the participant's signature, indicating informed consent. Subject confidentiality was maintained by using randomly assigned numbers on all questionnaires and scoring sheets, rather than full names.

### **3.3.1 Baseline Assessment**

After providing informed consent, participants completed a detailed baseline questionnaire (Appendix A4) in which their age, prevalence of major medical conditions and participation in physical activity was obtained. Following the baseline questionnaire, individuals completed the Instrumental Activities of Daily Living (IADL) questionnaire (Appendix A5) and the Mini Mental State Examination (MMSE) to assess cognitive function (Appendix A6). If Participants scored less than 19 points on the MMSE, they completed all aspects of data collection but their data were excluded from statistical analysis.

### **3.3.2 Anthropometric Assessment**

Once all questionnaires were completed, subject body weight (to the nearest 0.05kg) using an electronic scale (WANDA, model WD2003, Zhejiang, China) and height (to the nearest 0.5cm) using a wall-mounted measuring tape (Mastercraft, 1-in. x 25-ft./7.5m) were measured as well as shank length, which was measured (to the nearest 0.5cm) using anthropometric measuring tape (ALMEDIC, 150cm/60", Canada). "Shank length" was measured from the fibular head to the lateral malleolus. Shank length was used to calculate "Adjusted MCHS" scores using the following equation:

$$\text{MCHS Adjusted (female)} = \frac{\text{MCHS score} \times \text{Mean Shank length (females)}}{\text{Participant's Shank length}}$$

$$\text{MCHS Adjusted (males)} = \frac{\text{MCHS score} \times \text{Mean Shank length (males)}}{\text{Participant's Shank length}}$$

### **3.3.3 Incidence of Falls**

The incidence of falls was self-reported and recorded retrospectively using the Fall History Questionnaire (Appendix 7). The following questions were asked to document the incidence of past falls: “In the past 1 year, have you fallen? If yes, how many times?” A fall was defined as “when you suddenly find yourself on the ground, without intending to get there, after you were in either a lying, sitting or standing position” (Cwikel et al., 1998, p.168).

Those participants who reported having 1 or more falls in the past 12 months, were classified as “fallers”. Participants who reported no falls in the past 12 months, were classified as “non-fallers”. Additionally, individuals classified as “fallers” were asked to provide further information regarding the severity of the fall/s suffered (i.e. skeletal fractures, hip fractures, hip replacements).

### **3.3.4 Measurement of Minimal Chair Height Standing Ability**

The MCHS was conducted to determine the lowest height from which a participant could stand from a chair without arm support. Subjects were asked to sit on a backless 47cm-high chair, positioned with their feet hip width apart, toes under knees and arms folded across chest (Figure 1).



**Figure 1 Starting position for measurement of MCHS performance**

The chair was built specifically for this study; it was designed with a starting seat height of 47cm and the seat lowered by exactly 5cms each time. The material used for the main structure of the chair was aluminum, while the seat was made out of wood (Figure 2). The total cost of the chair was CAD\$250.



**Figure 2 MCHS testing chair (left) STS testing chair (right)**

Subjects were given three attempts at each height reached (47cm, 42cm, 37cm, 32cm, 27cm, 22cm, 15cm) and 1 to 2 minutes of rest between attempts. The chair was lowered 5cm if the subject was able to rise successfully from the seat. A successful attempt was recorded if participants kept their arms across their chest throughout the entire movement, and did not use the back of their legs against the chair to assist themselves.

If the subject was unsuccessful after three attempts, the testing procedure was finished and final seat height recorded. When a participant was unable to stand-up from the initial 47cm seat height, their performance was recorded as “N/A” in the scoring sheet. The complete procedure used to conduct the MCHS is detailed in Appendix A8.

Reliability of the MCHS test has been determined by Kwan, et al., (2011) who found the intra-rater reliability of the test to be high (0.83), while the inter-rater reliability for the MCHS test has previously been reported to be 0.9 (Schurr et al., 2002).

### **3.3.5 Measurement of STS Performance**

Once the MCHS was completed, participants were asked to complete the Sit-to-Stand test. Subjects began the test sitting on a 47cm-high chair (Figure 2), positioned with the feet hip width apart, toes under knees and arms folded across their chest.

The investigators recorded the length of time (to the nearest tenth of a second) it took for subjects to rise and sit back down five consecutive times without the use of their arms. Participants were given one practice trial to familiarize themselves with the procedure. After the practice trial, participants were given 3 minutes to rest before commencing testing. The complete procedure used to conduct the STS test is detailed in Appendix A9.

Test-retest reliability (0.95) and intra-class reliability (0.89) of the STS have been shown to be high by Jones et al., (1999) and Lord, et al., (2002) respectively. In addition, the STS has been shown to possess convergent, construct and discriminant validity (Bohannon, 2002)

### **3.4 Statistical Analysis**

The statistical analysis was conducted using SPSS 16.0 statistical software for Windows (2008, SPSS Inc., Chicago, IL). All physical performance scores and demographic data are expressed as mean  $\pm$  standard deviation (SD).

Prior to data analysis, normality of distribution of data were tested by the Kolmogorov-Smirnov test as well as normally distributed histograms. Significance was set at  $p < 0.05$ .

Independent-sample t-tests were used to assess differences in the means of test measures (MCHS, MCHS Adjusted, STS), age, and anthropometric characteristic (BMI, weight) between faller and non-faller groups. 95% confidence intervals were calculated for the means of MCHS, MCHS Adjusted and STS scores for fallers and non-fallers.

Independent-sample t-tests were also used to evaluate differences in the means of age, cognitive status and IADL scores between males and females. Pearson correlation analyses were used to evaluate the association between MCHS and STS performance.

In order to further examine the factors associated with MCHS ability, participants were divided into 3 groups based on their MCHS performance. Group 1 included the 25 participants who were not able to stand from a chair of standard height ( $>47\text{cm}$ ). Group 2 was comprised of the 76 participants who were able to stand from the MCHS chair height set at between 32 and 47cm high. Group 3 consisted of the 67 participants who achieved the best performance on the MCHS, and were able to stand from a chair height of 32cm or lower. A one-way between subjects ANOVA was conducted to compare the differences in age, BMI and IADL between these groups. Post hoc analyses using LSD were performed when significant main effects were found. Statistical significance was set at  $p < 0.05$ .

As many participants with joint disease (knee replacement, hip replacement, lower limb arthritis) reported feeling discomfort while performing the STS, statistical analysis was conducted to determine whether there was a difference in performance between the STS and MCHS for this sub-sample of the population with joint disease. Participants suffering from each medical condition were divided into “fallers” and “non-fallers”, and independent-sample t-tests were conducted to assess differences in the means of MCHS and STS scores. Since the STS test has a higher metabolic demand than the MCHS test, this analysis was also conducted for participants suffering from cardiac disease and/or stroke (as self-reported from the Baseline Questionnaire)

## Chapter 4: Results

### 4.1 Participant Characteristics

A total of 168 (120 female, 48 male) residents of Victoria, British Columbia voluntarily participated in this study. All participants completed the baseline questionnaire, IADL, and obtained a score of 19 or higher in the MMSE. One participant withdrew from the study following the anthropometric measurements due to reported fear of performing the STS and MCHS. As a result, 167 participants (mean  $\pm$  SD: 83.6  $\pm$  7.3yrs) completed the physical performance aspects of the study and were included in the statistical analysis.

Participant' age, anthropometric characteristics, IADL limitations and cognitive status (MMSE) are shown in Table 4. Men and women did not differ significantly with respect to age (83.3  $\pm$  6.9yrs and 83.8  $\pm$  7.5yrs respectively,  $p=.723$ ), cognitive status (28.5  $\pm$  1.5 and 28.5  $\pm$  1.8 respectively,  $p=.976$ ) or IADL scores (5.8  $\pm$  2.1 and 6.5  $\pm$  1.9 respectively,  $p=.069$ ). A total of 64 (38.3%) subjects reported using walking aids (walker and/or cane) to assist with everyday locomotion.

**Table 4 Age, Anthropometric Characteristics, ADL Limitations, and Cognitive Status of the Study Population (n=167)**

Variable	Mean $\pm$ SD	Range
Age (yrs)	83.6 $\pm$ 7.3	65-97
Height (cm)	164.5 $\pm$ 10.5	142.7-189.5
Weight (kg)	70.7 $\pm$ 16.8	41.4-137.3
BMI	26.0 $\pm$ 5.3	17.4-54.2
IADL	6.3 $\pm$ 2.0	1-8
MMSE	28.5 $\pm$ 1.7	22-30

#### 4.2 Minimal Chair Height Standing Ability, Age, BMI, and Gender

A total of 143 participants were able to complete at least one stage of the MCHS test (104 female, 39 men). Men and women did not differ significantly in their ability to perform the MCHS ( $30.7 \pm 10.4$ cm and  $34.4 \pm 10.2$  respectively,  $p=.057$ ). MCHS score was significantly correlated with age ( $r= .475$ ,  $P<.001$ ), but not significantly correlated to BMI ( $r= -.048$ ,  $P= .284$ ).

#### 4.3 Minimal Chair Height Standing Ability and Falls

Of the 143 participants who were able to complete at least one stage of the MCHS, 60 participants (42.0%) reported having 1 or more falls in the previous year. For those who experienced such events, 35 (58.3%) fell once, 12 (20.0%) fell twice, and 12 (20.0%) fell 3 or more times in the 12 months prior to the study. Additionally, 17 participants (28.3%) suffered skeletal fractures, and 6 participants (10%) suffered hip fractures due to falling.

Table 5 provides the mean  $\pm$  SD values for the MCHS, and Adjusted MCHS scores of those participants classified as fallers as compared to those participants classified as non-fallers. MCHS scores discriminated between fallers and non-fallers ( $p < .001$ ): non-fallers were able to stand from lower sitting height levels than fallers. Also shown in Table 5, MCHS scores and Adjusted MCHS scores were equally effective in discriminating between fallers and non-fallers.

Fallers and non-fallers did not differ significantly with respect to age ( $p = .107$ ), BMI ( $p = .465$ ) or weight ( $p = .171$ ) (refer to Table 5).

**Table 5 MCHS, STS, Age, and BMI means for the Faller and Non-faller Groups**

Variables	Fallers (n=60)	Non-fallers (n=83)	p
MCHS (cm)*	37.7 $\pm$ 8.7	30.3 $\pm$ 10.1	.000
Adjusted MCHS (cm) * †	37.4 $\pm$ 8.8	30.5 $\pm$ 10.5	.000
STS (s) *	17.7 $\pm$ 9.1 <sup>^</sup>	12.9 $\pm$ 4.5	.000
Age (yrs)	84.1 $\pm$ 7.3	82.5 $\pm$ 7.4	.107
BMI	26.0 $\pm$ 5.7	26.1 $\pm$ 4.7	.465
Weight (kg)	68.6 $\pm$ 17.1	71.2 $\pm$ 15.1	.171
IADL	6.4 $\pm$ 2.0	6.7 $\pm$ 1.7	.221
MMSE	28.4 $\pm$ 1.8	28.9 $\pm$ 1.4	.073

Note: This table only includes data for the 143 participants who were able to complete at least one stage of the MCHS test

Values are Mean  $\pm$  SD

† MCHS score (cm)  $\times$  mean shank length (cm)  $\div$  shank length (cm)

\* Significant between-group difference at  $p < .001$

<sup>^</sup> n=59

#### **4.4 Minimal Chair Height Standing Ability and Sit-to-Stand (functional strength)**

The mean MCHS score for fallers was 37.7cm (95% CI: 35.5-40.0cm) and 30.3cm (95% CI: 28.1-32.5cm) for non-fallers. The mean STS score for fallers was 17.7s (95% CI: 15.3-20.0s) and 12.9s (95% CI: 12.0-14.0s) for non-fallers.

MCHS performance was found to be significantly associated to STS performance ( $r = .534$ ,  $p < .001$ ). As shown in Table 5, both tests were able to discriminate between fallers and non-fallers ( $p < .001$ ).

#### **4.5 Inability to Perform the MCHS Test**

Of the total 167 participants included in this analysis, 25 individuals were not capable of successfully performing any part of the MCHS; the same 25 individuals were not able to successfully perform the STS test. These individuals were unable to stand from a standard height (47cm) chair without using their arms for assistance. Additionally, one individual who successfully completed the first stage of the MCHS (47cm), was unsuccessful in completing the STS due to fatigue caused by the metabolic demands of the test.

##### **4.5.1 Performance on the MCHS Test, Age, BMI and IADL**

In order to further examine the factors associated with MCHS ability, participants were divided into 3 groups based on MCHS performance. The group labeled "Poor Performance" included the 25 participants who were not able to stand from a chair of standard height (>47cm). The Group labeled "Moderate Performance" was comprised of the 76 participants who were able to stand from the MCHS chair height set at between 32 and 47cm high. The Group labeled

“Strong Performance” consisted of the 67 participants who were able to stand from a chair height of 32cm or lower. Differences between these three groups are detailed in Table 6. A between-subjects ANOVA showed no significant differences in BMI between the 3 groups ( $F_{2,165}=0.63$ ,  $p= .536$ ).

When examining age differences, a significant between-group difference was found ( $F_{2,165}=14.29$ ,  $p< 0.001$ ). Post-Hoc analyses indicated that participants in the “Poor Performance” ( $85.8 \pm 7.4$  yrs) and “Moderate Performance” groups ( $85.9 \pm 6.1$  y) were significantly older than participants in the “Strong Performance” group ( $80.0 \pm 7.4$  y) at  $p < 0.01$ .

In regards to IADL scores, a significant between-group difference was found ( $F_{2,165}=16.27$ ,  $p \leq 0.001$ ). Further post-hoc comparisons showed that individuals in the “Poor Performance” group scored significantly lower ( $4.7 \pm 2.0$ ) than participants in the “Moderate Performance” ( $6.1 \pm 2.1$ ) and “Strong Performance” groups ( $7.1 \pm 1.4$ ) at  $p < 0.01$ . Additionally, participants in the “Moderate Performance” group scored significantly lower ( $p = .002$ ) than participants in the “Strong Performance” group.

**Table 6 Age, BMI, Mobility and IADL Limitations, Participation in Physical Activity, and Prevalence of Medical Conditions for Participants in the Poor Performance, Moderate Performance and Strong Performance Groups**

<b>Variables</b>	<b>Poor Performance (25)</b>	<b>Moderate Performance (76)</b>	<b>Strong Performance (67)</b>
Age (yrs) (mean $\pm$ SD)	85.8 $\pm$ 7.4	85.9 $\pm$ 6.1	80.0 $\pm$ 7.4
BMI (mean $\pm$ SD)	26.6 $\pm$ 7.0	25.6 $\pm$ 5.8	26.5 $\pm$ 4.2
<b>Mobility and IADL</b>			
IADL (mean $\pm$ SD)	4.7 $\pm$ 2.0	6.1 $\pm$ 2.1	7.1 $\pm$ 1.4
Use of Walking aid	21 (84)	38 (50)	6 (9)
<b>Falling History</b>			
Falls	22 (88)	44 (58)	16 (24)
Multiple falls ( $\geq$ 2 falls in past year)	9 (36)	20 (26)	4 (6)
Skeletal Fracture from falling	9 (36)	14 (18)	3 (4)
<b>Physical Activity</b>			
Walks >15min/day	9 (36)	39 (51)	47 (70)
Vigorous PA >1hr/week	1 (4)	3 (4)	14 (21)
Lower Body RT > 2 days/week	1 (4)	16 (21)	31 (46)
<b>Medical Conditions</b>			
Stroke	5 (20)	6 (8)	3 (4)
Cardiac Disease	9 (36)	18 (24)	16 (24)
>4 medical conditions	15 (60)	16 (21)	7 (10)
Lower Limb Arthritis	15 (60)	36 (47)	22 (33)
Diabetes	3 (12)	9 (12)	6 (9)
Hypertension	12 (48)	36 (47)	27 (40)
Knee Replacement	2 (8)	6 (8)	4 (6)
Hip Replacement	6 (24)	15 (20)	4 (6)
Hip Fractures	7 (28)	10 (13)	1 (1)
Osteoporosis	9 (36)	10 (13)	8 (12)
Cancer	8 (32)	22 (29)	12 (18)
Parkinson's disease	1 (4)	2 (3)	2 (3)

Note: Values are n(%)

Abbreviations: BMI, body mass index; IADL, instrumental activities of daily living; MMSE, mini-mental state examination; PA, physical activity; RT, resistance training

#### **4.5.2 Performance on the MCHS Test and Falling History**

The proportion of participants who reported falling in the 12 months prior to the study was greatest in the “Poor Performance” group (88%) and lowest in the “Strong Performance” (24%) group (Table 6).

A similar trend was seen when evaluating the severity of the falls suffered. The percentage of falls resulting in skeletal fractures (including hip fractures) was greatest for the “Poor Performance” group (36%) and lowest for the “Strong Performance” group (4%) (Table 6).

#### **4.5.3 Performance on the MCHS Test, Mobility and Physical Activity Levels**

Of the 25 participants who were unable to perform the MCHS, 84% of them were dependent on walking aids (walker/cane) for locomotion and everyday functioning. The proportion of participants needing aid to walk was greatest for the “Poor Performance” group (84%) and lowest for the “Strong Performance” group (9%) (Table 6).

When evaluating physical activity data, subjects in the poorest performing group, reported the lowest levels of walking, resistance training participation and engagement in vigorous PA. In contrast, subjects who attained the best MCHS performance reported the highest levels of involvement in physical exercise (Table 6).

#### **4.5.4 Performance on the MCHS Test and Medical Conditions**

As shown in Table 6, the proportion of subjects who reported suffering from 4 or more medical conditions was highest in the “Poor Performance” group and lowest in the “Strong Performance” group. The proportion of participants with

cardiac disease, diabetes, hypertension, knee replacements and Parkinson's disease was similar between the three Groups.

The incidence of osteoporosis was highest (36%) in the "Poor Performance" group, compared to the "Moderate Performance" and "Strong Performance" groups (13 and 12% respectively) (Table 6).

#### **4.6 MCHS vs. STS for Participants with Medical Conditions**

##### **4.6.1 Cardiac Disease and/or Stroke**

Participants who reported having a history of stroke or cardiac disease were combined together to determine whether there was a difference in performance between the STS and MCHS for this sub-sample of the population. A total of 48 participants (23% "Poor Performance" group, 42% "Moderate Performance" group, 35% "Strong Performance" group) reported suffering from cardiac disease and/or stroke; 34 individuals with history of cardiac disease, 6 individuals with history of stroke, and 8 individuals with a history of cardiac disease and stroke.

Those individuals who were able to complete the two tests were divided into faller and non-faller groups. Within this "cardiac disease" sub-sample, the MCHS discriminated between fallers and non-fallers ( $p=.008$ ), but the STS did not ( $p=.147$ ) (Table 7).

**Table 7. MCHS and STS for Faller and Non-faller Groups of Participants with History of Cardiac Disease and/or Stroke**

Measures	Fallers (n=14)	Non-fallers (n=23)	p	Not Able to Perform Tests (n)
MCHS (cm)*	38.3 ± 8.4	30.0 ± 11.4	.008	11
STS (s)	18.6 ± 12.4	14.7 ± 5.9	.147	11

Note: Values are Mean ± SD

\* Significant between-group difference at  $p \leq .01$

#### 4.6.2 Knee Replacements

A total of 11 participants reported having knee replacements, with all but one of these individuals able to perform both MCHS and the STS. Those individuals who were able to complete the two tests were divided into faller and non-faller groups

Within this sub-sample of the study population, the MCHS discriminated between faller and non-faller groups ( $p=.044$ ), but the STS did not ( $p=.076$ ).

**Table 8. MCHS and STS for Faller and Non-faller Groups of Participants Who Have Had Knee Replacement Surgery**

Measures	Fallers (n=4)	Non-fallers (n=6)	P	Not Able to Perform Tests (n)
MCHS (cm)*	39.5 ± 2.9	30.0 ± 10.9	.044	1
STS (s)	17.6 ± 3.6	12.8 ± 5.8	.076	1

Values are Mean ± SD

\* Significant between-group difference at  $p \leq .05$

#### 4.6.3 Hip Replacements

A total of 25 participants reported having hip replacements: 6 (24%) individuals from this sub-sample were not capable of completing any part of the MCHS or STS.

Within this sub-sample of the population with hip replacements, neither the MCHS or STS was able to discriminate between faller and non-faller groups (Table 9)

**Table 9 MCHS and STS for the Fallers and Non-faller Groups of Participants Who Have Had Hip Replacement Surgery**

Measures	Fallers (n=7)	Non-fallers (n=12)	P	Not Able to Perform Tests (n)
MCHS (cm)	41.6 ± 5.0	37.7 ± 9.3	.170	6
STS (s)	19.0 ± 9.2	14.0 ± 6.8	.099	6

Values are Mean ± SD

#### 4.6.4 Lower Limb Arthritis

72 participants reported suffering from lower limb arthritis: 15 (21%) individuals from this sub-sample were not capable of completing any part of the MCHS or STS. One participant was capable of performing the first stage of the MCHS (47cm), but not the subsequently attempted STS. The results of this analysis of participants with arthritic conditions indicated that the MCHS and STS were equally effective in discriminating between fallers and non-fallers ( $p < 0.01$ ).

#### 4.7 Test Order Effects

Statistical analysis was conducted by performing independent sample t-test between fallers and non-fallers of the two groups. No difference in performance was found between the two groups, showing that the order of assignment had no effect on performance (table 10).

**Table 10 MCHS and STS for the Faller and Non-faller Groups of Participants Who's Testing Order was Randomized.**

Measures	Fallers (n=17)		p	Non-fallers (n=18)		P
	MCHS first (n=5)	STS first (n=12)		MCHS first (n=9)	STS first (n=9)	
MCHS (cm)	41.0 ± 4.9	40.3 ± 7.1	.418	33.4 ± 11.6	25.2 ± 11.7	.077
STS (s)	18.3 ± 6.3	21.5 ± 16.4	.330	14.5 ± 5.0	14.0 ± 5.0	.427

Values are Mean ± SD

## **Chapter 5: Discussion**

Falls are a major public health issue, for which the evidence strongly suggests that fall-related injuries can be prevented through effective identification of those individuals at high-risk (Gates et al., 2008). The present study is the first to assess the effectiveness of the MCHS test in a population of older adults living in Canada.

MCHS performance was able to significantly discriminate between a population of “fallers” and a population of “non-fallers”. The findings of this study demonstrate the effectiveness of the MCHS test as fall-risk screening tool for this population as compared to other commonly used methods of measuring risk of falling.

### **5.1 Population Characteristics**

#### **5.1.1 Age**

Numerous studies have been conducted in the area of fall-risk assessment. Similar to the present study, the majority of these have inclusion criteria of “older than 65 years” (Bongue et al., 2011; Muir et al., 2008; Kwan et al., 2011; Lin et al., 2004; Scott et al., 2007; Melzer et al., 2004; Stel et al., 2003; Shumway-Cook, Brauer, & Woollacott, 2000; Arnold & Faulkner, 2007; Kario et al., 2001; Lundin-Olsson et al., 2000; Murphy et al., 2003).

The age of participants in the present study is similar to that reported by Faber et al. (2006). However, participants in this study appear to be older than those who took part in the majority of fall-risk assessment studies (Cwikel et al., 1998; Muir et al., 2008; Kwan et al., 2011; Lin et al., 2004; Scott et al., 2007;

Melzer et al., 2004; Stel et al., 2003; Shumway-Cook et al., 2000; Arnold & Faulkner, 2007; Kario et al., 2001). In a study conducted by Bongue et al.(2011) the mean age of subjects was  $70.7 \pm 4.6$  years. The majority of participants were defined as “young-old” since 48.1% of them were between the ages of 65 and 69 years; only 4.6% of participants were aged 80 years and older. In comparison, 73.8% of participants in the present study were 80 years or older.

The population included in the present study is slightly older than most studies that evaluated fall-risk. This could be interpreted as meaning that the present study includes a higher percentage of participants at “high-risk” of falling (Melton, 1996). This can be attributed to the fact that 79.8% of participants were recruited from independent and assisted-living facilities, which are populations that tend to be older than the general older population. Studying a population of participants already at “high-risk” of falling (based on age), strengthens the results of this study which show the effectiveness of the MCHS test as a screening tool for this population.

Out of the 168 participants, only one individual refused to attempt the MCHS test due to reported “fear of falling”. In comparison, Lin et.al. (2004) conducted a study of 1,200 older adults to assess the responsiveness of four commonly used fall-risk assessment tools: the Timed Up-and-Go (TUG), One-leg stand (OLS), Tinetti Balance (TB), and Functional Reach (FR). They found the refusal rate of all four tests to be higher than the refusal rate reported in this study. The low refusal rate found in the present study, demonstrates the fact that older people will accept the MCHS test without fear of falling.

### **5.1.2 Gender**

The percentage of women who took part in the present study was 71.4%, which is a higher distribution than that of the general Canadian older population (56%) (Urquijo & Milan, 2012). This could be due to the fact that residential facilities have a higher percentage of female residents than the percentage described for older adults living in the community (Lord et al., 2001). For example, Faber et. al. (2006) and Lundin-Olsson et. al. (2000) reported similar gender distributions in their sample population as the ones reported in the present study. Both investigations evaluated the use of fall-risk assessment tools in older people living in residential-care and long-term care facilities.

In the present study, men and women did not differ significantly in their ability to perform the MCHS. These findings demonstrate the generalizability of the test; when used as a fall-risk screening tool, the same MCHS guidelines could be used for both genders.

### **5.1.3 Body Weight**

The mean body weight of participants in the present study was  $70.7 \pm 16.8$  kgs which is consistent to that reported by Melzer et al. (2004), Duncan et al. (1990) and Liu-Ambrose et al. (2004).

Similarly to previous research (Melzer et al., 2004; Lajoie & Gallagher, 2004), this study has found no statistical difference in the weight of fallers ( $68.6 \pm 17.1$  kgs) versus the weight of non-fallers ( $71.2 \pm 15.1$  kgs). Such a finding is inconsistent with some previous investigations that have found that fallers have lower body weights than non-fallers (Stel et al., 2003; de Rekeneire et al., 2003).

#### 5.1.4 Fall History

In this study, a fall was defined as ‘when you suddenly find yourself on the ground, without intending to get there, after you were in either a lying, sitting or standing position’ (Cwikel et al., 1998, p.163), and it was recorded retrospectively over a one year period. It is important to note, that other researchers have used the definition of a fall as ‘unintentionally coming to the ground or some lower level and other than as a consequence of sustaining a violent blow, loss of consciousness, sudden onset of paralysis as in stroke or epileptic seizure’ (Lord et al., 2001, p. 3) and have recorded falls either retrospectively or prospectively over a one year period (Lord et al., 2001).

Out of the total study population of 168 participants, 81 participants (48.2%) reported having one or more falls in the 12 months prior to the study. These findings are consistent with those found in a prospective study conducted by Muir et al. (2008) assessing the BBS as a fall-risk screening tool in a population of 210 Canadian older adults. Muir et. al. (2008) reported 42.8% of their subjects having experienced one or more falls in a 12 month period.

Participants in the present study reported a higher percentage of “serious falls” than participants from other investigations (Lord & Menz, 2003; Bongue et al., 2011). Specifically, 28.3% of subjects in the current study suffered skeletal fractures, and 10% suffered hip fractures due to falling. This could be attributed to the relatively older population that took part in the study, and to the high percentage of participants that were recruited from long-term care facilities.

An epidemiology study (Rubenstein, 2006) evaluating falls in North American older adults, concluded that the rates of falls and their associated complications rise steadily with age and are almost double for individuals aged >75 years compared to individuals aged >65. Additionally, Rubenstein (2006) found that falls among individuals living in care facilities resulted in more serious complications than falls for older individuals living in the community. Specifically, 10–25% of falls among individuals in care facilities resulted in skeletal fractures; these rates are similar to the ones found for individuals in the present study.

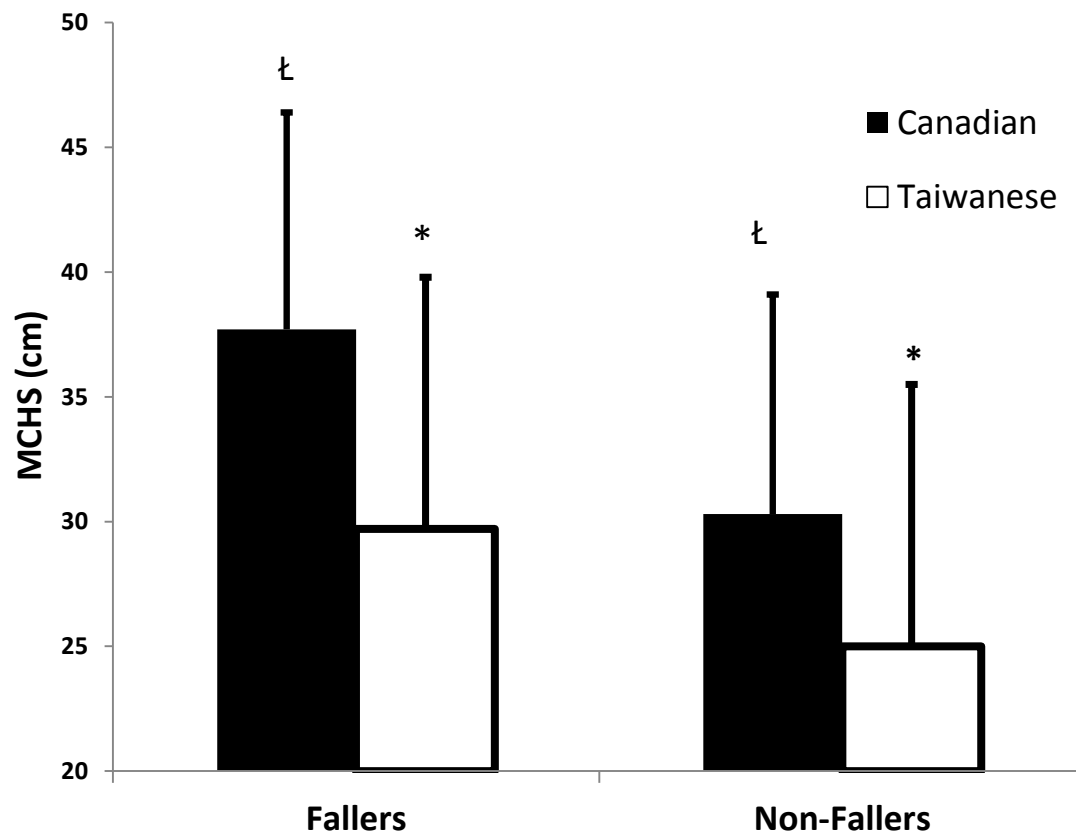
### **5.1.5 Cultural Influences on Lifestyle**

This is the first study to evaluate the use of the MCHS test as a fall-risk screening instrument in a population of Canadian older adults. To our knowledge, Kwan et al. (2011) were the first researchers to assess the effectiveness of the test in a population of Taiwanese older adults.

Several differences exist between Western and Eastern lifestyles that are worth mentioning to further understand the significance of our results. It has been shown that fall rates in Chinese older people are lower than those reported in Caucasian older people (Chu, Chi, Chiu, 2005). This is consistent with findings from the present study, in which 48.2% participants experienced falls in the 12 months previous to the study, compared to 28.9% of fallers from the study conducted in Taiwan (Kwan et al., 2011).

This higher incident of falls described in Western countries may reflect the cultural differences in squatting practices (Kwan et al., 2011). Overall, participants in the current study reported physical activity levels similar to those of the general

Canadian population (Kaplan et al., 2001). When looking into different types of physical activity, individuals in the present study reported similar levels of walking as those reported in Taiwanese older individuals (Kwan et al., 2011). However, participants from this study reported lower levels of lower body resistance training (i.e. squatting) as compared to those reported by Kwan et al. (2011).



**Figure 3. Differences in MCHS scores of Canadian versus Taiwanese participants for individuals classified as fallers and non-fallers**

Values are Mean  $\pm$  SD

\* Significant difference ( $p < 0.001$ )

† Significant difference ( $p < 0.001$ )

MCHS scores of Taiwanese population retrieved from (Kwan et al., 2011)

Squatting is a fundamental human movement pattern that aids in the maintenance of lower limb strength, coordination, and balance. Older people living in Taiwan rely on the practice of squatting for numerous activities such as, toileting, gardening, and playing with grandchildren (Kwan et al., 2011). It is likely that this is the reason why, on average, Taiwanese subjects performed better in the MCHS test than Canadian older adults who took part in this present study.

The results of the current study add to the literature to demonstrate that MCHS performance is able to discriminate between fallers and non-fallers in both the Taiwanese and Canadian populations. As shown in Figure 3, it is evident, however, that Taiwanese participants were able to stand from lower chairs than participants from this study. This finding has important implications since it shows that the incorporation of squatting in exercise routines for older adults in North America, may lead to a decreased risk of falls.

## **5.2 MCHS Test as a Fall Risk Screening Instrument**

The MCHS test is a recently developed functional mobility assessment, similar to deep squatting, which serves as a measure of functional strength, coordination and balance (Kwan et al., 2011). Findings from this study support the results from previous investigations that demonstrate its ability to identify individuals at a high risk of falling. The MCHS test may have scope for application in clinical settings, as a fall-risk screening instrument, due to its feasibility for use with the elderly, simplicity and quick administration time.

### 5.2.1 Feasibility for Use with the Elderly

In order for a physical performance test to be appropriate for older people to undertake, it must be non-invasive, short in duration, not require excessive effort and not cause pain or discomfort (Lord & Menz, 2003). Nonetheless, the test must be challenging enough to discriminate between individuals with different levels of strength, balance and coordination.

For the study population as a whole, both MCHS and STS scores were effective in discriminating between fallers and non-fallers. Both tests reported very narrow 95% confidence intervals, demonstrating their ability to estimate tight ranges for the general older population. Additionally, MCHS and STS scores were found to be moderately, yet significantly, correlated ( $r = .534$ ,  $p \leq .001$ ). However, findings from the current study suggest the MCHS test is a more appropriate test for older adults since it was effective without being physically strenuous.

The MCHS test is acceptable for use with the elderly since it “functionally” measures strength in a short bout of time. Functional strength is defined as the capability of a muscle to generate enough force and power to perform an activity (Perry et al., 2007). MCHS ability is dependent on the amount of force an individual can generate over a period of 1-3 seconds in order to stand up from a chair.

In contrary, the STS test is metabolically demanding. In our study, fallers took an average of  $17.7 \pm 9.1$  (mean  $\pm$  SD) seconds and nonfallers took an average of  $12.9 \pm 4.5$  (mean  $\pm$  SD) seconds to complete the STS test. It can be assumed that the lower physical demand of the MCHS test make it an appropriate test for use

with older adults who have medical conditions for which they must avoid excessive physical strain (e.g. cardiac disease, stroke).

A unique key finding of the present study is that when evaluating the 48 individuals with a history of cardiac disease and/or stroke, only MCHS performance was able to significantly discriminate between fallers and non-fallers, as compared to the STS which did not discriminate between fallers and non-fallers.

Similar findings were obtained for the sub-sample of individuals who had undergone knee replacement surgery. Where the MCHS was able to discriminate between fallers and nonfallers but the STS did not. Furthermore, a number of participants with knee and/or hip replacements reported discomfort while performing the STS test. This can be attributed to the fact that during the MCHS test, participants were able to achieve proper squatting technique without having to worry about the speed of their movement, which is an integral part of the STS. Previous work by Schoenfeld (2010) and Kritz (2009) provides evidence that, when performed properly, squatting places very minimal strain on lower-limb joints.

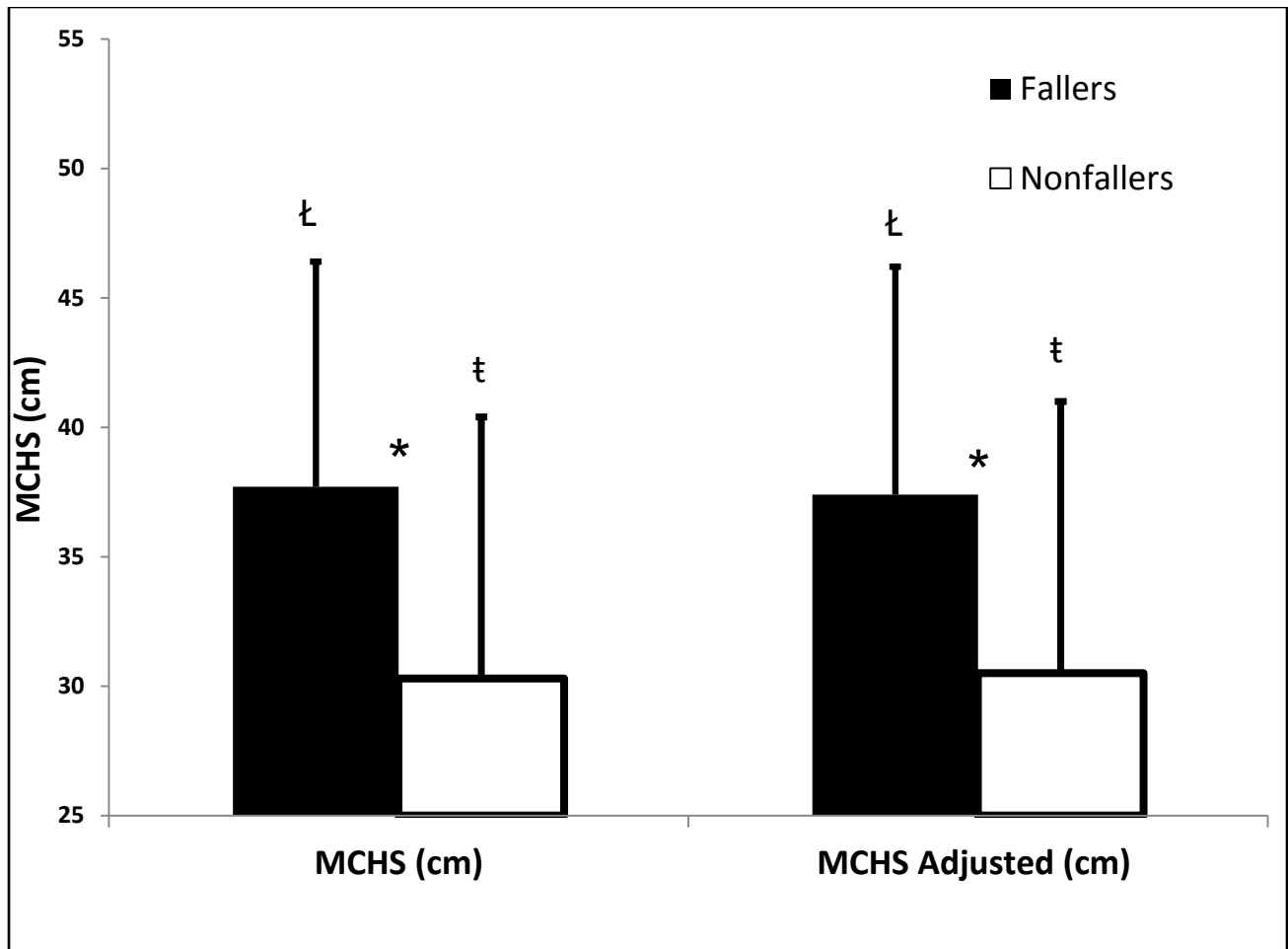
In conclusion, the MCHS test is an appropriate fall-risk screening instrument for elderly patients with joint disease and for participants who have suffered from cardiac disease or stroke. MCHS performance was able to discriminate between fallers and non-fallers without being physically strenuous for the participants. These characteristics of the MCHS are especially important for working with populations of frailer older Canadian adults.

### 5.2.2 Simplicity and Practicality

The MCHS differs from other fall-risk assessment tools primarily by its simplicity. Like most assessment tools, it must be administered in a standardized way. Learning the testing procedure requires minimal time-investment from health care practitioners. Additionally, the only equipment necessary to conduct the test is a chair of standard height. The simplicity of the MCHS test allows for it to be conducted in a variety of different settings, making it accessible to a vast majority of older adults in the community.

An important finding of the present study is that MCHS performance was able to discriminate between “fallers” and “nonfallers” regardless of gender, age, weight, and BMI. This shows the practicality of the test in that it can be conducted in multiple settings (e.g. Medical office, hospitals, recreation centres, long-term care facilities) where it is common to find patients/residents of a variety of populations and physical characteristics.

The original MCHS test methodology, includes the measurement and correction for “Shank Length”. Findings from this study showed that “MCHS scores” were equally as effective as “Adjusted MCHS scores” in discriminating between fallers and non-fallers (Figure 4). This indicates that it is unnecessary to measure “Shank Length” to discriminate between fallers and non-fallers. For the current study, the physical performance aspect of the test (including familiarization and resting times), took approximately 5 minutes to be completed.



**Figure 4. MCHS scores and Adjusted MCHS scores for a population of fallers and a population of non-fallers**

\* Significant between-group difference at  $p \leq .001$

‡ Non-significant between-group difference at  $p = .821$

‡ Non-significant between-group difference at  $p = .387$

Values are Mean  $\pm$  SD

$MCHS\ Adjusted(cm) = \text{Individual's MCHS score (cm)} \times \text{mean shank length (cm)} \div \text{Individual's shank length (cm)}$

The simplicity and short-administration time required to conduct the MCHS encouraged a high participation rate among our subjects. The refusal rate found in this study was 0.59%. This low refusal rate demonstrates the fact that older adults will accept the MCHS test without fear of falling.

### **5.2.3 Guidelines for Fall-Risk Assessment**

In order for the MCHS test to be included as part of a routine clinical assessment of fall-risk, specific guidelines should be established. Below are the suggested cutoff values for risk assessment that are recommended, based on findings from the present study:

- >47cm = Very High Risk of falling
- ≥32cm= High Risk of falling
- <32cm= Low Risk of falling

#### **5.2.3.1 Very High Risk of falling**

Of the total sample population, 25 individuals were not capable of successfully performing any part of the MCHS; these individuals were unable to stand from a standard height (47cm) chair. Out of these 25 individuals, 22 reported falling in the previous year and an additional 2 reported falling in the previous 18 months. Overall, the 96% of participants from this group who reported falling in the previous 18 months, is three-times that reported for the general North American older population (Liu-Ambrose et al., 2004; Tinetti, Speechley, & Ginter, 1988). Additionally, participants in this group reported an incidence of fall-related injuries, including hip fractures, which is almost triple of that reported for the general North American older population (Rubenstein, 2006).

The high incidence of falls reported for this group of participants could perhaps be explained by their lack of lower body strength, and/or balance which are necessary to perform functional activities (i.e. standing up from a chair, bed, etc.). Defining the physiological components that increase individuals' risk of

falling, and matching them with appropriate exercise programs will decrease their risk of falling, improve their quality of life, and reduce cost to the health care system.

Findings from this study demonstrate that those individuals who lack the ability to stand up from a 47cm chair, are at a very high risk of falling and at a very high risk of suffering fall-related fractures. Individuals who are unable to stand from a 47cm chair should be directed towards basic fall-prevention programs that focus primarily on developing lower limb strength and balance.

#### **5.2.3.2. High Risk of Falling**

The majority of “fallers” were able to complete the first 4 stages of the MCHS test (47cm, 42cm, 37cm, and 32cm).

Participants in this group seem to have low levels of functional strength and/or balance which led to a high incidence of falls. However, most of these falls did not result in serious injuries. Due to these reasons, individuals who are unable to stand from chairs 32cm or lower should be considered at “high-risk of falling” and directed towards fall-prevention programs.

#### **5.2.3.3 Low Risk of Falling**

The majority of “non-fallers” were able to complete the final 3 stages of the test (27cm, 22cm, and 15cm). The incidence and severity of falls for those participants who were able to stand up from chairs lower than 32cm was much lower than that reported for the general North American older population (Liu-Ambrose et al., 2004; Tinetti, Speechley, & Ginter, 1988). These individuals

showed the greatest levels of functional strength and balance and thus should be considered at a “low-risk of falling”.

### **5.3 Implications for Physical Activity Programs**

Numerous investigations have demonstrated that high levels of physical activity are associated with decreases in fall risk in the elderly (Heesch, Byles, & Brown, 2008; Sherrington et al., 2008). However, there is no evidence that shows falls can be prevented by simply encouraging older adults to be more active (Sherrington et al., 2008). Exercise comes in many forms, and the specifics of which activities are optimal for fall-reduction have not been fully identified (Liu-Ambrose et al., 2004). The purpose of the following section is to evaluate the physical activity information obtained from this study, and provide some insight into the possible mechanisms by which exercise reduces fall-risk in older adults.

#### **5.3.1 Walking**

Several trends can be seen from the physical activity data obtained from this study (see Table 6). First, it seems that a better performance in the MCHS test was associated with higher levels of walking. The proportion of participants who reported walking (for at least 15 minutes each day) was lowest for those in the “Poor Performance” group and highest for those in the “Strong Performance” group. Interestingly, 36% of participants in the “Poor Performance” group reported going for planned walks; none of these participants experienced multiple falls ( $\geq 2$ ) in 12 months prior to the study. Of the remaining 64% participants who did not walk, 88% experienced falls in the previous year and 56% participants experienced multiple falls ( $\geq 2$ ).

Findings from the present study suggest that walking could be associated with a lower risk of falling in older adults. However, these findings should be considered with caution due to the cross-sectional nature of the research and the fact that all physical activity data was self-reported and recorded retrospectively.

Walking programs have been shown to provide older adults with numerous health benefits (Nelson et al., 2007). Nonetheless, evidence regarding the effects of walking on falls-prevention is inconclusive. A systematic review of 44 randomized controlled trials, determined that walking programs were ineffective in reducing fall risk in older adults (Sherrington et al., 2008). Findings showed that exercise programs which did not include walking, reduced fall rates more than exercise programs that involved walking. It was concluded that walking could be included in falls-prevention programs only if it acted complimentary to balance and strength-training programs (Sherrington et al., 2008).

### **5.3.2 Resistance-Training**

A similar trend as that observed for walking was observed for lower-body resistance training. In the present study, participants who achieved the best performances in the MCHS reported a higher incidence of involvement in resistance training programs. Additionally, the sub-group of participants with the lowest incidence of falls reported the highest level of involvement in resistance training programs. These findings suggest that fall-prevention programs that include exercises which increase lower-body strength (i.e. squats, lunges, leg press, etc.) would be effective in reducing fall risk in older adults.

In this study, information about physical activity involvement was obtained through a modification of the EPIC Physical Activity Questionnaire (Wareham et al., 2003). Interviewers were instructed to go through the questionnaire with each participant and ask detailed questions about the mode, frequency and duration of all activities reported. If participants reported taking part in a resistance training program, interviewers were instructed to ask about the specific exercises performed during an exercise session in order to assess their involvement in lower body resistance training.

Evidence from the literature is inconclusive regarding resistance training programs and its effects on fall risk. Liu-Ambrose et al. (2004) conducted a single-blind, randomized controlled trial to evaluate the effectiveness of a high-intensity (75-85% 1RM) resistance training program in reducing fall risk. Liu et al. found the resistance-training program to significantly reduce fall-risk in their participants. These findings contrast with other investigations (Chandler, Duncan, Kochersberger, & Studenski, 1998; Sherrington et al., 2008) which demonstrated that strength training was not as effective as balance training in reducing fall-risk.

The inconsistencies in the literature may be explained by a number of factors. Firstly, it may be explained by the differences in the intensity of the resistance-training programs that have been used across studies. It seems that in order to achieve reductions in fall-risk, exercises must be performed at intensities higher than 75% of 1RM (Liu-Ambrose et al., 2004). Another important factor, might be the inclusion of exercises that improve strength, balance and coordination altogether (Sherrington et al., 2008).

There is strong evidence that both impaired balance and poor lower-limb strength are associated with falls. This confirms the importance of addressing both risk factors when prescribing exercise programs for older adults at high-risk of falling.

### **5.3.3 Squatting**

Results from the present study demonstrate that older individuals who had difficulties performing a basic functional activity, such as rising from a chair, had higher incidences of falls than those individuals who were able to perform a full-depth squat. It can be concluded then, that older adults with poor MCHS ability are more likely suffer falls and fall-related injuries when undertaking activities of daily living; such as rising from a bed, sitting on a toilet, and picking up grocery bags.

Squatting is a fundamental human movement pattern that involves nearly every muscle in the body. Evidence demonstrates that squatting activities are excellent for building strength, flexibility, and balance (Kritz, 2009; Schoenfeld, 2010). Kwan et al. (2011) demonstrated that Taiwanese participants who reported squatting during everyday activities performed significantly better in the MCHS test and had fewer falls than those who did not. Additionally, Liu-Ambrose et al. (2004) showed that increases in squat-load were significantly associated with improvements in postural stability in community-dwelling Canadian older adults.

These findings may help explain how resistance training is related to improving strength and balance, thus reducing fall-risk. Fall-prevention programs should focus on addressing impairments in the functional control of the body. Furthermore, poor MCHS performance could be improved by directing individuals to

exercise regimes that focus` on strengthening and stabilizing muscle groups that control MCHS ability.

#### **5.4 Limitations**

There are several notable limitations of this research which include the retrospective identification of people with a history of falls, the cross-sectional nature of the study, self-reporting bias, and the lack of control over additional risk factors associated with falls. Falling history was recorded retrospectively and thus may not accurately represent the true falling incidence of the study population. Moreover, the poorer MCHS performance of fallers may have been caused, in fact by their history of falling.

Due to the cross-sectional nature of the study, it was not possible to calculate predictive validity of the MCHS test. A prospective study where participants would have been followed over a one year period (and the prevalence of falls collected over this 1 year period) would have been a true predictor of fall-risk, and it would have allowed for sensitivity and specificity calculations for the MCHS test to be conducted. Few studies have evaluated predictive validity of fall-risk assessment instruments; nonetheless this information is required to demonstrate its effectiveness.

In this study, falling history was self-reported. This might have caused an overestimation of the number of falls reported, due to social desirability bias. Self-reported bias might have also affected recall for other measures including physical activity data, medical history information, and IADL limitations.

Finally, this study aimed to assess fall risk by evaluating physiological impairments in older adults. It is important to note, however, that identifying individuals at a high risk of falling is a complex task. There are numerous risk factors not included in our investigation that have been shown to be predictors of falls (i.e. adverse effects of psychoactive medication, visual acuity, hearing loss, dementia, etc.) Controlling for these risk factors would be advisable for future studies evaluating fall-risk screening instruments.

## **5.5 Conclusions**

Falls and fall-related injuries are a major health issue in the elderly population. Apart from the direct physical injuries associated with falling, long-term psychological consequences include loss of independence, and fear of a recurrent fall. Numerous screening instruments for identifying older adults at high-risk of falling have been proposed, these instruments vary in complexity and practicality for use in clinical settings. The current study provides valuable information regarding the MCHS test, a recently developed fall-risk screening instrument.

Findings of the present study showed that MCHS performance was effective in discriminating between fallers and non-fallers in an older Canadian population. The MCHS test has proven to be feasible for use with older individuals due to its quick administration time, simplicity and low-refusal rate. As compared to the commonly used STS, the theoretical lower physical demand of the MCHS test make it an appropriate test for use with older adults who have medical conditions for which they must avoid excessive physical strain (e.g. cardiac disease, stroke).

The MCHS may have scope for clinical application as a fall-risk screening instrument, although additional research is needed to determine its specificity and sensitivity measures. Further prospective studies should be undertaken to determine its predictive validity, and to evaluate its effectiveness when compared to existing fall-risk assessment instruments.

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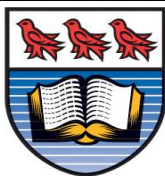
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## Appendix A1: Poster Advertisement



University  
of Victoria

### “Fall Prevention Study: Measuring Fall Risk”



#### **Participant Volunteers Required:**

Falls have devastating consequences for older adults in terms of morbidity, mortality, and loss of independence.

We are conducting a research project to evaluate the use of a Fall-Risk assessment tool in predicting falls in people over the age of 65.

**What is required?** 20-30mins of your time at a convenient location for you.

**What will happen?** You will be asked to stand up from a chair of different heights to assess lower limb strength, flexibility and balance.

If you are interested in participating in this study, **please contact Nadia Reider** (Master’s student, School of Exercise Science, Physical and Health Education, University of Victoria) [REDACTED]

## Appendix A2: Invitation to Participate



University  
of Victoria

### “Fall Prevention Study: Measuring Fall Risk”



## Invitation to Facilities

### Research Team:

Nadia Reider is a Master’s student in the school of Exercise Science, Physical & Health Education at the University of Victoria. Dr. Kathy Gaul is her academic supervisor and an associate professor at the University of Victoria with extensive experience working with participants in exercise science research.

### Our Research:

Falls have devastating consequences for older adults in terms of morbidity, mortality, and loss of independence. Falling is the leading cause of severe injury, such as hip fractures, in the elderly. Through this research, we hope to evaluate the use of a newly developed fall-risk screening test, the Minimal Chair Height Standing Ability test (MCHS), in identifying individuals at high risk of falling. The MCHS measures the lowest height chair from which a person can stand and provides information about personal physical strength, flexibility and balance.

### Your Possible Involvement:

We would like to set up a meeting with you to discuss the possibility of us conducting the research in a small room in your facility, We would be happy to meet at a convenient time for you to provide details of our planned investigation.

Please note that you will not be asked to recruit participants. We will be asking for your permission to contact individuals who are members of your facility and may be interested in participating in our study. We will also be asking for your

permission to conduct our research in a small private room in your facility in order to make the study more accessible for residents in your community.

**Importance of the research:**

Being able to identify individuals at risk of falling is the first step towards prevention. In Canada, the annual economic costs of hip fractures are 650 million and are expected to rise to 2.4 billion by the year 2041 because of the ageing population. Furthermore, the psychological implications of falls can be demoralizing.

Numerous fall-risk screening instruments are available, however, most have not been included as routine assessments by physicians or other health professionals. The lengthy administration time, need of cumbersome equipment, and inability to be applied within various settings are some of the reasons these tests have been underutilized in health-care. The MCHS is a newly developed, quick to administer, simple fall-screening instrument. The MCHS measures the lowest height chair from which a person can stand; the procedure for the MCHS was introduced at the Australian Physiotherapy Association Conference in May, 2002.

**Who Can Participate:**

Participants will be eligible to for this study only if they meet the following criteria:

- 65 years or older,
- Living in the Greater Victoria area
- Can effectively provide informed consent.
- Able to walk independently (with or without walking aids).

Those individuals interested in participating but who currently rely on a wheelchair or mechanical device to get around will not be included in this study.

Participation in this research is completely voluntary. Individuals may withdraw at any time without any consequences or any explanation. If participants choose to withdraw from the study, their data will be destroyed and not used in the study.

**How will the study be conducted:**

1. Once approval from your facility is granted, recruitment posters advertising the project will be displayed in your facility.
2. Following this, it will be up to the participants to contact the investigator, by means described in the poster (electronic mail or phone number), to indicate their interest in participating.
3. Organized testing sessions will be conducted in your facility at a time and date that is most convenient for you and the participants.
4. Testing sessions: After obtaining informed consent from potential participants and filling out a questionnaire with demographic information, individuals will be asked to stand from a sitting position from a chair for which seat height will be lowered for each consecutive attempt. Performance will assess lower limb strength, flexibility and balance. Participants will also be asked to perform the

traditionally used Sit-to-Stand test, in which they will be required to stand up and sit on a chair five times in a row.

**When will this take place and for how long**

It is anticipated that the study will be conducted in the Summer of 2012. We will work together with you to determine appropriate testing times.

Each test will take approximately 45-60 minutes per participant, thus we hope to have a dedicated space for a few consecutive hours on one or more occasion.

**What are the physical risks associated with participation**

It is possible that participants may feel fatigued due to the requirements of the tests. To minimize the likelihood of this happening, they will be given 1 to 2 minutes rest between attempts and 3-5 minutes rest between the MCHS and Sit-to-Stand tests. If at any point, an individual is having physical difficulty (such as increased shortness of breath), the test will be stopped immediately and medical attention will be pursued if necessary as determined by the investigator.

It is also possible, but unlikely, that an individual may fall down from the chair while performing the tests. In order to minimize the risk of this happening, the chair will be set up with padded mats around it, and the principal investigator will be positioned close to the participants throughout the entire testing procedure to be able to spot them if they lose their balance.

**If you would like more information on this study  
or are interested in participating in this study,  
please contact Nadia Reider at [REDACTED] or  
[REDACTED]**

This study is conducted with the approval of the Uvic Human Ethics Research Board

## Appendix A3: Participant Consent Form

### *Participant Consent Form*

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#### **Fall Prevention Study: Measuring Fall Risk**

You are invited to participate in a study entitled “Fall Prevention Study: Measuring Fall Risk” that is being conducted by Nadia Reider and Dr. Kathy Gaul. This research is being undertaken as part of a Master’s of Science degree thesis from the School of Exercise Science, Physical & Health Education at the University of Victoria. Dr. Kathy Gaul is the research supervisor and you may [REDACTED] you have any questions or concerns about this study.

Nadia Reider is Master’s student in the school of Exercise Science, Physical & Health Education at the University of Victoria and you may contact her if you have further qu [REDACTED]  
[REDACTED]

#### **Purpose and Objectives**

The aim of this study is to assess whether the use of a recently developed fall-risk screening test (Minimal Chair Height Standing Ability- MCHS) can help discriminate between a population of older adult fallers and a population of older adult non-fallers. A secondary objective is to determine if MCHS performance in an older Canadian population reflects functional strength, as measured by the Sit-to-Stand test.

#### **Importance of this Research**

If the findings demonstrate that MCHS performance can be used to screen for fall-risk in older adults, the test could have significant applications for use in clinical settings. As a simple and inexpensive procedure, it could benefit and improve the care of our elderly population, by predicting fall risk. Those identified as being at high risk for falls could be provided with appropriate strategies to reduce risk and directed towards fall-prevention programs.

#### **Participants Selection**

You are being asked to participate in this study because you are over 65 years old, are able to walk with or without walking aid, and you are a resident of the Greater Victoria area.

#### **What is involved in participating?**

If you volunteer to participate in this research, your participation will include: Completing a simple baseline questionnaire to record any major medical conditions, your recent participation in physical activities, and your Activities of Daily Living (IADL).

You will also be asked to complete the Mini Mental State Examination (MMSE) for a baseline measure of cognitive function.

We will then record your age, and measure your standing height and body weight using standardized measurement techniques.

You will be asked about your history of falls over the past 1 year.

The MCHS test will be conducted to determine the lowest height from which you can stand from a seated position.

Lastly, you will be asked to complete the Sit-to-Stand test in which the time it takes for you to stand from a sitting position on a standard height chair (43cm) will be measured.

### **Inconvenience**

Participation in this study is not expected to cause any inconvenience to you, except for the time required to participate (45-60 minutes).

### **Risks**

It is unlikely, but possible, that you may feel embarrassed or psychological discomfort about your performances in the MCHS and Sit-to-Stand tests if you think they might be limited or sub-optimal. To minimize the likelihood of this happening, only one person will be scheduled to complete the tests at a time so that only Nadia and/or Dr. Gaul know the results of your performance.

Further it is important to remember that it is your involvement that is most important to the success of the study. The results of the tests will help to direct better care for those who are at risk of falling. All performances will be equally valued.

It is also possible that you may feel stressed or fatigued due to the physical requirements of the tests. To minimize the likelihood of this happening, you will be given 1 to 2 minutes rest between attempts and 3-5 minutes rest between the two tests. If at any point, you find yourself having physical difficulty (such as increased shortness of breath), the test will be stopped immediately and medical attention will be pursued if necessary.

It is also important to mention that there are physical risks associated with the MCHS and Sit-to-Stand test; as you may fall down from the chair when performing the tests. To minimize these risks of falling, the chair will be set up with stretching mats around it, and the principal investigator will stay physically close to you throughout the entire testing procedure to be able to spot you if you lose balance.

### **Benefits**

The potential benefits of your participation in this research include benefits to you as a participant, to society and to the current state of knowledge. The information acquired from this investigation will help strengthen our understanding of how to effectively identify individuals at

a high risk of falling so they can be directed towards fall-prevention programs. Your own results may help to determine if you are at risk of experiencing a fall.

### **Compensation**

No compensation (i.e. gifts, honorariums, etc.) will be given to you for participating in this research. However, you will receive a report of the findings of this study as well as your own results.

### **Voluntary Participation**

Your participation in this research is completely voluntary. If you choose to participate, you may withdraw at any time without any consequences or any explanation. If you do withdraw from the study your data will be destroyed and not used in the study.

### **Researcher's Relationship with Participants**

The principle investigator (Nadia Reider) and the research supervisor (Dr. Gaul) and have no known relationship with potential participants. Nadia Reider will conduct all in person recruitment, and your performance will be treated according to the anonymity and confidentiality process outlined below.

### **Anonymity**

Participant names will not be used in the data collection/analysis (each participant will be represented by a number, coded randomly for which only the investigator and Supervisor will have access). Individual participant names will not appear in the final written report. Photographs will be captured in order to have a visual record of the testing procedures, and could be used in academic/research presentations. In such cases individual faces will not be shown. Also, each participant's contact/personal information will be stored securely in password protected electronic file during recruitment and after the study has been completed.

### **Confidentiality**

Your confidentiality and the confidentiality of the data will be protected by storing your coded data on a password protected computer, to which access is limited to the principle investigator and their supervisor.

### **Dissemination of Results**

It is anticipated that the results of this study will be shared with others in the form of a Master's thesis, academic presentations at scholarly meetings, and in recognized publications.

### **Disposal of Data**



## Appendix A4: Baseline Questionnaire

## Fall Prevention Study: Measuring Fall Risk Baseline Questionnaire

DATE FORM COMPLETED: \_\_\_\_ / \_\_\_\_ / \_\_\_\_ (yyyy/mm/dd)

PARTICIPANT'S ID: \_\_\_\_\_

### Section 1: DEMOGRAPHICS:

1a. Date of birth: \_\_\_\_\_ (yyyy/mm/dd)

1b. Gender (F = Female , M = male) : \_\_\_\_\_

### Section 2: MEDICAL CONDITIONS

**Have you suffered, or do you now suffer from any of the following:**

Hip Fracture	_____
Partial Hip Replacement	_____
Total Hip Replacement	_____
Lower Limb Arthritis	_____
Diabetes	_____
Hypertension	_____
Cardiac Disease	_____
Stroke	_____
Cancer	_____
Parkinson's disease	_____
Respiratory problems	_____
Others	_____

**If you answered YES to Others, please provide more information:**

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**Section 3: PHYSICAL ACTIVITY QUESTIONS** modified from the EPIC questionnaire (Wareham et al., 2003)

4a. **In a typical week** during the past 12 months, how many hours did you spend on each of the following activities? (Put "0" if none)

- Walking, including walking to/from/for work, shopping and leisure  
In summer \_\_\_\_\_ hours per week  
In winter \_\_\_\_\_ hours per week
- Cycling, including to/from/for work and during leisure time  
In summer \_\_\_\_\_ hours per week  
In winter \_\_\_\_\_ hours per week
- Other (i.e. swimming, dance class, yoga, resistance training...)  
In summer \_\_\_\_\_ hours per week  
In winter \_\_\_\_\_ hours per week

What activities: \_\_\_\_\_

4b. **In a typical week** during the past year did you participate in any of these activities vigorously enough to cause sweating or a noticeably higher heartbeat?

Yes\_\_\_ No\_\_\_ Don't know\_\_\_

**If Yes**, for how many hours per week in total did you participate in such vigorous physical activity? \_\_\_\_\_

## Appendix A5: Instrumental Activities of Daily Living

<b>Instrumental Activities of Daily Living</b> (Lawton & Brody, 1969)	
<p><b>A. Ability to use telephone</b></p> <ul style="list-style-type: none"> <li>- Operates telephone on own initiative: Looks up and dials numbers (1)</li> <li>- Dials a few well-known numbers (1)</li> <li>- Answers telephone but does not dial (1)</li> <li>- Does not use telephone at all (0)</li> </ul>	<p><b>E. Laundry</b></p> <ul style="list-style-type: none"> <li>- Does personal laundry completely (1)</li> <li>- Launders small items- rinses stocking, etc (1)</li> <li>- All laundry must be done by others (0)</li> </ul>
<p><b>B. Shopping</b></p> <ul style="list-style-type: none"> <li>- Takes care of all shopping needs independently (1)</li> <li>- Shops independently for small purchases (0)</li> <li>- Needs to be accompanied on any shopping trip (0)</li> <li>- Completely unable to shop (0)</li> </ul>	<p><b>F. Mode of Transportation</b></p> <ul style="list-style-type: none"> <li>- Travels independently on public transportation or drives own car (1)</li> <li>- Arranges own travel via taxi, but does not otherwise use public transportation (1)</li> <li>- Travels on public transportation when accompanied by others (1)</li> <li>- Travel limited to taxi or automobile with assistance of another (0)</li> <li>- Does not travel at all (0)</li> </ul>
<p><b>C. Food Preparation</b></p> <ul style="list-style-type: none"> <li>- Plans, prepares and serves adequate meals independently (1)</li> <li>- Prepares adequate meals if supplied with ingredients (0)</li> <li>- Heats, serves and prepares meals or prepares meals but does not maintain adequate diet (0)</li> <li>- Needs to have meals prepared and served (0)</li> </ul>	<p><b>G. Responsibility for own medications</b></p> <ul style="list-style-type: none"> <li>- Is responsible for taking medication in correct dosages at correct time (1)</li> <li>- Takes responsibility if medication is prepared in advance in separate dosage (0)</li> <li>- Is not capable of dispensing own medication (0)</li> </ul>
<p><b>D. Housekeeping</b></p> <ul style="list-style-type: none"> <li>- Maintains house alone or with occasional assistance (e.g. "heavy work domestic help")</li> <li>- Performs light daily tasks such as dish- washing, bed making</li> <li>- Performs light daily tasks but cannot maintain acceptable level of cleanliness.</li> <li>- Needs help with all home maintenance tasks</li> <li>- Does not participate in any housekeeping tasks</li> </ul>	<p><b>H. Ability to Handle Finances</b></p> <ul style="list-style-type: none"> <li>- Manages financial matters independently (budgets, writes checks, pays rent, bills goes to bank), collects and keeps track of income (1)</li> <li>- Manages day-to-day purchases, but needs help with banking, major purchases, etc (1)</li> <li>- Incapable if handling money (0)</li> </ul>

## Appendix A6: Mini Mental State Examination

### Fall Prevention Study: Measuring Fall Risk

#### The Mini-Mental State Examination (Folstein, 1983)

##### Orientation

- |                            |   |
|----------------------------|---|
| 1. What is the Year?       | 1 |
| Season?                    | 1 |
| Date?                      | 1 |
| Day?                       | 1 |
| Month?                     | 1 |
| 2. Where are we? Province? | 1 |
| Country?                   | 1 |
| Town or city?              | 1 |
| Building?                  | 1 |
| Floor?                     | 1 |

##### Registration

- |  |   |
|--|---|
| 3. Name three objects, taking one second to say each. Then ask the patient all three after you have said them. Give one point for each correct answer. Repeat the answers until the patient learns all three | 3 |
|--|---|

##### Attention and calculation

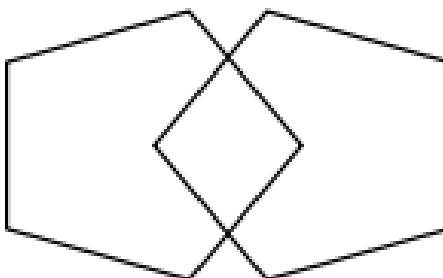
- |   |   |
|---|---|
| 4. Serial sevens (count backwards from 100 by sevens). Give one point for each correct answer. Stop after five answers. Alternatively: Spell WORLD backwards. | 5 |
|---|---|

##### Recall

- |  |   |
|--|---|
| 5. Ask for names of three objects learned in Question 3. Give one point for each correct answer. | 3 |
|--|---|

##### Language

- |  |   |
|--|---|
| 6. Point to a pencil and watch. Have the patient name them as you point.   | 2 |
| 7. Have the patient repeat "No ifs, ands, or buts."  | 1 |
| 8. Have the patient follow a three-stage command: "Take the paper in your right hand. Fold the paper in half. Put the paper on the floor."   | 3 |
| 9. Have the patient read and obey the following: "CLOSE YOUR EYES." (Write it in large letters)  | 1 |
| 10. Have the patient write a sentence of his or her own choice. (The sentence should contain a subject and an object and should make sense. Ignore spelling errors when scoring.)                | 1 |
| 11. Enlarge the design printed below to 3-5 cm per side and have the patient copy it. (Give one point if all sides and angles are preserved and if the intersecting sides form a quadrilateral.) | 1 |



## Appendix A7: Fall History Questionnaire

### Fall History Questionnaire

- Begin the questioning by using the phrase: “*We all fall from time to time...*”
- Proceed by defining a fall as “*when you suddenly find yourself on the ground, without intending to get there, after you were in either a lying, sitting or standing position*”
- Ask the following of the participant and record response (where?)

In the past year have you fallen, if yes how many times?

Y/N\_\_\_\_ # times\_\_\_\_

#### In the kitchen:

- Making food,
- reaching for cabinet,
- washing dishes,
- cleaning

#### In the Bathroom:

- Getting in/out shower,
- seating on toilet,
- reaching for medicine cabinet,
- cleaning

#### In the Bedroom:

Getting in/out of bed,  
getting dressed, c  
leaning/organizing

#### Stairs:

- Walking up/down,
- tripping over a step

#### Outdoors:

- slippery roads,
- uneven pathways,
- uneven steps,
- walking to store,
- stepping into a bus

Other:

- If Participant has replied YES to question 3, ask him/her to provide additional information regarding the consequences of the fall:
  - *Did any of the falls mentioned above result in a skeletal fracture?*  
YES\_\_\_\_\_ NO\_\_\_\_\_
  - If YES, *did it result in a hip fracture?*  
YES\_\_\_\_\_ NO\_\_\_\_\_
  - If YES, *did you receive hip fracture surgery?*  
Total Hip Replacement\_\_\_\_\_ Partial Hip Replacement\_\_\_\_\_

## Appendix A8: MCHS Testing Procedure

### Minimal Chair Height Standing Ability- Testing Procedure

- 1) Have the subject sitting on a backless 47cm high chair, positioned with the feet hip width apart, thighs parallel to floor, toes under knees and arms folded across chest.
- 2) Place a floor marker (tape) at the position of the feet. Explain the procedure using the following words: *"I want to find out the lowest height you can stand-up from without using your hands. The seat you are sitting on can be lowered and this will happen after each time you rise successfully from the seat. Fold your arms across your chest. When you stand-up keep your arms against your chest. Make sure that the backs of your legs do not push against the chair as you stand. Have three practice trials to make sure that you understand."* Manual guidance may be used in these trials
- 3) After the practice trials, give the participant positive feedback about their attempt if it is correct and advice about what to change if their attempt was incorrect. Only provide the subject with sufficient information to enable them to be successful. If the subject is unsuccessful after three attempts then cease the testing procedure.
- 4) Lower the chair gradually (by 5cm) following each successful rising from a sitting position. Continue to do this until the participant is unable to stand-up without assistance.
- 5) A successful attempt is one where the subject's arms remain folded against their chest and their legs do not push against the chair.
- 6) Allow 1 to 2 minutes rest between attempts at the lowest height if the subject is having physical difficulty such as increased shortness of breath
- 7) Record the seat height in centimeters.
- 8) MCHS score (seat height in cm) will be adjusted for leg shank length (lower leg) by multiplying MCHS by the sample average leg shank length for each gender and dividing it by the participant's shank length

$$\text{MCHS(female)} = \frac{\text{MCHS score} \times \text{Mean Shank length (females)}}{\text{Participant's Shank length}}$$

$$\text{MCHS(males)} = \frac{\text{MCHS score} \times \text{Mean Shank length (males)}}{\text{Participant's Shank length}}$$

## Appendix A9: STS Testing Procedure

### Sit-to-Stand Testing Procedure

- 1) Have the participant sitting on a 47cm high chair, positioned with the feet hip width apart, thighs parallel to floor; toes under knees and arms folded across their chest
- 2) Explain the procedure using the following words: "*I want to find out the length of time it takes for you to rise and sit back down on this chair five consecutive times without the use of your arms. Please keep your arms folded across your chest*".
- 3) Participants will be given one practice trial to familiarize themselves with the procedure.
- 4) After the practice trial, participants will be given a 3 minute rest.
- 5) Time taken to complete this task will be recorded to the nearest tenth of a second.
- 6) If participants are unable to complete the test, they will be given a score of 0 seconds.

## Appendix B: Data for Participants with Randomized Test Order

**Table 11 Data of Participants Randomized to Begin Testing with either the MCHS or STS**

ID	Gender	Age (Years)	BMI	Shank Length (cm)	MCHS (cm)	STS (s)	Random Assignment
1124	F	88	24.00	32.30	Not Able	Not Able	MCHS
1126	F	83	31.18	31.40	32	9.66	MCHS
1127	F	89	24.15	36.90	42	18.53	MCHS
1128	F	93	26.85	35.00	Not Able	Not Able	MCHS
1130	F	89	25.45	33.50	37	13.42	MCHS
1132	F	87	27.93	34.20	22	12.99	MCHS
1133	F	84	23.69	35.90	37	14.85	MCHS
1134	F	88	19.16	35.20	47	19.18	MCHS
1137	F	66	32.95	37.80	22	8.54	MCHS
1141	F	87	28.83	37.90	43	17.65	MCHS
1143	F	67	22.74	32.30	15	8.22	MCHS
1145	M	84	26.17	35.90	Not Able	Not Able	MCHS
1148	F	89	27.75	31.80	Not Able	Not Able	MCHS
1152	F	87	24.28	35.90	47	20.14	MCHS
1157	M	71	44.73	34.20	Not Able	Not Able	MCHS
1159	F	75	23.56	32.30	37	13.32	MCHS
1161	F	91	29.56	33.10	47	27.38	MCHS
1164	M	73	17.38	37.90	37	19.63	MCHS
1165	F	83	18.37	34.90	Not Able	Not Able	MCHS
1168	M	91	26.05	38.00	Not Able	Not Able	MCHS
1169	F	89	22.94	31.80	47	Not Able	MCHS
1125	F	86	32.89	33.20	47	56.98	STS
1129	F	92	28.51	34.60	Not Able	Not Able	STS
1131	F	85	25.29	30.30	37	15.98	STS
1135	F	85	21.83	35.80	37	10.73	STS
1136	M	81	24.40	33.20	22	14.74	STS
1138	F	69	25.23	32.90	15	8.79	STS
1139	M	70	32.87	36.80	22	10.07	STS
1140	F	69	30.96	33.90	22	14.68	STS
1142	F	76	25.18	35.00	37	13.61	STS
1144	F	71	24.48	34.20	15	12.41	STS
1146	M	80	28.65	33.10	27	10.81	STS
1149	M	90	31.84	38.90	15	9.07	STS
1150	F	97	22.22	32.10	Not Able	Not Able	STS
1151	M	79	27.48	38.10	27	12.60	STS
1153	F	91	20.93	33.10	42	20.51	STS
1154	F	85	22.28	35.00	Not Able	Not Able	STS
1155	F	92	21.17	34.20	42	12.34	STS
1156	M	86	31.99	39.60	Not Able	Not Able	STS
1158	F	75	40.54	34.10	47	23.44	STS
1160	F	68	26.67	33.20	32	20.66	STS
1162	F	93	19.79	37.10	47	48.03	STS
1163	M	83	26.97	37.50	Not Able	Not Able	STS
1166	F	71	20.66	33.20	15	8.14	STS
1167	F	97	18.38	31.10	47	30.88	STS

## Appendix C: Certificate of Approval- Human Research Ethics Board



**Human Research Ethics Board**  
 Office of Research Services  
 Administrative Services Building  
 PO Box 1700 STN CSC  
 Victoria British Columbia V8W 2Y2 Canada  
 Tel 250-472-4545, Fax 250-721-8960  
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### Certificate of Approval

PRINCIPAL INVESTIGATOR: <b>Nadia Reider</b>	ETHICS PROTOCOL NUMBER <b>12-112</b>
UVic STATUS: <b>Master's Student</b>	ORIGINAL APPROVAL DATE: <b>03-Apr-12</b>
UVic DEPARTMENT: <b>EPHE</b>	APPROVED ON: <b>03-Apr-12</b>
SUPERVISOR: <b>Dr. Kathy Gaul</b>	APPROVAL EXPIRY DATE: <b>02-Apr-13</b>
PROJECT TITLE: <b>Fall Prevention Study: Measuring Fall Risk</b>	
RESEARCH TEAM MEMBERS: <b>Patti-Jean Naylor, Member of Supervisory Committee (UVic)</b>	
DECLARED PROJECT FUNDING: <b>None</b>	
<b>CONDITIONS OF APPROVAL</b>	
<p>This Certificate of Approval is valid for the above term provided there is no change in the protocol.</p> <p><b>Modifications</b>          To make any changes to the approved research procedures in your study, please submit a "Request for Modification" form. You must receive ethics approval before proceeding with your modified protocol.</p> <p><b>Renewals</b>          Your ethics approval must be current for the period during which you are recruiting participants or collecting data. To renew your protocol, please submit a "Request for Renewal" form before the expiry date on your certificate. You will be sent an emailed reminder prompting you to renew your protocol about six weeks before your expiry date.</p> <p><b>Project Closures</b>          When you have completed all data collection activities and will have no further contact with participants, please notify the Human Research Ethics Board by submitting a "Notice of Project Completion" form.</p>	
<b>Certification</b>	
<p>This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Participants.</p> <div style="text-align: center;">  </div>	

12-112 Reider, Nadia

Certificate Issued On: 19-Dec-12