



uOttawa

L'Université canadienne  
Canada's university

**FACULTÉ DES ÉTUDES SUPÉRIEURES  
ET POSTDOCTORALES**



**FACULTY OF GRADUATE AND  
POSTDOCTORAL STUDIES**

**Bruce Contant**

AUTEUR DE LA THÈSE / AUTHOR OF THESIS

**M.Sc. (Human Kinetics)**

GRADE / DEGREE

**School of Human Kinetics**

FACULTÉ, ÉCOLE, DÉPARTEMENT / FACULTY, SCHOOL, DEPARTMENT

**The Effectiveness of Two Types of Balance-Boards to Improve Elderly Balance Over an 8-Week Training Intervention**

TITRE DE LA THÈSE / TITLE OF THESIS

**Yves Lajoie**

DIRECTEUR (DIRECTRICE) DE LA THÈSE / THESIS SUPERVISOR

CO-DIRECTEUR (CO-DIRECTRICE) DE LA THÈSE / THESIS CO-SUPERVISOR

EXAMINATEURS (EXAMINATRICES) DE LA THÈSE / THESIS EXAMINERS

**Heidi Sveistrup**

**Nicole Paquet**

**Gary W. Slater**

Le Doyen de la Faculté des études supérieures et postdoctorales / Dean of the Faculty of Graduate and Postdoctoral Studies

THE EFFECTIVENESS OF TWO TYPES OF BALANCE-BOARDS TO IMPROVE  
ELDERLY BALANCE OVER AN 8-WEEK TRAINING INTERVENTION.

By

BRUCE CONTANT

B.Sc., University of Ottawa, 2006

THESIS

Submitted to the Faculty of Graduate and Postdoctoral Studies in partial fulfillment  
of the requirements for the degree of  
Master of Science in Human Kinetics

University of Ottawa

©Bruce Contant, Ottawa, Canada, 2006



Library and  
Archives Canada

Bibliothèque et  
Archives Canada

Published Heritage  
Branch

Direction du  
Patrimoine de l'édition

395 Wellington Street  
Ottawa ON K1A 0N4  
Canada

395, rue Wellington  
Ottawa ON K1A 0N4  
Canada

*Your file* *Votre référence*  
*ISBN: 978-0-494-25757-9*  
*Our file* *Notre référence*  
*ISBN: 978-0-494-25757-9*

#### NOTICE:

The author has granted a non-exclusive license allowing Library and Archives Canada to reproduce, publish, archive, preserve, conserve, communicate to the public by telecommunication or on the Internet, loan, distribute and sell theses worldwide, for commercial or non-commercial purposes, in microform, paper, electronic and/or any other formats.

The author retains copyright ownership and moral rights in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

#### AVIS:

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque et Archives Canada de reproduire, publier, archiver, sauvegarder, conserver, transmettre au public par télécommunication ou par l'Internet, prêter, distribuer et vendre des thèses partout dans le monde, à des fins commerciales ou autres, sur support microforme, papier, électronique et/ou autres formats.

L'auteur conserve la propriété du droit d'auteur et des droits moraux qui protègent cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

---

In compliance with the Canadian Privacy Act some supporting forms may have been removed from this thesis.

Conformément à la loi canadienne sur la protection de la vie privée, quelques formulaires secondaires ont été enlevés de cette thèse.

While these forms may be included in the document page count, their removal does not represent any loss of content from the thesis.

Bien que ces formulaires aient inclus dans la pagination, il n'y aura aucun contenu manquant.

  
**Canada**

## Acknowledgements

I would first like to acknowledge my thesis supervisor Dr. Yves Lajoie for his support and dedication. Without our many enjoyable conversations about life, business and pleasure the task of completing this project would have been far more difficult. I would describe him as one of my strongest motivators in the past five years of my life and I am truly grateful for this.

Secondly, I would like to thank Patrick Bériault for the long hours he contributed to helping with data collection. Patrick always had positive attitude which is quiet enlightening during many consecutive hours of data collection.

Next, I would like to commend my girlfriend Vicky Dalrymple for her patience and encouragement over the past five years while waiting for me to finish my bachelor's degree and then my thesis. I won't forget her time spent at the computer helping with data analysis while mending a broken ankle.

Finally and most importantly I would like to thank The Good Companions Seniors' Centre for their extended hospitality, cooperation and appreciation for our research project. Specifically, I give thanks to Rosi Riopelle who supported me during her three years at The Good Companions. Of course, I also give many thanks to the seniors who participated in this study for making their contribution to the study a very positive one.

## Abstract

Background and aims: In the past, wobble-boards have been used to help rehabilitate patients with ankle injuries. Balance-boards have also been used to improve strength and balance in athletes. For the elderly population, wobble-boards have been shown to improve measures related to ankle proprioception but have never been used specifically to improve balance with the goal of fall prevention. The objective of this study is to compare the effectiveness of two types of balance-boards (wobble-board and rocker-board) to improve balance in elderly. The focus of the study is to measure any changes to functional balance, attentional demand while performing two tasks (dual task), postural sway during quiet standing and ankle joint dorsiflexion discrimination. Twenty-eight healthy elderly, 12 in the wobble-board group (age =  $72.9 \pm 4.62$ ), 11 in the rocker-board group (age =  $73.5 \pm 4.08$ ) participated in an 8-week intervention consisting of three sessions per week, 20 minutes each session. There were 5 elderly in the control group (age =  $76.2 \pm 5.49$ ). Baseline, post-training and retention measures of functional balance (CB&M), attentional demand, static balance (sway) and dorsiflexion discrimination were collected. Following the intervention, experimental groups had significantly improved their dynamic functional balance scores ( $p < 0.001$ ). Attentional demand and postural sway remained unchanged in all groups ( $p > 0.05$ ). The wobble-board group significantly improved ankle dorsiflexion discrimination ( $p < 0.001$ ); however, the control group also improved ( $p < 0.05$ ). In conclusion, balance-boards were effective for improving functional balance needed for daily activities. Lastly, more investigation is needed to assess the effect of a balance-board intervention on static balance and ankle dorsiflexion discrimination.

## Table of Contents

Acknowledgements .....	i
Abstract .....	ii
Table of Contents .....	iii
CHAPTER I .....	1
Introduction .....	1
Purpose Statement .....	1
Important Concepts .....	2
CHAPTER II .....	4
Review of Literature .....	4
Sensory Systems Related to Postural Stability and Changes with Aging .....	4
Risk Factors for Falling in the Elderly .....	8
Assessment of Postural Stability .....	11
Physical Training to Improve Risk Factors of Falling .....	12
Balance Specific Training .....	14
Wobble-board Training .....	18
Gaps in the Literature .....	20
Purpose and Hypothesis .....	20
CHAPTER III .....	23
THE EFFECTIVENESS OF TWO TYPES OF BALANCE-BOARDS TO IMPROVE ELDERLY BALANCE OVER AN 8-WEEK TRAINING INTERVENTION .....	24
Abstract .....	25
Introduction .....	26

Methods.....	30
Participants.....	30
Procedures.....	31
Training protocol .....	31
Measurements .....	32
Statistical Analysis.....	34
Results.....	34
Functional Abilities.....	35
Attentional Demand Measured with Reaction Time .....	36
Postural Sway during Quiet Standing & Dual Task .....	36
Proprioception.....	37
Discussion .....	38
Conclusion .....	40
Acknowledgements.....	41
References.....	41
Captions to Illustrations .....	45
Results.....	46
General Discussion .....	52
Differences between the Wobble-board and Rocker-board.....	52
Changes in Functional Balance.....	53
Changes in the Attentional Demand of a Postural Task .....	55
Changes in Static Balance.....	56
Changes in Ankle Joint Dorsiflexion Discrimination .....	59
Balance-board use in a Group Environment.....	61

Conclusions and Recommendations .....	63
CHAPTER V .....	65
References .....	65
Appendix 1 – Community Balance and Mobility Scale .....	73
Appendix 2 – Mini Mental State Examination .....	90
Appendix 3 – Proprioception and force plate data sheet .....	92
Appendix 4 – Health Status Questionnaire .....	93
Appendix 5 – Consent Form .....	94
Appendix 6 – Certificate of Ethical Approval .....	99
Appendix 7 – Contribution of Collaborators .....	100

## CHAPTER I

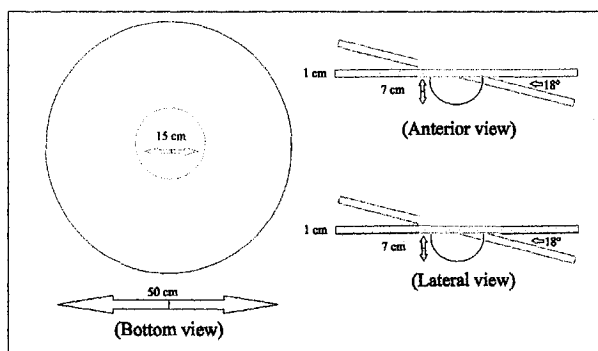
### Introduction

Aging past sixty-five years generally leads to a gradual decline in the functioning of the body's sensory and muscular systems. As a result, seniors are more likely to fall and suffer a serious injury. Physically training the body may reduce the risk of injury and delay the degradation of the body's systems. Sensory systems related to maintaining balance include the visual, somatosensory and vestibular systems. Furthermore, failure to maintain sensory systems into old age causes a decrease in the quality of life and a higher risk of death due to fall related injuries. Elderly people do not recover from physical injuries with as much ease as younger adults; therefore physical fitness training is important for the maintenance of strength and balance in the elderly.

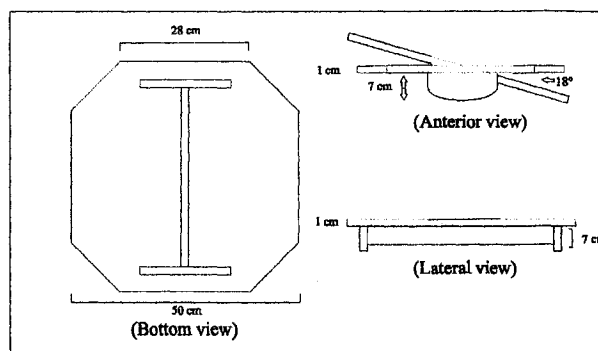
#### *Purpose Statement*

The purpose of this project was to measure the effects of an 8-week balance-board intervention on the balance characteristics of a healthy elderly population. Balance-boards are platforms for individuals to stand on which have an unstable base of support. There are two models used in this study. A wobble-board has a single hemisphere on the bottom (figure 1a); whereas a rocker-board has two rocker panels (figure 1b). The wobble-board tilts in every direction, whereas the rocker-board is unidirectional. The effectiveness of the intervention was quantified by measuring variables related to balance before and after the intervention period. These variables represent measures of balance, including: 1) *functional balance* measured using the community balance and mobility scale (CB&M), 2) *attentional demand* of a postural task using reaction time as the secondary task, 3) *static balance* by

measuring postural sway during quiet standing, and 4) *proprioception* represented by measuring ankle joint dorsiflexion movement discrimination.



**Figure 1.0a: wobble-board**



**Figure 1.0b: rocker-board**

### *Important Concepts*

The following definitions and concepts of balance are used throughout the literature review and are introduced here to clarify their meanings in this context. Furthermore, the theory of attentional demand will be discussed because it is an important component of the study. The implication of these terms to the study will be discussed briefly.

*Balance* was defined by Massion (1992) as a person's ability to maintain their centre of gravity within their functional base of support. When an individual is standing still they are in a static state, therefore referred to as having static balance. Similarly if a person is able to walk upright then they are said to have dynamic balance (Woollacott & Tang, 1997). If static or dynamic balance fails and is not recovered, then a fall will likely occur. The ability to control postural stability deteriorates as an individual ages due to changes in human physiology.

*Falling* has varying definitions depending on the research context. In this context a fall will be defined by Shumway-Cook & Woolacott (2001, p.226) as any contact with the ground due to the individual's inability to keep their center of mass within their functional

base of support. In addition, the authors state that a clear definition of a fall allows therapists to question patients more effectively regarding the nature and frequency of their falls.

*Attention* is defined by Woollacott & Shumway-Cook (2002) as the information processing capacity of an individual. When multiple tasks are performed simultaneously attention is divided between those tasks. If multiple tasks combine to require more than 100 percent of the person's attentional capacity, the performance of one or all tasks deteriorate (Woollacott & Shumway-Cook, 2002). The *attentional demand* of a task such as standing is measured by performing a measurable cognitive task simultaneously. For example, the difference in performance scores of the cognitive task when it is performed together with the standing task or separately from the standing task can indicate a high or low processing requirement of the standing task. Similarly, the attentional demand of different postural tasks can be compared by the scores achieved using the same cognitive task. The scores of a cognitive task can also be compared before and after a training intervention to measure improvements.

## CHAPTER II

### Review of Literature

As individuals mature into older adults their sensory systems have already started the degradation process (Kenshalo, 1979; Pitts, 1982; Rosenhall & Rubin, 1975). Elderly adults' gait and balance can also become noticeably impaired (Studenski, Duncan & Chandler, 1991) and the risk of falling is likely to increase (Ochs, Newberry, Lenhardt & Harkins, 1985). Falling is a serious concern that can leave the elderly with health concerns and complications. Past research has examined the relationships between balance, strength and attentional demand within an elderly population to help understand which factors are responsible for postural instability. The purpose of this literature review is divided into sections to highlight the research that has identified physiological changes to sensory systems with aging, risk factors for falling and interventions related to postural instability and finally balance-board specific studies that have created the foundation for this research project.

#### *Sensory Systems Related to Postural Stability and Changes with Aging*

When performing a postural task the central nervous system (CNS) is constantly gathering information from a number of subsidiary systems to maintain postural stability. These systems include the visual, somatosensory and vestibular systems. Inputs from each of these systems provide a separate frame of reference for postural control that is processed by the CNS (Hirschfeld, 1992; Gurfinkel and Levick, 1991). The function of these systems and age related changes are discussed below.

The visual system collects information about the surrounding environment through peripheral and central vision. A person knows that many things in the environment are completely vertical such as walls and doors; therefore it is possible to use vision to provide a reference point for what is up and down. As stated by Shumway-Cook & Woollacott (2001, p.181), the visual system is not essential for balance and it can play tricks, but nonetheless it is a highly influential input for maintenance of posture and gait. In addition, as people walk they experience the visual flow of objects moving past them. Studies have shown that visual flow cues help people determine walking speed (Lackner and Dezio, 1988) and influence the alignment of the body with reference to gravity and our external environment when walking (Lee and Young, 1986).

Poor vision is a factor related to loss of balance; unfortunately under some circumstances it can not be helped. Age related conditions such as glaucoma and macular degeneration can reduce visual acuity and visual contrast sensitivity (Lord & Dayhew, 2001). Without good visual sensitivity it is more difficult to spot obstacles and hazards in the environment which may lead to falls causing severe injury. In fact, it has been shown that visual flow can create incorrect postural responses significantly more in unstable older adults than in healthy older adults (Sundermier, Woollacott, Jensen & Moore, 1996).

The word somatosensory (somato + sensory) means 'body sense,' representing the body's ability to sense and process various stimuli. Somatosensory receptors include muscle spindles and Golgi tendon organs which are sensitive to muscle length and tension; joint receptors that are sensitive to joint movement and stress; and various receptors in the skin that sense vibration, skin stretch and pressure (Shumway-Cook & Woollacott, 2001, p.181). The combination of these stimuli provides an awareness of the body's position while standing still or while moving known cumulatively as proprioception. Based on findings of

Woollacott, Shumway-Cook & Nashner, (1986) under normal healthy conditions people sway less when standing on a steady support surface regardless of the availability of vision. This finding suggests that, "... under normal conditions, the nervous system may weight the importance of somatosensory information for postural control more heavily than vision and vestibular inputs," (Shumway-Cook & Woollacott, 2001). This statement emphasizes the importance of the somatosensory system.

Proprioception has been found to decrease with age, (Pai, Rymer, Chang & Sharma, 1997; Petrella, Lattanzio & Nelson, 1997) specifically the sense of vibration in the lower leg that significantly affects balance (Lord, Clark & Webster, 1991). A study by Kenshalo (1979) showed that vibratory sensation threshold at the great toe increases threefold by the age of ninety. In some cases elderly are not able to detect any vibration in the ankle whatsoever (Whanger and Wang, 1974). Consequently, reduced somatosensory input can lead to individuals tripping when they walk. This occurs because people depend on this information to control stride phases, length and frequency (Nashner, 1980).

The vestibular inputs are a powerful source of information for postural control. Simply stated, vestibular inputs provide the central nervous system with a gravitational frame of reference for balance (Shumway-Cook & Woollacott, 2001, p.181). The vestibular system senses and provides information about angular and linear acceleration of the head to the central nervous system (Shumway-Cook & Woollacott, 2001, p.182). Angular acceleration is detected by semicircular canals of the inner ear that are sensitive to fast head movements like those experienced when tripping and falling (Horak, Schupert, Dietz & Horstmann, 1994). Semicircular canals contain fluid which comes in contact with tiny innervated hairs which communicate to the central nervous system. Otoliths are also a component of the inner ear that signal linear acceleration, are sensitive to slow movements of the head and provide

information about head position with respect to gravity (Shumway-Cook & Woollacott, 2001, p.182).

Rosenhall and Rubin (1975) claim that by the age of 70 years the vestibular system shows a reduction in function, with a loss of 40% of the vestibular hair and nerve cells. The vestibular system is especially important when there is a conflict between the somatosensory and visual systems; therefore dizziness can result as a consequence of some types of vestibular weakness (Shumway-Cook & Woollacott, 2001, p236). Other degenerative problems related to the vestibular system include: positional vertigo, imbalance during walking, faintness and feelings of unsteadiness and imbalance (Shumway-Cook & Woollacott, 2001, p. 236). As previously mentioned, the vestibular system acts as an absolute reference for the other systems (visual & somatosensory), therefore when not functioning properly there is a much higher risk of falls and injury.

In summary, this section has identified the sensory systems that are related to postural control. The visual system delivers information about the surrounding environment through peripheral and central vision. The somatosensory system delivers information through the use of Golgi tendon organs and stretch receptors located in our muscles, joints and skin. The somatosensory system provides our central nervous system with information about the position of our body known as proprioception. The vestibular system uses semi-circular canals and otoliths inside the ear to signal information about angular and linear acceleration of the body. Combined, the sensory systems provide a wealth of information to the central nervous system. As a function of aging, these systems can become less sensitive to stimuli causing the risk of falling to increase. Therefore, it is in the best interest of healthy older adults to maintain their sensory systems as they continue to age.

### *Risk Factors for Falling in the Elderly*

In fact, according to Wade & Jones (1997) the primary risk factor for falling is the age related decline of the sensory systems that relay information to the central nervous system. This decline arises as a function of aging past sixty-five years old (Prudham & Evans, 1981; Campbell, Reinken, Allan & Martinez, 1981). There are several other risk factors for falling such as poor muscular strength, poor reaction time, a reduced processing capacity and the fear of falling.

Physical muscular strength plays an important role in balance and mobility. A study by Sandler, Burdett, Zaleskiewicz, Sprowls-Repcheck & Harwell (1991) showed that a deficit in leg strength is related to a slower walking speed, reduced stride length and decreased balance. Their results also showed that most muscular strength is lost between the ages of 45 and 65 which supports why elderly are more likely to fall or do not have the strength to regain their balance if they slip. This study also showed that older women who participate in physical activity do retain a significant amount of their strength and are less susceptible to falls.

A study done by Lord et al. (1991) suggests that aside from muscular strength, poor reaction time is also a risk factor for falling. This study divided ninety-five people between the ages of 59 and 97 into three groups: non-fallers, one-time fallers or multiple fallers. They defined a fall as 'when a person comes to rest unintentionally on the ground or other lower level'. Each participant was subject to a battery of tests including reaction time and postural sway. The study concluded that individuals who had fallen more than once had significantly slower reaction times and increased postural sway compared to the others. One year after the initial evaluation a follow-up evaluation took place which confirmed the previous results.

Those who fell on two or more occasions since the initial investigation had slower reaction time and increased postural sway. This study suggests that slow reaction time and increased postural sway may predict falls in the elderly population. The reason why poor reaction time is a predictor for falls is because it represents the speed of the neuromuscular system. The signal to the muscles from the central nervous system may not be fast enough to make corrections to balance in potentially dangerous situations (Lord et al., 1991). Furthermore, when attention is diverted reaction time is slower as seen in the following text.

In relation to physical muscle strength and reaction time is the ability to make anticipatory postural adjustments quickly and effectively. Postural adjustments are often made to stabilize the body before making a voluntary movement such as lifting, pushing, pulling or carrying objects. According to Shumway-Cook & Woollacott (2001, p. 240) most falls are going to occur while performing the abovementioned activities. Research has shown that older adults activate both voluntary muscles and postural muscles at nearly the same time, whereas a young adult will activate the postural muscles earlier to provide stability (Man'kovskii, Mints & Lysenyuk, 1980). Also, when performing a complex reaction time test, older adults took significantly longer to activate both postural and voluntary muscles than young adults when responding to a stimulus (Inglin and Woollacott, 1988). These results suggest that many older adults have problems making anticipatory postural adjustments promptly enough to avoid the risk this delay presents to falling.

A study by Kerr, Condon & McDonald (1985) studied the effect of a secondary verbal memory task on postural control in young adults. Postural sway values taken during a standing task were the same as those taken during the same standing task combined with a memory task. The key finding was that participants were less successful performing the memory task (recalling numbers placed in a matrix) when standing as compared to sitting.

The study showed that standing is attentionally demanding in young adults and decreases the effectiveness of certain cognitive tasks. In addition, Lajoie, Teasdale, Bard & Fleury (1996) showed that attentional demands increase with the complexity of the postural task. This was shown by observing reaction times increase when subjects performed harder postural tasks. These tasks included sitting, standing with a normal and narrow base of support and walking.

Based on what is known about the aging process it is not a surprise that healthy older adults are outperformed by healthy young adults under dual-task conditions using reaction time as the secondary task (Lajoie et al, 1996; Eichhorn, Orner, Rickard & Craik, 1998). Also, depending on the complexity of the secondary task, a decrement in the primary task (postural control) was observed in older adults (Maylor & Wing, 1996). These results suggest that more complicated postural tasks consume attention that could be needed to avoid falls.

A study investigating the attentional demands of healthy versus balance-impaired older adults during postural recovery was done by Brauer, Woollacott & Shumway-Cook (2001). This study shows very convincing evidence that balance recovery is attentionally demanding in older adults and even more so in balance impaired older adults when a secondary task is introduced. Results showed that the balance impaired group took up to 50% longer to recover balance and 140ms longer on a reaction time task. Balance impaired older adults have been witnessed moving slower or stopping movement altogether when talking (Lundin-Olsson, Nyberg & Gustafson, 1998; Shumway-Cook, Woollacott, Kerns & Baldwin, 1997) which may be a safety adaptation, but a predictor of falls nonetheless. Finally, fear of falling is a psychological issue that may increase the risk of falling. For example, a study by Tinetti, Richmond & Powell (1990) showed that twenty-five percent of older adults who have previously fallen choose to avoid activity because of their fear of

falling. Choosing not to perform any physical activity due to fear of falling is a choice that results in reduced physical capacity and balance; this inevitably leads to reduced muscular strength (Nevitt, Cummings, Kidd & Black, 1989). The resulting decrease in strength and balance may lead to a more intense fear of falling and greater anxiety towards falling (Murphy & Isaacs, 1982). Balance confidence may be improved with exercise (Liu-Ambrose, Khan, Eng, Lord, McKay, 2004) but the hard part may be convincing the victim that exercise is the correct treatment. Therefore, it may be necessary to use educational sessions which have been shown to alleviate any negative psychological beliefs about exercise and its relationship to falling (Brouwer, Walker, Rydahl & Culham, 2003).

In summary, reduced muscular strength leads to poor gait and slower postural adjustments. Poor reaction time can also be a risk factor for fallings because it represents the speed of the neuromuscular system's response to postural instability. Brauer et al (2001) showed that balance recovery is very attentionally demanding in balance impaired older adults; therefore, poor attention measured using a dual-task assessment tool may indicate a risk factor for falling. Lastly, fear of falling was identified by Tinetti et al. (1990) as a risk factor for falling because fear results in less physical activity.

#### *Assessment of Postural Stability*

Numerous assessment tools are used to assess balance characteristics. These tests range from easy to hard and are usually selected based on the characteristics of the experimental group and the type of balance being assessed. Tests have been created to measure functional, dynamic and static balance; as well as the attentional demand of postural tasks, reaction time, muscular strength, proprioception and balance confidence. In the current study only functional balance was measured using a test that requires the participants to

complete a series of tasks. This test is called the Community Balance and Mobility Scale (CB & M) was used to measure functional balance.

The CB&M scale was developed by Inness & Howe (2002) to evaluate the postural stability of patients who had suffered a traumatic brain injury (TBI). The CB&M was created because a ceiling effect was observed when using scales and tests created for frail older adults on TBI patients. The CB&M consists of thirteen functional tasks rated on a scale from 0 to 5. Some of the tasks include: standing on one foot, pivoting on the toes, running, walking while looking over the shoulder, hopping, descending stairs and forward to backwards walking. Most of the tasks are performed on a track that is 8 meters long with distance indicators and visual targets. Furthermore, many of the tasks are timed in order to distinguish between those people who can complete the task and those who can do it quickly. The CB&M has been successfully used to evaluate healthy elderly people between the ages of 70 & 80 years (Bisson, 2004); the purpose was to investigate the effects of virtual reality training and biofeedback training on dynamic balance. The tasks were challenging and posed a moderate risk of falling but proved to be safe with adequate supervision. Bisson (2004) showed the average post-training score to be 63 (s.d.  $\pm$  10) points out of a possible 96 points for the twenty-four older adult participants indicating that the test was difficult enough to avoid a ceiling effect. Lastly, the CB&M has been shown to have high inter-rater reliability (0.98) and a high internal consistency amongst the items (Cronbach alpha = 0.96) (Inness & Howe, 2002).

### *Physical Training to Improve Risk Factors of Falling*

After having identified the risk factors associated with falling the next step is to investigate what can be done to maintain these factors at a healthy level or to improve them.

Therefore, it is important to review various physical training programs which have been designed to achieve improvements to postural stability. It is important to be mindful of the time commitment, location, cost and value of a training program because these factors may determine the likeliness that elderly people will participate.

In 2001, Rogers, Fernandez & Bohlken showed that a training program for participants with an average age of 74 years improved their balance significantly after ten weeks (two sessions per week of 60 minutes) of training. The training program included: balance training using exercise balls, dumbbells for increasing strength and a number of flexibility exercises. The exercises were designed to target the vestibular, somatosensory and visual systems. The training improved postural sway by decreasing the range of sway by 9% in the medial-lateral direction and the instantaneous velocity of sway by 13%. Functional reach while keeping the feet apart also improved by 20.3%. When measuring sway, the participants were directed to remain as still as possible. This type of training is ideal for older adults who need to improve their balance. A well rounded fitness program including balance, strength and flexibility comes highly recommended for a person of any age, but it is possible that not everyone has the time, money or mental resources available to learn and to commit to a mixed training program.

A review article written by Rubenstein and Josephson (1997) reported that decrements in leg strength could increase the risk of falling by up to five times in the elderly population. This study also reported that poor gait and balance only resulted in a threefold increase to the risk of falling. Evidence from sixteen different controlled studies showed that having good leg strength is just as important as balance and gait characteristics. However, Rubenstein did not suggest how strength and balance were related to gait and balance. The

study implied that the two are separate entities when in fact there is a clear relationship between strength and gait effecting balance (Lord, Caplan & Ward, 1993).

Regardless of the type and intensity of resistance training interventions, most have shown to improve elderly balance to some extent. With regard to exercise in general, it has been shown that the more exercise an elderly person does at home the less likely they are to fall (Myers & Hamilton, 1985). To support this finding Lord et al. (1993) suggested that regular exercise helped preserve postural control. They demonstrated this by testing active elderly women between the ages of 57 and 75 who had been participating in various exercise programs for at least twelve months. The women showed better quadriceps strength, reaction time and postural sway compared to inactive women of the same age group. However, there was no significant change in proprioception.

In summary, results have shown that healthy elderly who participate in physical activities at home or in a group setting have better strength and balance than those who do not exercise. Therefore, this active elderly population is less likely to suffer fall related injuries.

### *Balance Specific Training*

Improving balance in the elderly has become an area of intense research due to the high financial burden of falls to health care. Many studies have effectively discovered which internal mechanisms are responsible for poor balance (Behm, Bambury, Cahill & Power, 2004; Chong, Ambrose, Carzoli, Hardison & Jacobson, 2001) such as proprioception, vision, the vestibular system, and the muscular system. In addition, many other studies have isolated external factors that contribute to falling (Fortinsky et al, 2004; Tinetti, Baker, Gallo, Nanda, Charpentier, & O'Leary, 2002) such as medication, poor foot wear and environmental

hazards. As a result these studies have increased awareness about fall prevention; and suggested that being physically active is the first step to improved balance. Therefore, adapted training programs for the elderly are now offered to improve or maintain balance. These programs may include strength training, balance classes, yoga and Tai chi. Research has also identified ways to improve balance using simple exercises focusing on postural stability.

A simple sensory orientation training study conducted by Hu & Woollacott (1994) trained twelve older adults five times per week for 2 weeks in 1-hour sessions. Participants trained under a combination of different sensory conditions while standing on a force plate. The conditions included: eyes open, head neutral; eyes closed, head neutral; eyes open, head extended; eyes closed, head extended. Each of the four conditions was performed while standing on a solid support surface and while standing on foam. These exercises likely challenged each individual to use and integrate different sensory inputs. Static balance was measured by recording forces from the force plate and calculating postural sway. Participants improved static balance significantly on all of the foam surface conditions and the eyes closed, head extended condition on a solid surface ( $p < 0.006$ ). Four weeks following the intervention the study group was able to stand significantly longer on one foot compared to a control group ( $p < 0.001$ ). These findings suggest that balance training multiple sensory systems concurrently improves balance performance in healthy elderly.

Balance training using computerized visual biofeedback emerged in the early nineteen-nineties. Hamman, Mekjavic, Mallinson & Longridge (1992) were the first to study the effect of visual biofeedback training on postural sway in young adults. They used a device called the Balance Master which provided continuous biofeedback on the position of the centre of pressure in relation to the limits of stability. In essence, the device showed a

pointer on a computer monitor which moved in the same direction as the subject's centre of gravity while standing force platforms. The purpose of the study was to find out if training on the balance master would improve postural sway under three conditions: with eyes open, eyes closed and with biofeedback. The subjects were also divided into two groups: the first group trained each day for five days, the second group trained once per week for five weeks. The training involved moving their centre of pressure around their limit of stability using biofeedback on the monitor. Following the training intervention participants were re-evaluated to measure any improvement. The results showed no significant changes for either group, under any condition. All seventeen subjects were healthy and between the ages of twenty and thirty-five.

Three years later Hamman, Longridge, Mekjavic & Dickenson (1995) used the Balance Master to study three elderly groups. Hamman and colleagues used the same procedure and training as in Hamman et al's 1992 study. The older adult group only trained once per week for five weeks. Once again, they found no significant improvement when measuring changes in the postural sway with eyes open or closed. However, they did note a faster transition time between visual targets during the training sessions for the older adult group. This suggests that the balance master improves dynamic balance by teaching subjects where their theoretical limits of stability are located. Having this knowledge, people are likely to be safer when moving because they know and can feel their limit of stability through the somatosensory system. The limitation of this study was that the researchers only measured static and dynamic balance using the balance master.

A biofeedback study was also conducted by Bisson (2004). The primary difference from Hamman et al. (1995) was that Bisson measured the effectiveness of biofeedback training to improve dynamic balance, static balance and attention demands. Following ten

weeks of biofeedback training, twice per week for 20 minutes, scores on a functional balance scale called the CB&M significantly improved; as did the attentional demands of a postural task under a dual task condition (using reaction time as the secondary task). Similar improvements were shown following ten weeks of training using virtual reality. The virtual reality training required participants to reach sideways and catch falling balloons while watching themselves on a large television monitor. These results have shown that biofeedback and virtual reality training can improve balance in older adults.

Recently, balance related literature has emerged which identifies various types of training programs and their associated benefits to balance related variables in the elderly population. Xu, Hong, Li and Chan (2004) studied the effects of tai chi on the proprioception of the ankle and knee joints in the elderly. Elderly participants who had consistently practiced tai chi, running or swimming for four or more years were recruited by answering a questionnaire. It was concluded that proprioception and kinethesis (sense of joint movement) in both joints was significantly better for those who had practiced Tai Chi compared to those who swam or ran regularly ( $p < 0.05$ ) and the control group ( $p < 0.001$ ) which had done no regular exercise for the previous four years. They attributed the complex weight bearing, flexibility and coordinated movements of Tai Chi to the superior proprioceptive capabilities of the study population.

Lastly, Bellew, Fenter, Chelette, Moore & Loreno (2005) studied the effects that training on semi-compressible foam-rollers had on healthy elderly women. The basis for choosing this type of equipment was similar to that of choosing balance-boards in the current study. In essence, this type of equipment was affordable, time efficient, did not require a clinical setting and could be used without supervision. The participants performed squats; bi-lateral and anterior-posterior movements while standing on the foam rollers. After 5-weeks

of training, twice per week, for 15-minutes the participants' functional reach was re-measured showing significant improvements in both lateral reach ( $p < 0.014$ ) and lower extremity reach ( $p < 0.001$ ). There was no improvement in functional forward reach possibly because most daily tasks are performed in that direction leaving little room for improvement, as stated by the author. These findings support the idea that challenging the body in novel ways can produce results that improve elderly dynamic balance over a short period of time following a simple protocol.

In summary, a wide variety of balance training programs are available. Some take place in a clinical setting such as virtual reality and biofeedback and some are practiced in a group environment or at home such as tai-chi and training on foam rollers. Most protocols have used dynamic exercises to strengthen balance and have shown to improve dynamic balance measured using different tools. It is possible that balance training improves the sensitivity of the sensory systems and leads to better integration of stimuli by the CNS.

#### *Wobble-board Training*

A wobble-board is a tool used by physiotherapists for rehabilitation of injuries but it has also been used to train balance and proprioception (Emery, Cassidy, Klassen, Rosychuk & Rowe, 2005). The wobble-board could also be known as a balance-board or a BAPS (biomechanical ankle platform system). The wobble board (figure 1a) is a round piece of wood, 1 cm thick with a hemisphere underneath. Therefore, standing on the board is very balance challenging. The size of the hemisphere underneath the platform has been shown to correlate with the degree of muscle activation (Soderberg, Cook, Rider & Stephenitch, 1991). Soderberg challenged participants to exercise on the wobble-board while conducting an electromyography (EMG) recording on the muscles of the lower leg. An EMG can record

the intensity of a muscle contraction because of the electrical signal in the muscle. Participants using a wobble-board that was further from the ground had larger muscle contractions in the tibialis anterior muscle. These results show that the size of the hemisphere is a factor to consider when prescribing exercise on a balance-board.

Studies investigating the effects of wobble-board training on ankle proprioception have found positive results (Waddington, Adams & Jones, 1999; Waddington, Seward, Wrigley, Lacey & Adams, 2000; Chong et al., 2001). All studies have shown significant improvement in ankle proprioception in young adults. Waddington and colleagues (1999 & 2000) showed that after five and eight weeks of training rugby and football players, respectively, the participants were able to discriminate passive ankle movements of the same speed earlier than before the training. This suggests wobble-board training improved ankle proprioception. Chong et al. (2001) agreed that wobble-board training improves ankle proprioception; however they believed that it was a result of improved proprioception in the entire leg including the ankle, hip and knee.

The most recent wobble-board study done by Waddington & Adams (2004) investigated the effect of the wobble-board to improve ankle proprioception in elderly people. Their study showed that detection of ankle movement improved significantly in this population, even more so than the younger populations they studied in 1999 and 2000. Subject's trained at home for five weeks, five times every day for three minutes each session. These results support the idea that wobble-boards may be able to improve measures of static and dynamic balance in elderly. Proprioceptive inputs relay information to the central nervous system to control postural stability (Shumway-Cook & Woollacott, 2001, p. 181); therefore it is possible that the wobble-board may also improve the sensitivity of the

vestibular, visual and muscular systems which are also linked to postural stability (Shumway-Cook & Woolacott, 2001, p.181) and may reduce the risk of falling.

### *Gaps in the Literature*

The number of studies done on balance-board training in the elderly has been limited to two studies (Waddington & Adams, 2004; Nordt, Sachatello, Plotkin, & Dintino, 1999). It has been found that ankle proprioception can be improved in the elderly population but no other balance related variables have been measured before and after a training program. What remains to be known is if balance-board training can improve functional balance, the attentional demand of a postural task and static balance. If these values were known it would provide information about how effective balance-board training is for an elderly population.

Lastly, with the exception of Soderberg et al. (1991) there have been no studies which compared different types of balance-boards. As described earlier, Soderberg et al. discovered that larger hemispheres under the wobble-board equated to greater muscle contractions. It is unknown if different types of balance-boards yield similar balance improvements and which type of balance-board is more appropriate for an elderly population.

### Purpose and Hypothesis

The purpose of this study was to measure the effectiveness of balance-board training to improve balance related characteristics of a healthy elderly population. The types of balance characteristics measures were: 1) dynamic balance using the thirteen tasks of the CB&M scale; 2) attentional demand of a postural task by measuring reaction time; 3) postural sway during quiet standing (static balance) and 4) ankle joint proprioception.

The first group of participants trained on a balance-board called a wobble-board which moves in an unlimited number of directions. The second group of participants trained on a rocker-board which only rocks along one axis. The third group of participants formed the control group. Therefore, upon conclusion of the study it was possible to measure differences between the two experimental groups and the control group.

The intervention period lasted for eight weeks with a total of three sessions per week. The sessions were approximately twenty minutes including breaks. The training consisted of dynamic movements on the balance-boards including front-to-back and side-to-side exercises. The training also included static balance exercises while standing on one foot and both feet. The purpose was to discover if the eight-week training intervention would improve balance related characteristics.

The first hypothesis regarding the outcome of the intervention was that the balance-boards would significantly improve the functional balance of the participants. Biofeedback and virtual reality showed a significant improvement in functional balance scores on the CB&M using a similar elderly population (Bisson, 2004) and as a general observation; balance-boards are no less challenging to postural stability than biofeedback or virtual reality.

The second hypothesis was that the attentional demand of a quiet standing task would be significantly reduced (as measured with a secondary reaction time task). Attentional demands have been shown to improve with computerized postural training (Lajoie, 2004), biofeedback training and virtual reality training (Bisson, 2004). Therefore, the balance-board intervention would have reduced the processing demands of the postural task because balance-board exercises are challenging to postural stability.

The third hypothesis was that ankle joint proprioception would improve significantly following the balance-board intervention and that the improvement would be made by reducing the angular displacement required for the elderly participants to detect dorsiflexion in the ankle joint. The hypothesis was based on the assumption that the intervention would strengthen the sensitivity of the somatosensory system. Furthermore, wobble-board training had been shown to improve ankle inversion proprioception sensitivity (Waddington & Adams, 2004).

The final hypothesis was that balance-board training would improve postural sway during quiet standing. In a balance training intervention that modified the sensory inputs, postural sway was shown to improve under most conditions (Hu & Woollacott, 1994). It was theorized based on these conclusions that balance-board training would improve sway because of the increased dependency of the sensory and muscular systems to provide stability.

## CHAPTER III

Article to be submitted

Aging Clinical and Experimental Research

The Effectiveness of Two Types of Balance-boards to Improve Elderly Balance Over an 8-  
week Training Intervention

B. Contant<sup>1</sup>, P. Beriault<sup>1</sup>, Y. Lajoie<sup>1</sup><sup>1</sup>School of Human Kinetics, University of Ottawa, Ottawa

Correspondence to:

Yves Lajoie, PhD  
School of Human Kinetics  
Faculty of Health Sciences  
University of Ottawa  
125 University St.  
Ottawa, Ontario  
K1N 6N5  
Canada  
Phone: (613)562-5800 ext. 4273  
Fax: (613)562-5149  
Email: [ylajoie@uottawa.ca](mailto:ylajoie@uottawa.ca)

THE EFFECTIVENESS OF TWO TYPES OF BALANCE-BOARDS TO IMPROVE  
ELDERLY BALANCE OVER AN 8-WEEK TRAINING INTERVENTION.

## Abstract

Background and aims: Balance-boards have been used to rehabilitate patients with ankle injuries and to improve strength and balance in athletes. Wobble-boards have been shown to improve elderly ankle proprioception but have never been used specifically to improve balance with the goal of fall prevention. The objective of this study was to compare the effectiveness of two types of balance-boards (wobble-board and rocker-board) to improve balance in older adults. The focus of the study was to measure any changes to functional balance, attention while performing two tasks (dual task), postural sway and ankle joint dorsiflexion discrimination following a balance-board intervention.

Methods: Twenty-eight healthy elderly were distributed into three groups, 12 in the wobble-board group (age =  $72.9 \pm 4.62$ ) and 11 in the rocker-board group (age =  $73.5 \pm 4.08$ ) participated in an 8-week intervention consisting of three 20 minute sessions per week. There were 5 elderly in the control group (age =  $76.2 \pm 5.49$ ). Baseline, post-training and retention measures of functional balance (CB&M), attentional demand (reaction time while standing), postural sway and ankle dorsiflexion discrimination were collected.

Results: Following the intervention experimental groups had significantly improved their functional balance CB&M scores ( $p < 0.001$ ) and showed improved attentional demand. The wobble-board group significantly improved proprioception ( $p < 0.001$ ). Postural sway remained unchanged in all groups ( $p > 0.05$ ).

Conclusion: Balance-boards are effective for improving functional balance for elderly people but further testing is needed to assess static balance, attentional demands and ankle joint dorsiflexion discrimination.

Keywords: Aged, Attention, Balance Training, Proprioception, Rocker-board, Wobble-board

### Introduction

The primary risk factors for falling are associated with aging past sixty-five years (1, 2). This is due to the decline of the somatosensory, vestibular and visual systems that relay sensory information to the central nervous system (CNS) (3). The CNS is then responsible for integrating and processing this information and then generating the appropriate muscular responses in order to maintain postural stability (Shumway-Cook & Woollacott, 2001, page 165). A lack of physical activity can result in the accelerated decline of the sensory systems responsible for balance (5). To strengthen balance in the elderly, it is necessary to examine the effectiveness of exercise modalities that target one or more of the sensory systems responsible for static and dynamic balance.

Each of the sensory systems provides unique information to the CNS. The somatosensory system provides the CNS with sensory information related to muscle tension, muscle length, skin pressure, vibration and skin stretch (4). The combination of these stimuli provides an awareness of the body's position while standing still or while moving known cumulatively as proprioception. The vestibular system senses and provides information about angular and linear acceleration of the head by using a gravitational frame of reference (4). The visual system is also of great importance because it provides a reference for what is up and down and helps each person make both conscious and subconscious postural adjustments based on their environment when they are moving or when they are stationary.

Research has shown that the sense of vibration in the lower leg significantly contributes to balance (6, 7). In fact, research has shown that vibratory sensation threshold at

the great toe increases threefold by the age of ninety (7); and in some cases, elderly were not able to recognize any vibration in the ankle joint. It has been suggested that this problem can lead to elderly tripping when they walk because they depend on somatosensory information to control stride lengths, phases and frequency (8).

Attention is defined by Woollacott & Shumway-Cook (9) as the information processing capacity of an individual. Standing requires the brain to process information from the visual, somatosensory and vestibular systems (3). When multiple tasks are performed simultaneously, attention is divided between the postural task and the secondary task (9). To measure the effect that standing has on attention, researchers can combine standing with a secondary cognitive task (9). The difficulty of the postural task is negatively correlated with the cognitive task score when both tasks are performed at the same time (9). Reaction time is used as the cognitive task in this study and research has shown that balance training can improve reaction time when standing (10). This suggests that with practice, standing can become less attentionally demanding; therefore the brain can perform better on other tasks occurring simultaneously. Focusing attention away from balance can result in falls and injury (9); consequentially, aiming to improve the attentional demand of postural tasks may be important.

It is known that elderly who fall can suffer serious injuries leading to death. As a result it is important for elderly to maintain or improve sensory and muscular systems related to balance. Studies have shown that training programs such as sensory system training, tai chi, biofeedback, virtual reality, foam rollers and wobble-boards can improve balance in elderly people (10, 11, 12, 13, 14, 15, 16). Resistance training has been shown to increase strength but has shown few signs of improving balance specific characteristics (17). Therefore it is important for elderly to include balance specific training in their exercise

routine. The challenge remains to introduce elderly to a variety of interventions that effectively improve balance and strength.

A simple sensory orientation training study conducted by Hu & Woollacott (10) trained twelve older adults five times per week for 2 weeks in 1-hour sessions. Participants trained under a combination of different sensory conditions including: eyes open, head neutral; eyes closed, head neutral; eyes open, head extended; eyes closed, head extended. Each of the four conditions was performed while standing on a solid support surface and while standing on foam. Challenging the different sensory systems led to improved postural sway under all foam conditions and four weeks following the intervention the study group was able to stand significantly longer on one foot compared to a control group ( $p < 0.001$ ). These findings suggest that balance training multiple sensory systems concurrently improves balance performance in healthy elderly.

In 2004, a study by Bisson (11) compared the effectiveness of virtual reality and biofeedback to improve balance in the elderly. The virtual reality group training required participants to reach sideways and juggle falling balloons by watching themselves on a large television. The biofeedback group was required to move a visual representation of their centre of pressure towards their limit of stability on a computer monitor. For Bisson, both intervention groups resulted in a significant improvement in functional balance measured using the Community Balance and Mobility Scale, and a significant improvement in the amount of attention required to perform a static postural task. As seen with another biofeedback study (14), there was no improvement in postural sway; however, Bisson showed that 10 weeks of biofeedback and virtual reality training, twice per week could improve elderly functional balance and reaction time.

A tai chi study by Xu et al. revealed that elderly who practiced tai chi regularly for at least four years had better ankle and knee proprioception (threshold for detecting passive motion) compared to a group of seniors who either ran or swam regularly for at least four years and a sedentary control group (12). The researches attributed the complex weight bearing, flexibility and coordinated movements of Tai Chi to the superior balance capabilities of their study population.

An intervention using semi-compressible foam rollers on healthy elderly women was studied by Bellew, Fenter, Chelette, Moore & Lorenzo (15). The basis for choosing this type of equipment was similar to that of choosing balance-boards in the current study; training on foam was time efficient, inexpensive and could be done at home. The foam pad was described as a football cut in half lengthwise. The participants performed squats; bi-lateral and anterior-posterior movements while standings on the foam rollers. After 5-weeks of training, twice per week, for 15-minutes the participants' functional reach had improved significantly in both lateral reach ( $p < 0.014$ ) and lower extremity reach ( $p < 0.001$ ). These findings support the idea that following a simple balance exercise regime can produce improved elderly dynamic balance over a short period of time.

In the past, balance-boards have mostly been used to improve balance in competitive athletes and to treat ankle injuries. Standing on balance-boards creates an unstable and changing base of support. A wobble-board is a type of balance-board with a half sphere underneath. Waddington and colleagues (18) showed that five weeks of wobble-board training could improve ankle proprioception in young adults. Five years later, Waddington (16) investigated the effect of the wobble-board on ankle proprioception in elderly. A five-week intervention, fifteen minutes per day yielded better results than it had for the younger

adults in a previous study (18). There were no data quantifying the effect of the wobble-board intervention on balance, therefore further investigation was needed.

The aim of this project was to study the effects of an 8-week balance-board intervention on functional balance, the attentional demand of a postural task, static balance and proprioception of a healthy elderly population. Balance-board training was done using two types of balance-boards, the wobble board and the rocker-board. The wobble-board moves in every direction and the rocker-board in one direction. Results of previous balance studies led to the hypothesis that the balance-board intervention should have improved functional balance, static balance, attention and proprioception. Alternatively, the control group should remain unchanged over the course of the study.

## Methods

### *Participants*

Thirty-six older-adult volunteers from Canada's National Capital region agreed to participate in this study. Three participants dropped out due to illness or injury, three participants did not qualify to participate because of diagnosed balance impairments and two participants were dropped due to poor attendance. Subjects were required to be healthy with no signs of the following conditions: severe arthritis, neurological disorders, vestibular problems or balance impairments. Volunteers were screened by means of a questionnaire for use of narcotics that could alter judgment or balance such as sleeping pills, alcohol or antidepressants. Participants were required to achieve a score of 25 points on a mini-mental state evaluation. They also had to be autonomous with the ability to walk without aid.

Subjects were recruited from a seniors' center during their seasonal program registration period. Volunteers who met the above criteria submitted their name and phone

number. Baseline evaluations were scheduled by phone for those participants who were still interested. All participants traveled to the training site from their homes by car, public transportation or by walking. Most participants were active in various activities around the centre but were asked to report any new activities. None of the participants started any new activities during the twelve week study; nor had they started any new activities during the four months leading up to the training intervention.

### *Procedures*

During the baseline evaluation, participants read and signed a consent form and completed a questionnaire on their health status and level of activity. The participants completed a functional balance test, a standing reaction time task, a quiet standing task and a proprioception task. Participants were then assigned to one of three groups by the primary researcher: 1) wobble-board group, 2) rocker-board group or 3) control group. Group assignment was based on convenience and those who agreed to participate in the training were randomly placed in one of the experimental groups. Remaining participants were placed in the control group. As shown in table 1, twenty-eight participants (age =  $74.0 \pm 4.59$ ) completed the study; 12 from the wobble-board group (age =  $72.9 \pm 4.62$ ), 11 from the rocker-board group (age =  $73.5 \pm 4.08$ ) and 5 from the control group (age =  $76.2 \pm 5.49$ ).

### *Training protocol*

The intervention was 8-weeks long with three 30 minute sessions per week. Sessions included sixteen minutes of training, setup, clean-up and short breaks as needed by the participants. Participants trained in small groups guided by an instructor. Multiple sessions

were available each day; of which participants were not allowed to train more than once each day or on three consecutive days.

Each participant had two solid chairs on each side of their balance-board. The back of the chair provided support for the participants to hold during training. During the first session, participants were instructed on how to properly use the balance-boards to maintain a high level of safety. Each board was 50 centimeters wide and had an angle of 18° degrees between the ground and the support surface. Each training session included a combination of forward-backward, left-right movements while standing with feet together and shoulder width apart (4 exercises). Additional exercises included standing in equilibrium with feet together, feet apart and while standing on one foot (4 exercises); there were two 1-minute sets of each exercise for wobble-board participants. Rocker-board participants were required to change the orientation of their rocker-board in order to perform each exercise in both directions (front-back & bi-laterally) for 1-minute each.

### *Measurements*

The subjects in the experimental groups had their baseline measures recorded immediately before and after the 8-week training intervention. Retention measures were recorded approximately four weeks following the completion of the training. Control subjects were tested at baseline, after eight weeks and after twelve weeks.

Functional balance was measured using the Community Balance and Mobility Scale (CB&M). The CB&M was created by Inness & Howe (19) and consists of thirteen functional balance tests that are scored on a 6-point scale. The CB&M includes tasks such as: standing on one foot, tandem walking, tandem pivot, lateral scooting, running with a controlled stop, lateral movement, descending stairs, walking and looking and other dynamic tasks. The

CB&M has been shown to have a high inter-rater reliability (0.98) and a high internal consistency amongst the items (Cronbach alpha = 0.96) (18).

The attentional demand of standing was recorded by having the subject stand with feet together on the force plate as used by Bisson (11). The participant completed a reaction time task for three one-minute trials while the force plate collected data used to calculate postural sway. The reaction time task required the subject to say the word 'TOP' as quickly as possible on hearing a short (20 ms) beep generated by a computer software program. Six beeps were generated manually at random intervals each minute. Beeps and the voice response were recorded using a digital recorder. Reaction time data were measured manually to the nearest millisecond using computer audio software. In this dual-task condition the subject was told to focus primarily on standing still and secondly, to say 'TOP' when hearing the beep.

Postural sway (static balance) was measured with the subject standing still and quietly with their feet together on an AMTI force plate for three trials of one minute. A computer recorded forces from the force plate using an analog to digital converter. A software program called Scope32 was used to calculate the average deviation in millimeters (mm) from the person's mean center of pressure. This indicator of postural sway known as root mean squared (RMS) was measured in both axes, medial-lateral and anterior-posterior as it has been in past studies (11, 20).

Ankle proprioception was determined using similar instrumentation and procedures previously used in another study (21). The participant sat on a chair with the left foot resting in a neutral position on a single-axis motorized platform. The subjects were instructed to say 'stop' only when the technician caused dorsiflexion (toes moving up) of the ankle joint. When the foot remained still or when it was being plantarflexed (toes moving down) the

subjects were instructed to remain quiet. The foot was moved at a speed of 0.4 degrees / s, a speed previously used by Xu et al. (12). A laser pen attached to the foot platform aimed at a measuring tape was used to measure the displacement from the moment the movement was initiated to when the participant said 'stop'. Ten trials were recorded while the participants listened to radio static on headphones and were blindfolded to prevent them from hearing the motor or seeing their foot move. The mean value of the ten trials was calculated following the test. A visual demonstration was given prior to starting the test to ensure understanding on behalf of the participant.

### *Statistical Analysis*

Data were compared between the wobble-board group, the rocker-board group and the control group using a 2-way repeated measure ANOVA for Time (baseline, post-test, retention) and Exercise (wobble, rocker, control) for the following variables: functional balance, attentional demand of standing using reaction time and proprioception. Group and Time interactions for functional balance and proprioception were deconstructed using the LSD (least significant difference) post hoc test. Main effects for group and time were also deconstructed using LSD post hoc testing. Postural sway was analyzed using a 4-way repeated measure ANOVA for Time (baseline, post-test, retention), Group (wobble, rocker, control), Direction of sway (anterior-posterior, medial-lateral) and Task (dual task, quiet standing).

### **Results**

Table 1 shows that age, mental state, height and weight of the three groups were similar. However, there was a slight gender difference between groups. There was no

significant gender difference found for reaction time,  $F(2, 25) = 0.05$ ,  $p > 0.05$  or postural sway,  $F(2, 25) = 0.046$ ,  $p > 0.05$  or proprioception  $F(2, 25) = 0.134$ ,  $p > 0.05$ . Although results for functional abilities (CB&M) showed a significant gender difference,  $F(2, 25) = 12.07$ ,  $p < 0.01$ , no significant interaction was found between gender and the time of evaluation,  $F(2, 25) = 1.305$ ,  $p > 0.05$  signifying that the change due to training was not effected by gender.

INSERT TABLE 1 HERE

### *Functional Abilities*

A 3 Time X 3 Group repeated measure ANOVA was conducted on the scores of the Community Balance and Mobility scale (CB&M) over three time periods. The results as shown in figure 1, indicate a significant main effect for Time,  $F(2, 54) = 28.3$ ,  $p < 0.001$ ,  $\eta^2 = 0.599$ , power = 1.00; no Group effect,  $F(2, 27) = 0.388$ ,  $p > 0.05$ ), and a significant interaction effect (Time X Group),  $F(4, 54) = 7.27$ ,  $p < 0.001$ ,  $\eta^2 = 0.223$ , power = 0.84. The interaction effect was followed by a LSD post-hoc analysis. The results revealed that the wobble-board and rocker-board groups improved significantly from baseline to post-test ( $p < 0.001$ ); whereas the control group didn't significantly change from baseline to post-test ( $p > 0.05$ ). Furthermore, the wobble-board (66 points) and rocker-board (64 points) groups were not different at baseline,  $p > 0.05$ , however; at post-test the wobble-board group (11 points) improved significantly more than the rocker-board group (6 points),  $p < 0.001$ . None of the groups changed significantly from post-test to retention test,  $p > 0.05$ . Finally, the control group was significantly higher at baseline than the wobble-board group (6 points),  $p < 0.05$  and the control group (8 points),  $p < 0.05$ . In summary, the wobble-board group had the

greatest improvement, the rocker-board group improved significantly and the control group remained the same.

INSERT FIGURE 1 HERE

#### *Attentional Demand Measured with Reaction Time*

A 3 Time X 3 Group repeated measures ANOVA was conducted on reaction time scores over three time periods. Results indicated a significant main effect for Time,  $F(2, 54) = 4.83$ ,  $p < 0.05$ ,  $\eta^2 = 0.281$ , power = 0.733; no significant main effect for Group and no significant interaction. The main effect for time was followed up with a LSD post-hoc analysis that revealed a significant decrease in reaction from baseline ( $M = 383$  ms) to post-test ( $M = 370$  ms),  $p < 0.05$ , as shown in figure 2. There was a greater decrease in reaction time from baseline ( $M = 383$  ms) to retention (363 ms),  $p < 0.001$ . As shown in figure 3, the experimental groups' attentional demand improved between baseline and the post-test but this improvement was not shown to be significantly different from the control group which stayed the same.

INSERT FIGURE 2 HERE

INSERT FIGURE 3 HERE

#### *Postural Sway during Quiet Standing & Dual Task*

A 4-way (Time X Group X Task X Sway-direction) repeated measures ANOVA was conducted on postural sway values over three time periods. As presented in figure 4, postural sway results did not show a significant main effect for Time,  $F(2, 54) = 0.0267$ ,  $p > 0.05$ . There was a significant main effect for Group,  $F(2, 27) = 4.65$ ,  $p < 0.05$ , Direction of sway,  $F(1, 27) = 4.82$ ,  $p < 0.05$ , there was also a significant triple interaction between Group,

Direction of sway and Task,  $F(2, 27) = 9.90$ ,  $p < 0.001$ . The main effects were followed up with LSD post-hoc analyses that indicated the wobble-board group ( $M = 4.41\text{mm}$ ) had significantly less sway than the rocker-board group ( $M = 5.80\text{mm}$ ),  $p < 0.05$ , and the control group ( $M = 5.91\text{mm}$ ),  $p < 0.05$ . Furthermore, all groups swayed less in the anterior-posterior direction ( $M = 5.20\text{mm}$ ) than in the medial-lateral direction ( $M = 5.50\text{mm}$ ),  $p < 0.05$ . The follow up for the triple interaction showed the rocker-board group ( $M = 5.77\text{mm}$ ) swaying significantly more than the control group ( $M = 5.37$ ) for the quiet-standing (ant-posterior) condition,  $p < 0.05$ ; however, the control group ( $M = 6.14\text{mm}$ ) swayed significantly more than the rocker-board group ( $M = 5.44\text{mm}$ ) during the dual-task (ant-posterior) condition,  $p < 0.001$ . However, there was no difference between the rocker-board group ( $M = 5.96$ ) and the control group ( $M = 6.13$ ) when standing quietly with feet together in the medial-lateral direction ( $p > 0.05$ ). In summary, there was greater sway in the medial-lateral direction, the wobble-board group had significantly less sway than the rocker-board and control groups; and the three groups' magnitude of sway varied by direction, the task under which sway was measured and by group.

INSERT FIGURE 4 HERE

### *Proprioception*

Values for proprioception were normalized using the natural log function ( $\ln$ ). A 3 Time X 3 Group repeated measures ANOVA was conducted on the distance required to recognize ankle joint dorsiflexion. Results indicated a significant main effect of Time,  $F(2, 50) = 7.89$ ,  $p < 0.001$ ,  $\eta^2 = 0.255$ , power = 0.672; no Group main effect; and a significant interaction between Group and Time,  $F(4, 50) = 3.04$ ,  $p < 0.05$ ,  $\eta^2 = 0.216$ , power = 0.759. Figure 5 presents the average distance (cm) that each group required to detect motion for

each testing period. A LSD post-hoc test showed that the wobble-board group decreased their distance to detect motion significantly ( $p < 0.001$ ), as did the control group ( $p < 0.05$ ) between baseline and post-test. In summary, the wobble-board group improved the most, the control group improved significantly and the rocker-board group stayed the same.

INSERT FIGURE 5 HERE

### Discussion

Functional balance results measured using the CB&M showed that both the wobble-board (WB) and rocker-board (RB) groups improved significantly more than the control group. Previous balance training interventions for healthy older adults have shown improvements in CB&M scores (11) but have not shown such large improvements as seen in the WB group. The WB group improved between baseline and post-training by 11 points which is more than double the score needed to satisfy a significant clinical improvement according to Inness & Howe (19). It was observed that WB training is very challenging due to the unlimited degrees of tilt that standing on a half sphere provides. It is hypothesized that this unique challenge effectively strengthened muscle synergies in the lower leg, thus improving functional balance significantly more than the RB group. These results suggest that training on an unstable base of support with a large number of degrees of freedom improves functional balance more effectively than standing on a semi-predictable surface such as the RB.

Attentional demand of a static postural task was shown to improve significantly between baseline values (383ms) and post-intervention values (371ms). Although there was no significant interaction between the three groups, there was a trend suggesting that balance-board training can improve the attentional demands of standing. The difference

between baseline and post-test measures indicate that the WB group improved by 13ms and the RB group improved by 24ms, whereas the control group remained the same. These results suggest that less dynamic tasks such as RB training may improve the attentional demand of a static postural task more than a highly dynamic task such as WB training. Studies have shown that more difficult postural tasks equate to slower reaction times during a dual task condition (9). Therefore, a significant difference between the intervention groups and the control group may have been found if the postural task being measured was more difficult; therefore demanding more attention and allowing greater room for reaction time improvements. Improvement in attention has previously been shown following balance training interventions using biofeedback and virtual reality (11) but results were not compared with a control group.

Static balance measured by postural sway was not shown to change as a result of the training intervention. Throughout the study, participants were shown to sway more in the medial-lateral direction because of the narrower base of support in that direction. Group sway averages in both directions were significantly lower for the WB group but did not change as a result of the intervention. As shown in previous studies, sway values have not been shown to change with static or dynamic training using biofeedback (11, 13, 14) or with virtual reality (11). These results suggest that measuring sway values with feet together may not be an effective way to measure changes in static balance. It is possible that the task was not sensitive enough to show improvement because it was too automatic. For example, if participants felt that sway was under control their attention may have drifted away from the task. Alternatively, changing the support surface, removing vision, altering the head position or a combination of the above may yield measurable improvements (10). These more

difficult postural tasks would pose a threat to postural stability thereby forcing the subject to concentrate on the postural task.

Proprioception was shown to improve significantly for both the WB group and the control group between baseline values and post-test values; however the RB group did not improve. The improvement in the WB group is likely due to the high demands of training. The WB itself was observed tilting in various directions almost spontaneously during the intervention. These quick directional changes may be responsible for strengthening the sensitivity of the somatosensory, vestibular and muscular systems. Muscles were observed working constantly, especially in the lower leg as the feet moved in every direction; also resulting in movements of the head. Past research has shown that wobble-boards may improve ankle inversion discrimination (16) but no studies have previously examined the rocker-board. It is possible that because the predictable movements of the rocker-board are similar to walking (dorsiflexion and plantarflexion) this group did not improve. The control group's baseline performance scores were high compared to the other groups and there were few participants ( $n = 5$ ). This bias may have been responsible for the significant improvement found for the ankle dorsiflexion discrimination variable. In summary, the high demand of wobble-board training may effectively improve ankle joint proprioception but the results are not conclusive due to the improvement of the control group.

### Conclusion

In conclusion, results show that balance-board training effectively improves the functional balance healthy elderly people. This suggests that making balance-board training a part of an exercise program can improve activities of daily living. Furthermore, training on a balance board may free attention normally used when standing to process other information

in the environment. However, this balance-board training study has not shown conclusive evidence that proprioception in the ankle joint can be improved; this implies that more research is needed to assess proprioception following balance training interventions. Finally, since many falls take place during dynamic exercise it can be suggested that balance-boards are effective at reducing the risk of falls because of significant improvements to functional balance.

#### Acknowledgements

The authors express gratitude to The Good Companions Seniors' Centre for their long-term hospitality and cooperation during the training intervention and testing.

#### References

1. Prudham, D., & Evans, J. G. (1981). Factors associated with falls in the elderly: a community study. *Age & Ageing*, 10(3), 141-146.
2. Campbell, A. J., Reinken, J., Allan, B.C., Martinez, G.S. (1981). Falls in old age: a study of frequency and related clinical factors. *Age & Ageing*, 10(4), 264-270.
3. Wade, M. G., & Jones, G. (1997). The role of vision and spatial orientation in the maintenance of posture. *Physical Therapy*, 77(6), 619-628.
4. Shumway-Cook, A., Woollacott, M. H. (2001). *Motor Control: Theory and Practical Applications* (2nd ed.). Baltimore, MD: Lippincott, Williams and Wilkens.
5. Nevitt, M. C., Cummings, S. R., Kidd, S., & Black, D. (1989). Risk factors for recurrent nonsyncopal falls. A prospective study. *JAMA*, 261(18), 2663-2668.

6. Lord, S. R., Clark, R.D., Webster, I.W. (1991). Postural stability and associated physiological factors in a population of aged persons. *Journal of Gerontology*, 46(3), M69-M76.
7. Kenshalo, D. R. (1979). Aging effects on cutaneous and kinesthetic sensibilities. In Han, S.S., Coons, D.H. *Special senses in aging*. Anna Arbor: University of Michigan.
8. Nashner, L. M. (1980). Balance adjustment of humans perturbed while walking. *Journal of Neurophysiology*, 44, 650-664.
9. Woolacott, M., Shumway-Cook, A. (2002). Attention and the control of posture and gait: a review of an emerging area of research. *Gait & Posture*, 16(1), 1-14.
10. Hu, M. H., & Woollacott, M. H. (1994). Multisensory training of standing balance in older adults: I. Postural stability and one-leg stance balance. *Gerontology*, 49(2), 52-61.
11. Bisson, E. (2004). *L'Effet de l'entrainement de l'equilibre par biofeedback visual et par realite virtuelle sur la demande attentionnelle et l'equilibre des personnes ages.*, University of Ottawa, Ottawa.
12. Xu, D., Hong, Y., Li, J., Chan, K. (2004). Effect of tai chi exercise on proprioception of ankle and knee joints in old people. *British Journal of Sports Medicine*, 38(1), 50-54.
13. Hamman, R., Longridge, N. S., Mekjavic, I., & Dickinson, J. (1995). Effect of age and training schedules on balance improvement exercises using visual biofeedback. *Acta Oto-Laryngologica*, 24(4), 221-229.

14. Hamman, R. G., Mekjavic, I., Mallinson, A. I., & Longridge, N. S. (1992). Training effects during repeated therapy sessions of balance training using visual feedback. *Archives of Physical Medicine & Rehabilitation*, 73(8), 738-744.
15. Bellew, J. W., Fenter, P. C., Chelette, B., Moore, R., & Lorenzo, D. (2005). Effects of a short-term dynamic balance training program in healthy older women. *Journal of Geriatric Physical Therapy*, 28(1), 4-8.
16. Waddington, G., Adams, R. (2004). The effect of a 5-week wobble-board exercise intervention on ability to discriminate different degrees of ankle inversion, barefoot and wearing shoes: a study in healthy elderly. *Journal of the American Geriatrics Society*, 52(4), 573-576.
17. Ryushi, T., Kumagai, K., Hayase, H., Abe, T., Shibuya, K., & Ono, A. (2000). Effect of resistive knee extension training on postural control measures in middle aged and elderly persons. *Journal of Physiological Anthropology & Applied Human Science*, 19(3), 143-149.
18. Waddington, G., Adams, R., Jones, A. (1999). Wobble board (ankle disc) training effects on the discrimination of inversion movements. *Australian Journal of Physiotherapy*, 45(2), 95-101.
19. Inness, L., Howe, J. (2002). The community balance and mobility scale (CB&M) - an overview of its development and measurement properties. *Synapse*, 22(1), 2-6.
20. Dickstein, R., Shupert, C. L., & Horak, F. B. (2001). Fingertip touch improves postural stability in patients with peripheral neuropathy. *Gait & Posture*, 17(2), 238-247.

21. Lentell, G., Baas, B., Lopez, D., McGuire, L., Sarrels, M., P, P. S. (1995). The contributions of proprioceptive deficits, muscle function, and anatomic laxity to functional instability of the ankle. *Journal of Orthopaedic & Sports Physical Therapy*, 21(4), 206-215.

### Captions to Illustrations

Figure 1. Group differences in average CB&M scores between baseline, post-training and retention measures.

Figure 2. Differences in average reaction time between baseline, post-training and retention measures with all groups combined.

Figure 3. Group differences in reaction time between baseline, post-training and retention measured during a dual task condition.

Figure 4. Group differences in average RMS values for both anterior-posterior and medial-lateral directions during quiet standing (static balance) between baseline, post-training and retention measures.

Figure 5. Group differences in angular displacement during ankle dorsiflexion used to between baseline, post-training and retention.

Table 1

Table 1 - Subject Characteristics			
	WB (n = 12)	RB (n = 11)	Control (n = 5)
Age (mean $\pm$ SD)	72.9 $\pm$ 4.62	73.1 $\pm$ 4.48	76.2 $\pm$ 5.50
MMSE (mean $\pm$ SD)	28.8 $\pm$ 1.21	28.7 $\pm$ 1.49	29.2 $\pm$ 0.84
Gender (M:F)	0:12	2:9	2:3
Height (cm) (mean $\pm$ SD)	157.0 $\pm$ 5.67	164.6 $\pm$ 12.75	162.5 $\pm$ 7.03
Weight (kg) (mean $\pm$ SD)	62.0 $\pm$ 10.94	73.6 $\pm$ 25.37	62.2 $\pm$ 8.90

WB = Wobble-board, RB = Rocker-board, MMSE = Mini Mental State Examination

Figure 1

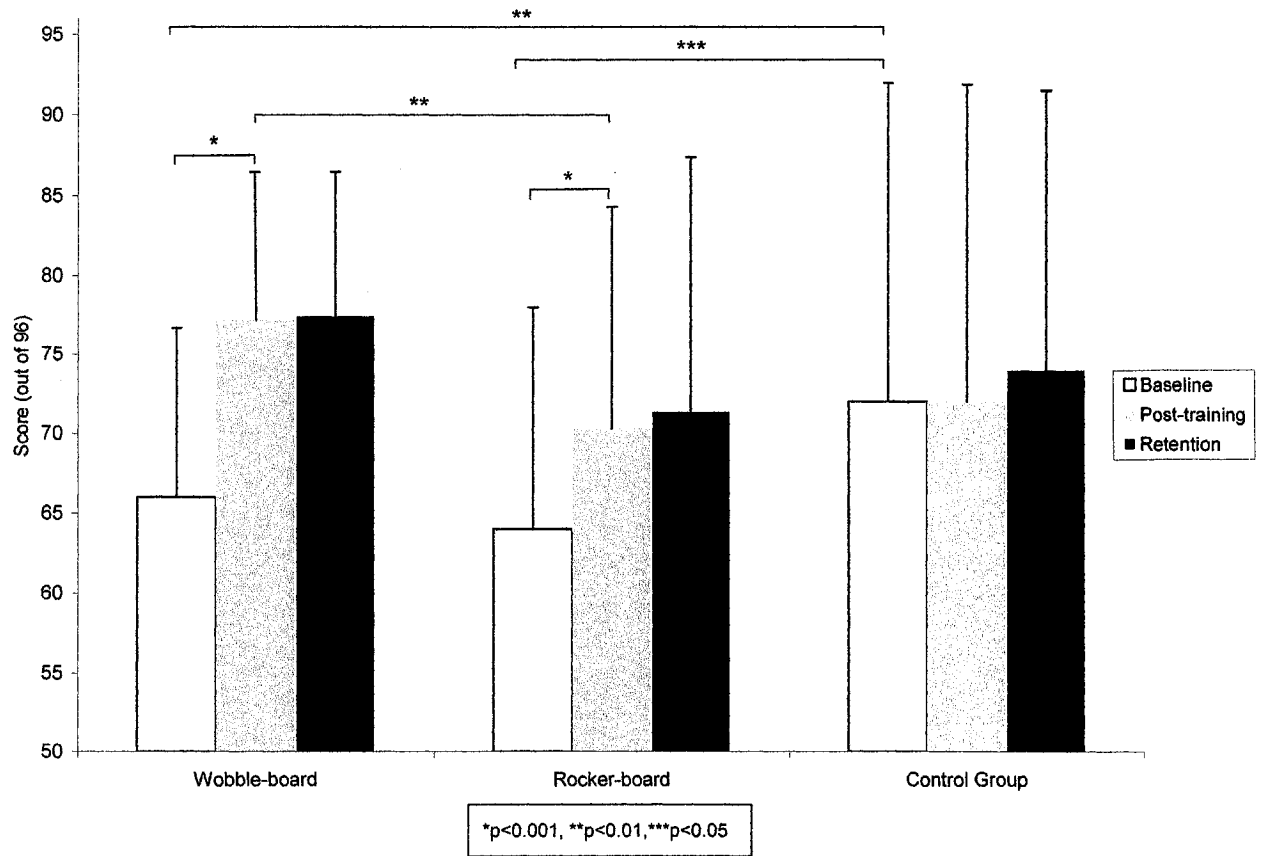


Figure 2

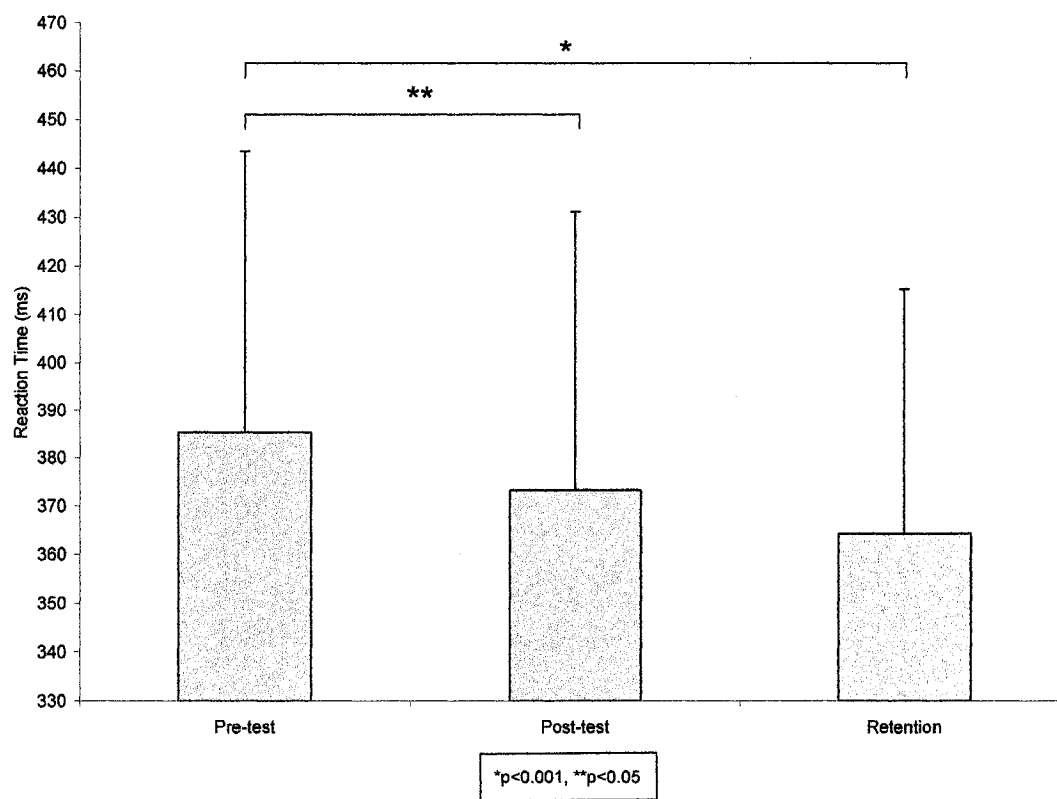


Figure 3

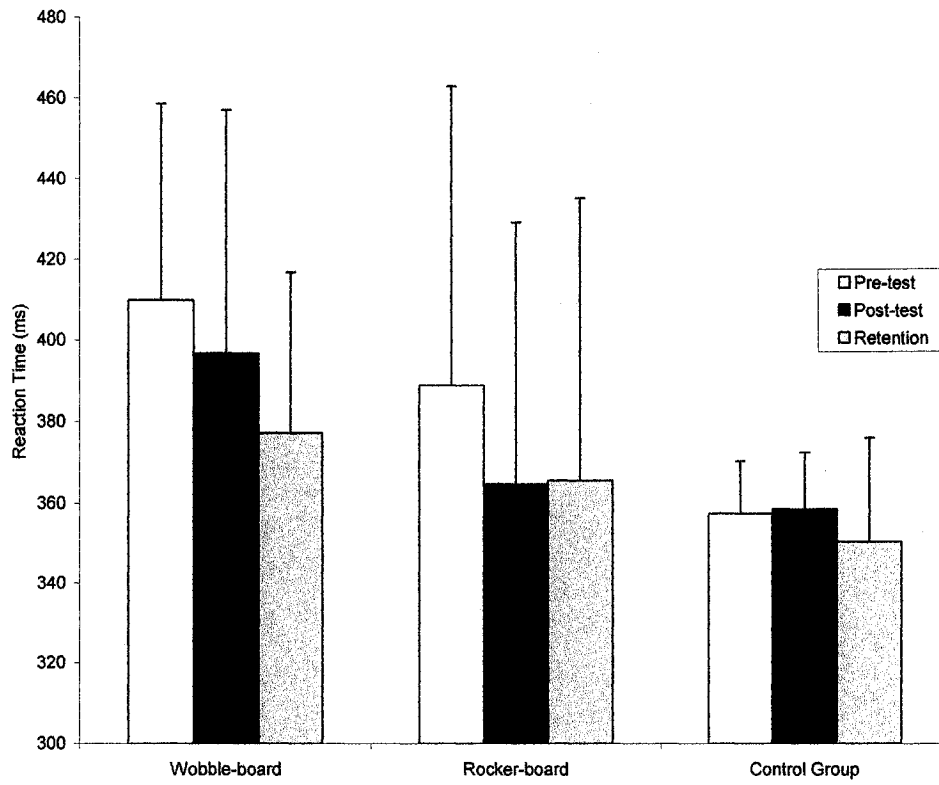


Figure 4

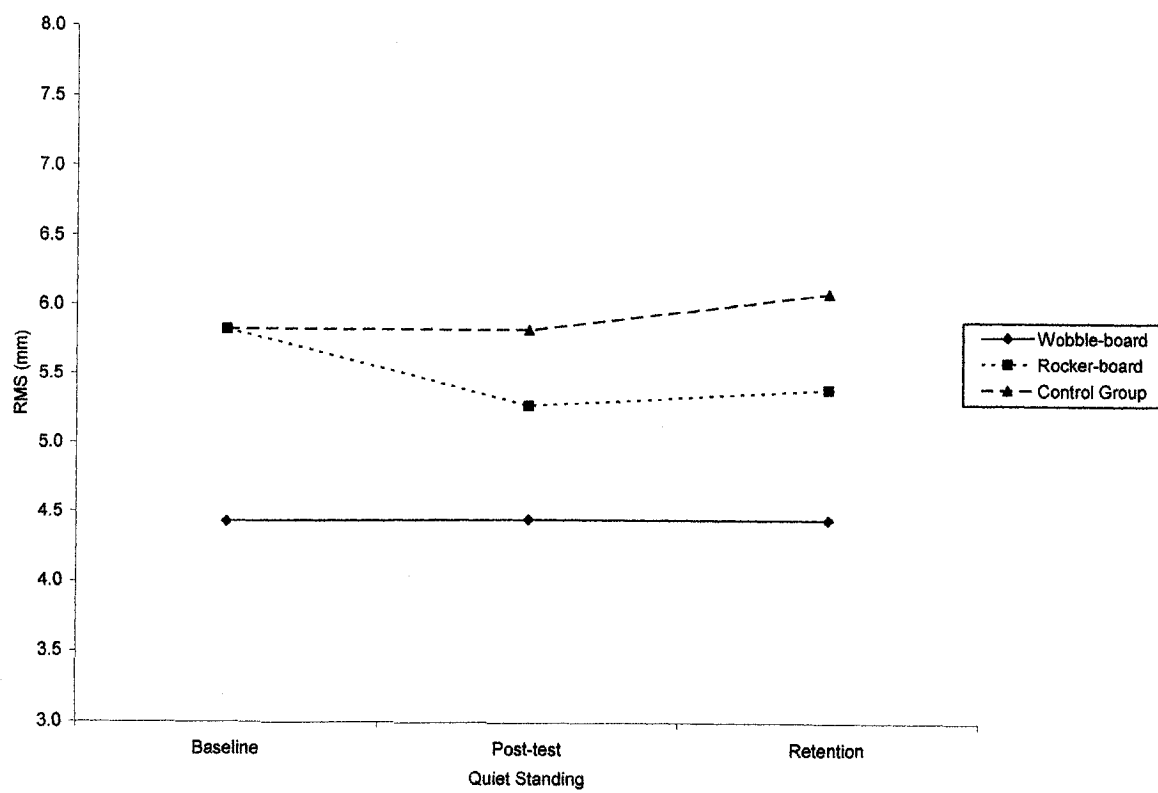
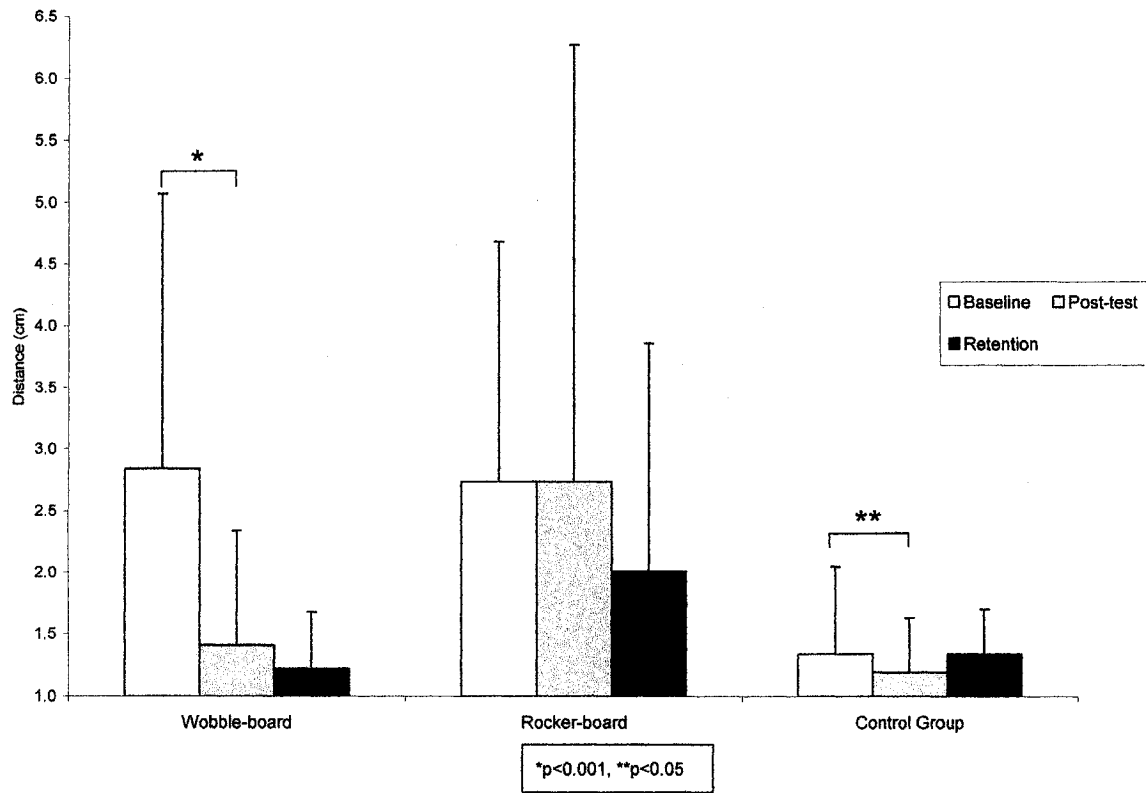


Figure 5



## CHAPTER IV

### General Discussion

This thesis examined the effectiveness of two balance-board training interventions to improve balance characteristics in healthy elderly people. It was hypothesized that the two types of balance-boards would improve balance characteristics following the intervention. The balance variables measured included functional balance, attentional demand, static balance and ankle dorsiflexion discrimination. The following discussion will focus on how the outcome measures changed following the eight week balance-board training intervention. Each variable is interpreted and discussed based on findings from past research. The first section of the discussion will revisit the differences between the wobble-board and rocker-board in terms of structure and observations made during the training intervention. The discussion will conclude with recommendations for further research and conclusions.

#### *Differences between the Wobble-board and Rocker-board*

The structure of the two balance-boards differed primarily because of their base of support. The wobble-board base of support is constructed of a half sphere; therefore, it has an unlimited number of degrees that it can tilt while a person is standing on it. The rocker-board has two parallel rocker-panels similar to a rocking chair; this limits the board to a predictable pattern of movement over a single axis. Therefore, it may be suggested that the wobble-board is more challenging.

The training program was intended to be challenging but safety was also an important concern. Each participant had a stable chair placed on each side as a safety measure. It was observed throughout the eight weeks of training that the wobble-board group was far more dependant on the chairs. The vast majority of participants (92%) used both chairs

simultaneously throughout each training session. Only one participant was observed letting go of the chairs on occasion. The rocker-board group began using both chairs but it was observed after approximately four weeks of training that the majority of participants (64%) were only using a single chair or using no chair at all. These observations suggest that the wobble-board is sufficiently challenging and the rocker-board allows participants to control the pace of their progression.

### *Changes in Functional Balance*

Functional balance was measured using the Community Balance and Mobility (CB&M) scale. The authors of the CB&M, Inness & Howe (2002) created the CB&M to identify balance and mobility impairments in a higher functioning population and to measure improvement after training interventions. It was designed to reflect the goals and activities of individuals functioning in the community, in other words, activities of daily living or activities requiring dynamic balance. The CB&M was used in this study because it consists of thirteen different tasks designed to avoid a ceiling effect, therefore it may be difficult for a healthy person to achieve a perfect score. It was hypothesized that both balance-board interventions would strengthen functional balance scores.

The CB&M scores improved significantly for both experimental groups and didn't change for the control group. The improvement for the wobble-board group (11 points) was nearly double the rocker-board group (6 points) showing that statistically the wobble-board will improve functional balance more than the rocker-board. It is possible that due to the unlimited degrees of movement provided by the wobble-board that strength and flexibility in the lower leg were improved more than the rocker-board. Furthermore, Bernstein's systems theory suggests that when many degrees of freedom need to be controlled, muscle synergies

help to accomplish the task. As stated by Shumway-Cooke and Woollacott (2001, p.18), muscle synergies are achieved by constraining certain muscles to work together as a unit. Bernstein (1967) put forward the idea that some aspects of postural control can be controlled by synergies on an unconscious level, just like breathing and walking. Using Bernstein's theory it can be predicted that the muscle synergies were reinforced more often during the wobble-board training due to the unlimited degrees of freedom. This 8-week rehearsal of the muscle synergies could explain the additional improvement observed in the wobble-board group.

Other possible contributions to the improvement in functional balance scores include increased balance confidence levels and the effect of home practice. First, balance confidence has been seen to improve following training interventions (Liu-Ambrose, Khan, Eng, Lord & McKay, 2004; Hakim, Burke, Hoy & Roberts, 2004) so it is possible that functional balance improved because the participants were more confident following the intervention. Increased confidence levels may be responsible for participants trying to move quicker and perform challenges that they may not have done during the baseline evaluation. Secondly, it is possible that participants remembered the CB&M exercises from their baseline evaluations and practiced them at home. Participants were asked not to start any new exercise programs besides the balance-board training and no participants reported practicing at home; however, a practice effect is still a possible consideration even though the control group did not improve.

The results of the CB&M have previously been shown to improve after balance-training interventions using elderly participants. Bisson (2004) showed that CB&M scores improved significantly after 10-weeks of training using virtual reality and visual biofeedback. Bisson's findings, in addition to the findings of the current study suggest that

different types of dynamic balance interventions can improve functional balance in healthy elderly people. Finally, CB&M scores were shown to remain the same from the post-test to the retention test. This indicates that the strategies and benefits from the training intervention were effectively learned by the participants.

#### *Changes in the Attentional Demand of a Postural Task*

Postural tasks are more attentionally demanding in older adults (Teasdale, Bard, LaRue & Fleury, 1993; Shumway-Cook et al., 1997) and more complex postural tasks equate to longer reaction times (Lajoie et al., 1996). The postural task used in this study was standing quietly with feet together and it was measured using a simple reaction time task. Other research has suggested that improved reaction time during a postural task following a training intervention is a result of postural task becoming more automatic (Lajoie, 2004; Bisson, 2004). The hypothesis in this study was that balance-board training would significantly reduce the attentional demands of quiet standing as shown by reducing reaction time during a dual-task.

Results revealed a significant decrease in reaction time between baseline scores (383ms) and post-test scores (371ms); however, there was no group difference or interaction between group and time. As previously mentioned, the reason dual-task reaction time improves is based on the theory that a training intervention results in the postural task becoming more automatic. This means that at some fundamental level, the nervous system has learned to control the postural task with less processing demands. Bernstein's theory (1967) suggested that muscle synergies can be formed and used on an unconscious level supporting Lajoie (2004) and Bisson's (2004) theory that postural tasks can become automatic.

The principle of specificity states that, "... training effects derived from an exercise program are specific to the exercise performed and muscles involved" (Balady et al., 2000, p.138). The intervention targeted postural muscles, therefore it could be predicted that postural muscle synergies were strengthened and that standing on the balance-boards became more automatic.

Assuming this is the case, the question remaining is why there was no significant improvement to reaction time following the intervention. The most likely explanation is that the postural task was not difficult enough to challenge the healthy elderly participants. If the postural task had been more difficult, such as standing with eyes closed or with heel touching toes (tandem stance) it would have been more difficult for participants to maintain their centre of pressure over their base of support; resulting in greater sway, especially bilaterally. The greater postural threat would consume more attention, making reaction time slower. This slower baseline measurement would have allowed greater room for greater improvement following the intervention and eliminating the ceiling effect. As a result, when comparing the experimental groups' reaction time results to a control group the improvements were not large enough to be statistically significant.

#### *Changes in Static Balance*

Postural sway was used in this study as a measure of static balance. It was measured both as an individual task and with reaction time as a secondary task. Results showed a significant difference between the three groups, a significant difference between the directions of sway (anterior-posterior & bi-lateral) and a significant interaction between group, direction of sway and the task being performed (dual task & standing). Past research measuring sway during quiet standing has shown not to change after a balance training

intervention using visual biofeedback (Bisson, 2004; Lajoie, 2004; Hamman et al., 1992) or virtual reality (Bisson, 2004). The findings in this study are in accordance with the findings of past studies, therefore, the hypothesis that static balance values would improve proved false.

It has been reported that highly skilled athletes such as dancers with good balance have shown an increased range of sway (Brauer, 1998); this is likely because they have a high awareness of their limit of stability and do not constrain themselves to sway less. On the other end of the spectrum, Horak (1992) reminds us that patients with neurological disorders such as Parkinson's disease have shown reduced sway which may be due to stiffness and rigidity. The participants in the current study were not elite athletes, nor were they unhealthy, so it was reasonable to anticipate a static balance improvement. However, since participants were asked to stand still it is likely that the lack of improvement was due to the postural task being too easy.

As a result of the postural task not being challenging enough it is possible that the participants did not use strategies that they may have acquired during the intervention to reduce sway. For example, when practicing balance-board exercises for consecutive weeks the participants learned strategies to control the movement of the balance-board. The strategies may have included bending the knees and visually focusing on a fixed point. The static balance task during the evaluation was to stand 'as still as possible' with the feet together. If this task was not challenging enough then the participants may not have tried using these strategies to reduce sway. In summary, the dynamic training intervention was not specific to the type of static balance task being evaluated. Alternatively, had the postural task included a combination of: standing on foam, altered vision, altered stance (tandem) or with

an altered head position as previously used by Hu & Woollacott (1994) there may have been a significant improvement in static balance.

There was a significant difference between the groups indicating that the wobble-board group swayed less than the rocker-board group and the control group. There was no difference between the control group and the rocker-board group. This suggests that throughout the study the wobble-board group had and maintained better static balance.

The significant difference between the directions of sway can be explained by the base of support. When standing with feet together the base of support in the medial-lateral direction is smaller than in the anterior-posterior direction. This would result in more sway occurring in the medial-lateral direction. The root mean squared (RMS) in the medial-lateral direction was 5.54mm compared to 5.20mm in the anterior-posterior position. Similar results were shown by Bisson (2004).

The interaction between the groups, sway direction and task occurred under two conditions, 1) between the quiet standing task (ant-post) and the dual-task (ant-post), the control group increased sway and the rocker-board group decreased sway significantly; 2) between the quiet standing (med-lat), and the quiet standing (ant-post) the control group swayed significantly less in the ant-post direction and swayed slightly more in the med-lat direction. The first condition suggests that the control group may not have been focusing on the postural task during the dual-task condition because of the increased sway in the ant-post direction. The second condition suggests that the control group which swayed significantly more from side-to-side was less focused and allowed sway to deteriorate in the direction where there was less base of support.

Over the three measurement periods there were no noticeable improvements in static balance. It may have been possible that standing with feet together created a ceiling effect for

healthy elderly subjects; therefore the test was not sensitive enough to measure improvements over time. If the postural task was not challenging, the participants may have felt that there was no need to constrain their movement. Dickstein, Shupert and Horak (2001) used a task such as standing on foam with eyes closed to measure static balance. Initially, this type of task may produce great sway values but leave room for improvement following a training intervention.

#### *Changes in Ankle Joint Dorsiflexion Discrimination*

Proprioception is a component of the somatosensory system which can provide information to the central nervous system about muscle length and tension. Golgi tendon organs and muscle spindles help detect changing joint angles around the body and are present in the ankle joint and surrounding tendons. In this study proprioception was recorded by initiating passive dorsiflexion in the ankle joint and measuring the distance required for the participant to recognize the movement. It was hypothesized that a balance-board intervention would reduce the angular displacement required for the participant to recognize dorsiflexion in their ankle joint.

The results showed that dorsiflexion discrimination results improved significantly between baseline values and post-test values. Results showed that both the wobble-board group and control group improved between baseline and post-test measures; the rocker-board group did not change over time. Therefore, the significant effect over time was due to the improvement in both the control and wobble-board groups. There was also a significant interaction between testing periods and group results. The interaction was a result of the rocker-board group not changing between the baseline evaluation and post-test, while the other groups improved.

The wobble-board group improvement is likely a reflection of the unlimited degrees of freedom of the wobble-board. Observations during the training sessions revealed that participants trying to move their board in a specific direction experienced perturbations in directions oblique to the direction of intended movement. Overall, participants were observed wobbling in various directions unintentionally. Bernstein's systems model (1967) can be used to explain how muscle synergies being formed from this type of training would also improve the proprioception in the ankle joint. Furthermore, the wobble-boards have been shown to cause muscle contractions between 20% and 80% of maximum (as determined by electromyography) in muscles surrounding the lower leg including the tibialis anterior, gastrocnemius and peroneus longus (Soderberg et al., 1991).

The rocker-board group showed no improvement in proprioception. In contrast to the wobble-board, the rocker-board only moves from side-to-side or front-to-back, therefore it is not very different from walking. Walking consists of both dorsiflexion and plantarflexion of the ankle joint which is similar to the front-back motion of the rocker-board. The side-to-side motion of the rocker-board may have involved slight eversion and inversion of the ankle joint; however it was mostly knee and hip flexion that were responsible for the movement. It is possible that rotating the rocker-board  $\pm 45^\circ$  to allow diagonal movement would improve proprioception but this exercise was not considered. Nonetheless, the rocker-board does not compare to the unpredictable nature of the wobble-board.

As mentioned above, the improvement of the control group contributed to the significant main effect that time had on the proprioception measurement. This result suggests that proprioception improves with no intervention. This contradicts knowledge that without training, human systems decrease in sensitivity; including the somatosensory system (Kenshalo, 1979; Whanger & Wang, 1974). No previous balance-board studies have shown

proprioception improvement in control subjects (Waddington et al., 1999; Waddington & Adams, 2004). It is possible that the control group may have been too small and upon further study would reveal similar results to other controlled studies. In addition, upon further analysis of the control group it can be observed that this group had significantly higher baseline values for functional balance. This demonstrates that this group was superior compared to the experimental groups. Physical activity questionnaires also showed a higher activity level for this group compared to experimental groups. These factors may have unknowingly created a statistical bias from the beginning of the study based on the possibility that the statistically different control group would respond differently, albeit unexpectedly to the intervention.

In summary, it is likely that the high demand of wobble-board training effectively improved ankle joint dorsiflexion discrimination; however, due to the fact that the control group also improved further study is needed and results are not conclusive. The rocker-board intervention showed no improvement and therefore may not be effective at improving ankle dorsiflexion discrimination in healthy elderly.

#### *Balance-board use in a Group Environment*

The training groups used the balance-boards in the fitness room of a seniors' centre. Participants traveled to and from the centre to their homes by walking, driving or using public transportation. Training groups were never larger than eight people and most participants didn't know each other prior to the study. The training lasted approximately twenty minutes including some breaks between exercises. During some of the less attentionally demanding tasks (side-side or front-back movement), participants interacted making the exercise more enjoyable. Interactions often involved conversations about their

balance-board progress and the difficulty of certain exercises. The instructor observed that it was a supportive and positive group environment. Furthermore, there were no incidents of falls, injuries or problems resulting from the balance-board training. Appropriate supervision by the instructor may have been the reason why there were no reported problems.

Many participants joined the study because they had other commitments at the centre during two or more days of the week. Participants observed that many of their friends were not interested in joining the study because of the time commitment of having to travel to the centre at least three days per week for only twenty to thirty minutes. Furthermore, others reported that their friends or associates were scared of falling off the balance-boards and causing injury. Upon completion of the training, the general consensus was that participants would continue training on the balance-board if they could do it at home but they could not afford the time to train away from home long-term. This feedback suggests that the value of supervised group training is not very high among healthy seniors. Home balance-board training could be safe but more information is needed on this subject. It is possible that seniors would value supervised balance-board training more if they felt more strongly about treating preventing impaired balance. It is also possible that balance impaired seniors would value supervised balance-board classes and healthy seniors would value home training.

#### *Balance-board use in the home environment*

Thus far results have shown that balance-board training improves functional balance and proprioception (Waddington & Adams, 2004). Results also showed a trend towards balance-board training improving attentional demands of a postural task. As a result, balance-board training can be deemed practical for home use based on certain assumptions about the trainee: he/she will train safely, can afford to purchase a balance-board, understands how to train or has a training program, and will train on a regular basis. The

most important criterion for a healthy senior to achieve results on the balance-board is to practice. An elderly person purchasing their own board would have more opportunities to practice. If proper precautions are taken (use of a chair or wall) when practicing, it can be done safely on an individual basis. Seeking advice from a professional may also be necessary to learn the exercises that will help improve balance. Finally, if safety is in question, the rocker-board may be a worthwhile investment.

### *Conclusions and Recommendations*

Healthy elderly need balance training to help increase the sensitivity of balance related systems. Strength training alone has not been shown to improve balance in the elderly. Good balance can increase the quality of daily living activities and reduce the risk of fall related injuries. Different types of balance training such as biofeedback, virtual reality, tai chi and training on foam rollers have shown to improve balance in healthy elderly but some of these interventions require elderly people to leave their home if the training is available in their area. Balance-boards present the opportunity for elderly to choose training in a group or home environment.

Both balance-board types were shown to significantly improve functional balance in healthy elderly people. The rocker-boards produced adequate improvements and are recommended for less active elderly people who have lower baseline balance measures. Wobble-boards are recommended for more active elderly people who desire to improve strong baseline balance measures. Wobble-board training resulted in greater functional balance improvements possibly due to the greater difficulty level. The wobble-board may challenge the lower body enough to strengthen muscle synergies, increase strength and flexibility in the lower leg.

Balance-board training was shown to create a trend towards improving the attentional demands of standing. It was suggested that dynamic exercises produce little improvement in attentional demands measured during a static postural task; therefore, a recommendation for future research is to measure dual-task reaction time during a dynamic postural task such as standing on a balance-board or on another unstable surface. Since elderly are more likely to fall during dynamic activities it would be important to discover if attention can be improved using a dynamic postural task to measure attention. The result could reveal that dynamic exercise mostly improves dynamic balance; whereas static exercise mostly improves static balance.

Finally, proprioception as measured in this study was shown to improve following the wobble-board intervention. Furthermore, the control group also significantly improved in the same amount as the wobble-board group. Therefore it is questionable if wobble-board training in this study improved proprioception in healthy elderly; as a result, more study is needed. Proprioception is very important to fall prevention because it has been shown to have a strong relationship with the quality of gait. Future studies could measure the effects of balance training on gait patterns in the elderly to help identify more ways to prevent falls during dynamic activities such as walking.

## CHAPTER V

## References

- Balady, G., Berra, K., Golding, L., Gordon, N., Mahler, D., Myers, J., Sheldahl, L. (2000). *ACSM's Guidelines for Exercise Testing and Prescription* (6th ed.). Baltimore: Lippincott Williams and Wilkins.
- Behm, D. G., Bambrury, A., Cahill, F., Power, K. (2004). Effect of acute static stretching on force, balance, reaction time, and movement time. *Medicine & Science in Sports & Exercise*, 36(8), 1397-1402.
- Bellew, J. W., Fenter, P. C., Chelette, B., Moore, R., & Lorenzo, D. (2005). Effects of a short-term dynamic balance training program in healthy older women. *Journal of Geriatric Physical Therapy*, 28(1), 4-8.
- Bernstein, N. (1967). *The Coordination and Regulation of Movement*. London: Pergamon.
- Bisson, E. (2004). *L'Effet de l'entrainement de l'equilibre par biofeedback visual et par realite virtuelle sur la demande attentionnelle et l'equilibre des personnes ages.*, University of Ottawa, Ottawa.
- Brauer, S. G. (1998). *Mediolateral postural stability: changes with age and prediction of fallers*. Doctoral dissertation, University of Queensland.
- Brauer, S. G., Woollacott, M., Shumway-Cook, A. (2001). The interacting effects of cognitive demand and recovery of postural stability in balance-impaired elderly persons. *J Gerontol A Biol Sci Med Sci*, 56(8), 489-496.
- Brouwer, B. J., Walker, C., Rydahl, S. J., & Culham, E. G. (2003). Reducing fear of falling in seniors through education and activity programs: a randomized trial. *Journal of American Geriatrics Society*, 51(6), 829-834.

- Campbell, A. J., Reinken, J., Allan, B.C., Martinez, G.S. (1981). Falls in old age: a study of frequency and related clinical factors. *Age & Ageing*, 10(4), 264-270.
- Chong, R. K., Ambrose, A., Carzoli, J., Hardison, L., Jacobson, B. (2001). Source of improvement in balance control after a training program for ankle proprioception. *Perceptual & Motor Skills*, 92(1), 265-272.
- Dickstein, R., Shupert, C. L., Horak, F. B. (2001). Fingertip touch improves postural stability in patients with peripheral neuropathy. *Gait & Posture*, 17(2), 238-247.
- Eichhorn, J., Orner, J., Rickard, K., Craik, R. (1998). Ageing effects on dual task methodology using walking and verbal reaction time. *Issues Aging*, 21, 8-12.
- Emery, C. A., Cassidy, J.D., Klassen, T.P., Rosychuk, R.J., Rowe, B.H. (2005). Effectiveness of a home-based balance-training program in reducing sports-related injuries among healthy adolescents: a cluster randomized controlled trial. *Canadian Medical Association Journal*, 172(6), 749-754.
- Fortinsky, R. H., Iannuzzi-Sucich, M., Baker, D. I., Gottschalk, M., King, M. B., Brown, C. J., et al. (2004). Fall-risk assessment and management in clinical practice: views from healthcare providers. *Journal of the American Geriatrics Society*, 52(9), 1522-1526.
- Gurfinkel, V. S., Levick, Y.S. (1991). Perceptual and automatic aspects of the postural body scheme. In *Paillard, J. Brain and Space*. New York: Oxford Science.
- Hakim, D., Burke, Hoy, Roberts. (2004). Differences in Balance Related Measures Among Older Adults Participating in Tai Chi, Structured Exercise, or No Exercise. *Journal of Geriatric Physical Therapy*, 27(1), 13-17.
- Hamman, R., Longridge, N. S., Mekjavic, I., & Dickinson, J. (1995). Effect of age and training schedules on balance improvement exercises using visual biofeedback. *Acta Oto-Laryngologica*, 24(4), 221-229.

- Hamman, R. G., Mekjavic, I., Mallinson, A. I., Longridge, N. S. (1992). Training effects during repeated therapy sessions of balance training using visual feedback. *Archives of Physical Medicine & Rehabilitation*, 73(8), 738-744.
- Hirschfeld, H. (1992). *On the integration of posture, locomotion and voluntary movement in humans: normal and impaired development.*, Karolinska Institute, Stockholm.
- Horak, F. B. (1992). Effects of neurological disorders on postural movement strategies in the elderly. In *Vellas, B., Toupet, M., Rubenstein, L., et al., Falls, balance and gait disorders in the elderly.* (pp. 137-152). Paris: Elsevier.
- Horak, F. B., Shupert, C. L., Dietz, V., Horstmann, G. (1994). Vestibular and somatosensory contributions to responses to head and body displacements in stance. *Experimental Brain Research*, 100(1), 93-106.
- Hu, M. H., & Woollacott, M. H. (1994). Multisensory training of standing balance in older adults: I. Postural stability and one-leg stance balance. *Gerontology*, 49(2), 52-61.
- Inglin, B., Woollacott, M.H. (1988). Age-related changes in anticipatory postural adjustments associated with arm movements. *Journal of Gerontology*, 43, m105-m113.
- Inness, L., Howe, J. (2002). The community balance and mobility scale (CB&M) - an overview of its development and measurement properties. *Synapse: Neurosciences Division Newsletter, Canadian Physiotherapy Association.*, 22(1), 2-6.
- Kenshalo, D. R. (1979). Aging effects on cutaneous and kinesthetic sensibilities. In *Han, S.S., Coons, D.H. Special senses in aging.* Anna Arbor: University of Michigan.
- Kerr, B., Condon, S. M., McDonald, L. A. (1985). Cognitive spatial processing and the regulation of posture. *Human Perception & Performance.*, 11(5), 617-622.
- Lackner, J. R., DiZio, P. (1988). Visual stimulation affects the perception of voluntary leg

- movements during walking. *Perception*, 17, 71-81.
- Lajoie, Y., Teasdale, N., Bard, C., Fleury, M. (1996). Upright standing and gait: are there changes in attentional requirements related to normal aging? *Experimental Aging Research*, 22, 185-198.
- Lajoie, Y. (2004). Effect of computerized feedback postural training on posture and attentional demands in older adults. *Aging-Clinical & Experimental Research*., 16(5), 363-368.
- Lee, D. N., Young, D.S. (1986). Gearing action to the environment. *Experimental Brain Research*, 15, 217-230.
- Liu-Ambrose, T., Khan, K. M., Eng, J. J., Lord, S. R., & McKay, H. A. (2004). Balance confidence improves with resistance or agility training. *Journal of Gerontology*, 50, 373-382.
- Lord, S. R., Clark, R.D., Webster, I.W. (1991). Postural stability and associated physiological factors in a population of aged persons. *Journal of Gerontology*, 46(3), M69-M76.
- Lord, S. R., Caplan, G.A., Ward, J.A. (1993). Balance, reaction time, and muscle strength in exercising and non-exercising older women: a pilot study. *Archives of Physical Medicine & Rehabilitation*, 74(8), 837-839.
- Lord, S. R., & Dayhew, J. (2001). Visual risk factors for falls in older people. *American Geriatrics Society*, 49(5), 508-515.
- Lundin-Olsson, L., Nyberg, L., Gustafson, Y. (1998). Attention, frailty, and falls: the effect of a manual task on basic mobility. *Journal of American Geriatrics Society*, 46(6), 758-761.
- Man'kovskii, N. B., Mints, A. Y., Lysenyuk, V. P. (1980). Regulation of the preparatory

- period for complex voluntary movement in old and extreme old age. *Human Physiology of Moscow*, 6, 46-50.
- Massion, J. (1992). Movement, posture and equilibrium: interaction and coordination. *Progress in Neurobiology*, 38(1), 35-56.
- Maylor, E. A., Wing, A. M. (1996). Age differences in postural stability are increased by additional cognitive demands. *Journal of Gerontology B*, 51(3), 143-154.
- Murphy, J., & Isaacs, B. (1982). The post-fall syndrome. A study of 36 elderly patients. *Gerontology*, 28, 265-270.
- Myers, A. M., Hamilton, N. (1985). Evaluation of the Canadian Red Cross Society's Fun and Fitness Program for Seniors. *Canadian Journal on Aging*, 4, 201-212.
- Nashner, L. M. (1980). Balance adjustment of humans perturbed while walking. *Journal of Neurophysiology*, 44, 650-664.
- Nevitt, M. C., Cummings, S. R., Kidd, S., Black, D. (1989). Risk factors for recurrent nonsyncopal falls. A prospective study. *JAMA*, 261(18), 2663-2668.
- Nordt, W. E., Sachatello, S.A., Plotkin, E.S., Dintino, K. (1999). The effects of single-axis balance board intervention on balance parameters in the elderly. *American Journal of Orthopedics*, 28(8), 447-450.
- Ochs, A. L., Newberry, J., Lenhardt, M.L., Harkins, S.W. (1985). Neural and vestibular aging associated with falls. In J. E. Birren, Schaie, K.W. (Ed.), *Handbook of Psychology of Aging* (pp. 378-399). New York: Van Nostrand & Reinholdt.
- Pai, Y. C., Rymer, W.Z., Chang, R.W., Sharma, L. (1997). Effect of age and osteoarthritis on knee proprioception. *Arthritis & Rheumatism.*, 40(12), 2260-2265.
- Petrella, R. J., Lattanzio, P.J., Nelson, M.G. (1997). The Effect of Age and Activity on Knee-Joint Proprioception. *American Journal of Phys. Med. Rehabilitation.*, 76, 235-241.

- Pitts, D. G. (1982). The effects of aging on selected visual functions: dark adaptation, visual acuity, stereopsis, and brightness contrast. In R. Sekular, Kline, D., Dismukes, K. (Ed.), *Modern aging research: aging and human visual function*. (pp. 131-160). New York: Alan R. Liss.
- Prudham, D., Evans, J. G. (1981). Factors associated with falls in the elderly: a community study. *Age and Aging*, 10(3), 141-1466.
- Rogers, M. E., Fernandez, J.E., Bohlken, R.M. (2001). Training to reduce postural sway and increase functional reach in the elderly. *Journal of Occupational Rehabilitation*., 11(4), 291-298.
- Rosenhall, U., & Rubin, W. (1975). Degenerative changes in the human vestibular sensory epithelia. *Acta Oto-Laryngologica*, 79(1-2), 67-80.
- Rubenstein, L. Z., Josephson, K.R., (1997). *Interventions to reduce the multifactorial risks for falling, in Gait Disorders of Aging: Falls and Therapeutic Strategies*. Philadelphia, PA.: Lippincott-Raven Publishing.
- Sandler, R. B., Burdett, R., Zaleskiewicz, M., Sprowls-Repcheck, C., Harwell, M. (1991). Muscle strength as an indicator of the habitual level of physical activity. *Medicine & Science in Sports & Exercise*, 23(12), 1375-1381.
- Shumway-Cook, A., Baldwin, M., Pollisar, N., Gruber, W. (1997). Predicting the probability of falls in community dwelling older adults. *Physical Therapy*, 77(8), 812-819.
- Shumway-Cook, A., Woollacott, M., Kerns, K., Baldwin, M. (1997). The effects of two types of cognitive tasks on postural stability in older adults with and without a history of falls. *Journal of Gerontology Series A-Biological Sciences & Medical Sciences*., 52(4), M232-240.
- Shumway-Cook, A., Woollacott, M. H. (2001). *Motor Control: Theory and Practical*

- Applications* (2nd ed.). Baltimore, MD: Lippincott, Williams and Wilkens.
- Soderberg, G. L., Cook, T.M., Rider, S.C., Stephenitch, B.L. (1991). Electromyographic activity of selected leg musculature in subjects with normal and chronically sprained ankles performing on a BAPS board. *Physical Therapy*, 71(7), 514-519.
- Studenski, S., Duncan, P. W., & Chandler, J. (1991). Postural responses and effector factors in persons with unexplained falls: results and methodologic issues. *Journal of American Geriatrics Society*, 39(3), 229-234.
- Sundermier, L., Woollacott, M., Jensen, J., Moore, S. (1996). Postural sensitivity to visual flow in aging adults with and without balance problems. *Journal of Gerontology*, 51a, m45-m52.
- Teasdale, N., Bard, C., LaRue, J., Fleury, M. (1993). On the cognitive penetrability of postural control. *Experimental Aging Research*, 19, 1-13.
- Tinetti, M. E., Baker, D., Gallo, W. T., Nanda, A., Charpentier, P., O'Leary, J. (2002). Evaluation of restorative care vs usual care for older adults receiving an acute episode of home care. *JAMA*, 287(16), 2098-2105.
- Tinetti, M. E., Richman, D., Powell, L. (1990). Falls efficacy as a measure of fear of falling. *Journal of Gerontology*, 45(6), 239-243.
- Waddington, G., Adams, R., Jones, A. (1999). Wobble board (ankle disc) training effects on the discrimination of inversion movements. *Australian Journal of Physiotherapy*, 45(2), 95-101.
- Waddington, G., Seward, H., Wrigley, T., Lacey, N., Adams, R. (2000). Comparing wobble board and jump-landing training effects on knee and ankle movement discrimination. *Medicine and Science in Sports and Exercise*, 3(4), 449-459.
- Waddington, G., Adams, R. (2004). The effect of a 5-week wobble-board exercise

- intervention on ability to discriminate different degrees of ankle inversion, barefoot and wearing shoes: a study in healthy elderly. *Journal of the American Geriatrics Society*, 52(4), 573-576.
- Wade, M. G., Jones, G. (1997). The role of vision and spatial orientation in the maintenance of posture. *Physical Therapy*, 77(6), 619-628.
- Whanger, A., Wang, H.S. (1974). Clinical correlates of the vibratory sense in elderly psychiatric patients. *Journal of Gerontology*, 29, 39-45.
- Woolacott, M., Shumway-Cook, A. (2002). Attention and the control of posture and gait: a review of an emerging area of research. *Gait & Posture*, 16(1), 1-14.
- Woolacott, M. H., Shumway-Cook, A., Nashner, L. (1986). Aging and posture control: changes in sensory organization and muscular coordination. *International Journal of Aging and Human Development*, 23(108).
- Woolacott, M. H., Tang, P.F. (1997). Balance control during walking in the older adult: research and its implications. *Physical Therapy*, 77(6), 646-660.
- Xu, D., Hong, Y., Li, J., Chan, K. (2004). Effect of tai chi exercise on proprioception of ankle and knee joints in old people. *British Journal of Sports Medicine*, 38(1), 50-54.

## Appendix 1 – Community Balance and Mobility Scale

### Community Balance & Mobility Scale\*(CB&M) Administration and Scoring

#### PHYSICAL SETTING

Much of the testing of the CM&M is designed to occur within a clinic setting upon a measured track. (The set-up is outlined below) The therapist must also have access to a full flight of stairs (min. 8 steps)

The following materials are required for testing:

- stop watch
- average size laundry basket or large rigid box of same dimension
- 2 lb, & 7 1/2 pound weights
- visual target used in Item 7  
(paper circle 20 cm. in diameter with a 5 cm, diameter black circle in the middle)
- bean bag

#### CLOTHING

The patient should wear comfortable clothing and enclosed, flat footwear. Footwear should be consistent on subsequent testing. The patient is allowed to use whatever orthotic is customarily worn at the time of testing.

#### RATING PROCEDURE

Use of **Ambulation Aides** All tasks are to be performed without ambulation aides (with one exception in Item 12 – Descending Stairs)

**Timed Tasks** The clock beside the title of an item indicates that the task is timed. ⌚

**Demonstration of Tasks** To ensure understanding of the tasks, the therapist should demonstrate all tasks while instructing the patient.

**Standardized Starting Position** Unless otherwise indicated, the following starting position should be used: standing feet slightly apart, arms at sides, head in neutral position with eyes forward, toes touching start line.

**Scoring Patient Performance** One practice trail is allowed to ensure understanding, except for the Unilateral Stance.

The therapist should judge the patient's performance in comparison to a young adult with a normal neuromusculoskeletal system.

Scale descriptors are details and precise. It is recommended that the grading criteria be reviewed well, including criteria for when the "test is over" prior to performing the tasks.

**Patient Safety** If in the therapist's clinical judgment the patient would be unsafe in performing part or all of a task, the patient should not attempt it. Score according to the guidelines if part of the task attempted or "0" if it is not attempted.

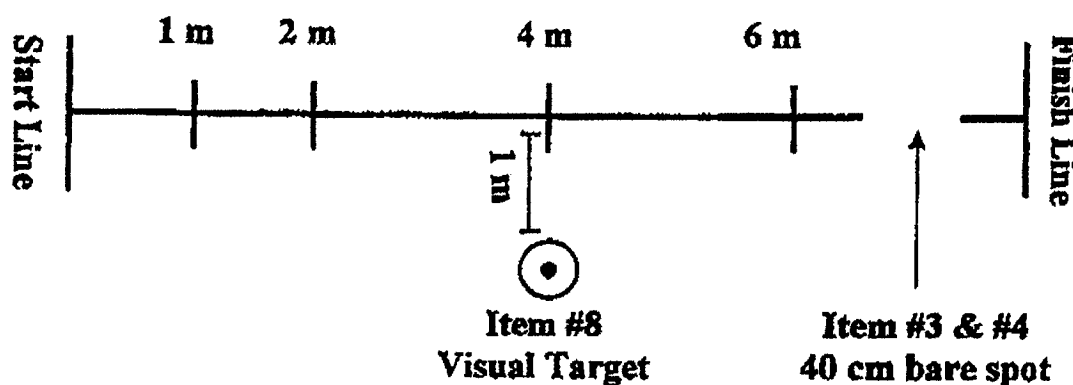
**Rest Periods** Rest periods are acceptable within or between tasks, as required

## DEFINITION OF TERMS

**Equilibrium Reactions** For the purpose of this measure, the term equilibrium reactions is defined as the use of movement strategies of the trunk and limbs to maintain centre of mass within the base of support

## THE TRACK

**Set-up** The total area recommended for testing is 10 meters by 2 meters. The track is an 8 meter line with a perpendicular start and finish line. It may be applied to the floor with paint or duct tape, 5 cm wide. The 1m, 2m, 4m and 6m points should be demarcated. A 40 cm bare spot for item # 3 and 4 as diagrammed below is recommended if taped is used. The visual target for Items 8 and 11 is placed at the 4m mark, at the patients eye level and 1 meter from the outside of the track.



**Use of the track for measurement** The track is used in two ways for measurement of the balance items:

- i) as a direct measurement, when foot placement on the line is part of the scoring criteria
- ii) as a reference to indicate whether the patient maintains a straight course or veers from a straight trajectory during the task eg. Walking & looking.

© 1998 Toronto Rehabilitation Institute/University of Toronto

\*This scale was initially developed as part of a IV yr. Physical Therapy project by a student from the University of Toronto. The student, Vasant Moro, was supervised by Jo-Anna Howe and Liz Inness

The scale is currently undergoing testing for reliability and validity by a research team: Jo-Anne Howe, Liz Inness, Molly Verrier and Jack Williams, Rehabilitation Institutes of Toronto; Depts. of Physical Therapy and graduate Department of Rehabilitation Science, University of Toronto; ICES.

**TORONTO REHABILITATION INSTITUTE**

**CB&M SCORE SHEET**

Date \_\_\_\_\_

Patient's Name \_\_\_\_\_

<b>Item</b>	<b>Score</b>	
1. Unsupported Unilateral Stance	R	
	L	
2. Tandem Walking		
3. 180° Tandem Pivot		
4. Lateral Foot Scooting	R	
	L	
5. Hopping Forward	R	
	L	
6. Crouch and Walk		
7. Lateral Dodging		
8. Walking and Looking	R	
	L	
9. Running with Controlled Stop		
10. Forward to Backward Walking		
11. Walk, Look & Carry	R	
	L	
12. Descending Stairs		
13. Step Ups	R	
	L	
<b>Total Score</b>		

## 1) Unilateral Stance ☹

- i) Test to be performed on the right leg
- ii) Test to be performed on the left leg

**Starting position:** Standardized starting position

**Instructions to Patient:**

Stand on you right/left les and hold as long as you can up to 45 seconds. Look straight ahead.

**Instructions to Therapist:**

Begin timing as soon as the patients' foot leaves the ground. So not allow the patient to brace the elevated leg against the supporting leg.

**Test is over:** Stop timing if stance foot moves from starting position or opposite foot touches ground.

**Grading:**

0	Unable to sustain unilateral stance independently, i.e. able to unweight leg for brief moments only
1	Able to sustain unilateral stance for 2-4 sec
2	Able to sustain unilateral stance for 5-9 sec
3	Able to sustain unilateral stance for 20-19 sec
4	Able to sustain unilateral stance for $\geq 20$ sec
5	Able to sustain unilateral stance for 45 sec, in a steady & coordinated manner
	NOT acceptable: excessive use of equilibrium reactions

## 2) Tandem Walking

**Starting position:** Standardized starting position but one foot is positioned on the 8m line.

**Instructions to Patient:**

Walk forward on the line heel touching toes. Keep your feet pointing straight ahead. Look ahead down the track, not at your feet. I will tell you when to stop.

**Instruction to Therapist:**

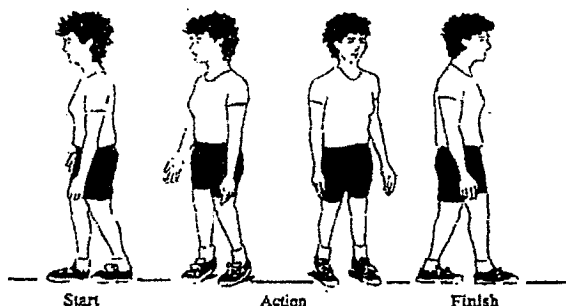
If able, allow the patient to take a maximum of 7 steps. For your scoring, count only those consecutive steps for which the heel is on the line and the heel-toe distance is < 8 cm (3 inches)

**Grading:**

- |   |   |
|---|---|
| 0 | Unable to complete 1 step on the line independently e.g.: Requires assistance, upper extremity support, or takes a protective step.   |
| 1 | Able to complete 1 step independently, acceptable to toe out  |
| 2 | Able to complete 2 or 3 steps consecutively on the line, acceptable to toe out  |
| 3 | Able to complete more than 3 steps consecutively, acceptable to toe out   |
| 4 | Able to complete more than 3 steps consecutively, in a good alignment (heel-toe contact, feet straight on the line, no toeing out), but demonstrates excessive use of equilibrium |
| 5 | Able to complete 7 steps consecutively, in good alignment (heel-toe contact, feet straight on the line, no toeing out), and in a steady * coordinated manner.                     |
| 5 | Not acceptable: excessive use of equilibrium reactions<br>Looking at feet   |

### 3) 180° Tandem Pivot

**Starting position:** Tandem stance on bare spot in track (see set up diagram) – aligned heel to toe, no toeing out, arms at sides, head in neutral position and eyes forward. Patient allowed to choose either foot in front and may use assist or upper extremity support to achieve, but not sustain, tandem stance.



**Instruction to Patient:**

Lifting your heels just a little, pivot all the way around to face the opposite direction without stopping. Put heels down and maintain your balance in this position.

**Instruction to Therapist:**

When right foot is in front in tandem position, patient to turn towards left. When left foot is in front in tandem position, patient to turn towards right. Therapist may assist patient to assume starting position.

**Test is over:** When patient puts heels down or steps out of position

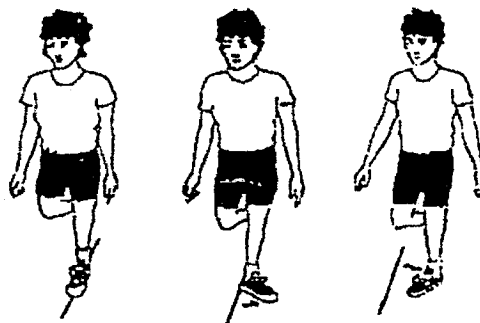
**Grading:**

- |   |  |
|---|--|
| 0 | Unable to sustain tandem stance independently, i.e. requires assistance or upper extremity support.  |
| 1 | Able to sustain tandem stance independently, but unable to unweight heels and/or initiate pivot.   |
| 2 | Able to initiate pivot, but unable to complete 180° turn.  |
| 3 | Able to complete 180° turn but discontinuous i.e. pauses on toes during pivot.   |
| 4 | Able to complete 180° turn in a continuous motion but unable to sustain reversed position.<br>NOT acceptable : heel-toe distance > 8cm (3 inches)  |
| 5 | Able to complete a 180° turn in a continuous and coordinated motion and sustain reversed position. Acceptable to have feet slightly angled out in reversed position.<br>NOT acceptable: heel-toe distance > 8cm (3 inches)<br>Excessive use of equilibrium reactions |

#### 4) Lateral Foot Scooting

Lateral foot scooting is defined as alternately pivoting on the heel and toe of one foot while moving sideways.

- i) move to the right when performing on right leg
- ii) move the left when performing on left leg.



**Starting position:** Standing on the line beside the bare spot in unilateral stance on right/left foot, arms at sides, Foot is perpendicular to the track.

#### **Instructions to Patient:**

Stand on your right/left leg and move sideways by alternately pivoting on you heel and toe. Keep pivoting until you reach the line and maintain your balance in this position.

#### **Instructions to Therapist:**

The patient moves laterally along the length of the bare spot and stops on the line. For the grading, one lateral pivot is defined as either pivoting on heel, moving toe lateral or pivoting on toes, moving heel laterally.

**Test is over:** When patient steps, hops, or touches opposite foot to floor

#### **Grading:**

- |   |  |
|---|--|
| 0 | Unable to sustain unilateral stance independently, e.g. requires assistance or upper extremity support.                        |
| 1 | Able to perform 1 lateral pivot in any fashion   |
| 2 | Able to perform 2 lateral pivots in any fashion  |
| 3 | Able to perform $\geq 3$ lateral pivots, but unable to complete 40cm   |
| 4 | Able to complete 40cm in any fashion, and/or unable to control final position  |
| 5 | Able to complete 40cm in continuous & rhythmical motion, demonstrating a controlled stop briefly maintaining unilateral stance |
|   | NOT acceptable: Pausing while pivoting to regain balance   |
|   | Veering from a straight line course  |
|   | Excessive use of equilibrium reactions   |
|   | Excessive trunk rotation while pivoting  |

## 5) Hopping Forward

- i) to be performed on right leg
- ii) to be performed on left leg

**Starting position:** Unilateral stance on right/left with entire foot on the track. Heel placed on inside edge of starting line.

### **Instruction to Patient:**

Stand on your right/left foot. Hop twice straight along this line to pass the 1 meter mark with your heel. Maintain your balance on you right/left leg at the finish.

### **Instruction to Therapist:**

It is recommended that the therapist assess safety prior to commencing task by having the patient hop in one spot. Patient is successful in completing 1 meter when the heel of the foot is touching or beyond the 1 meter line.

**Test is over:** if patient touches down with suspended foot between hops.

### **Grading:**

- |   |   |
|---|---|
| 0 | Unable to sustain unilateral stance independently or hop, i.e. requires assistance or upper extremity support   |
| 1 | Able to perform 1 or 2 hops sequentially with poor control, i.e. unable to sustain 1 foot landing for even brief moments, unable to complete 1 meter  |
| 2 | Able to perform 2 hops sequentially in a controlled manner, unable to complete 1 meter  |
| 3 | Able to complete 1 meter in 2 hops, but difficulty sustaining 1 foot landing, i.e. hops or pivots on stance foot to maintain landing. Acceptable to deviate from the line   |
| 4 | Able to complete 1 meter in 2 hops, but difficulty controlling landing, i.e. hops or pivots on stance foot to maintain landing. Acceptable to deviate from the line<br>NOT acceptable: touching down or stepping with opposite limb to achieve stability on landing |
| 5 | Able to complete 1 meter in 2 hops in a coordinated manner and sustain a stable landing<br>NOT acceptable: Deviate from the line<br>Excessive use of equilibrium  |

## 6) Crouch and Walk ⌚

**Starting position:** Standardized starting position. Bean bag is placed to the right or the left side of the 2 meter mark considering which hand the patient will use to pick it up.

**Instruction to Patient:**

Walk forward and, with out stopping, bend to pick up the bean bag and then continue walking down the line.

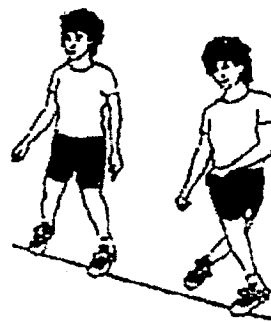
**Instructions to Therapist:**

This task is performed using only half of the track. Starting timing when the patient's foot leaves the ground. Stop timing when the both feet cross the 4 meter line. Patient should use the less affected upper extremity for the task. This will avoid down grading the scoop due to limitations of the upper extremity function as opposed to balance function.

**Grading:**

- |   |  |
|---|--|
| 0 | Unable to crouch (descend) to pick up bean bad independently i.e. Requires assistance or upper extremity support   |
| 1 | Able to crouch (descend), but unable to maintain crouch to pick up bean bag or rise to stand independently i.e. Requires assistance or touches hands down to floor                                     |
| 2 | Able to crouch to pick up bean bag and rise to stand independently but must hesitate at any time during activity i.e. Unable to maintain forward momentum  |
| 3 | Able to crouch and walk in a continuous motion (i.e. Maintain forward momentum) with time < 8 seconds and demonstrates protective step at any time during the task                                     |
| 4 | Able to crouch and walk in a continuous motion with time < 8 seconds and/or uses excessive equilibrium reactions to maintain balance at any time during the task<br>NOT acceptable: veering off course |
| 5 | Able to crouch and walk in a continuous and rhythmical motion with time $\leq$ 4 seconds<br>NOT acceptable: veering off course<br>Excessive use of equilibrium reactions                               |

## 7) Lateral Dodging Ⓛ



**Starting position:** Standing at the 2 meter mark with feet perpendicular to the track. The toes of both feet should cover the track.

**Instruction to Patient:** Move sideways along the line by repeatedly crossing one foot on front of and over the other. Place part of your foot on the line with every step. Reverse direction whenever I call “change”. Do this as fast as you can, yet at a speed that you feel safe.

**Instruction to Therapist:** Patient moves laterally back n forth along the line, between the 2 meter and 4 meter marks by repetitively crossing one foot over and in front of the other. One cross-over includes crossing one leg over to land beside the other and returning the back leg to an uncrossed position.

Once cycle requires the patient to cross-over for a 2 meter distance and return. The test requires that the patient performs two of these cycles (a total of 8 meters).

To cue the patient to change direction, call out “Change!” when one foot passes the 2 meter and 4 meter marks. The patient should believe directions changes are random. Begin timing as soon as the patient’s foot leaves the ground. Stop timing when both feet cross the final mark.

### Grading:

- |   |  |
|---|--|
| 0 | Unable to perform one cross-over in both directions without loss of balance or use of support.   |
| 1 | Able to perform cross-over in both directions with out use of support, but unable to contact the line with part of the foot.                           |
| 2 | Able to cross-over for 1 or more cycles to and from the 2 meter mark but unable to contact the line with every step.                                   |
| 3 | Able to perform 2 cycles in any fashion (to the 2 meter line and back <u>twice</u> ) and one part of each foot must contact the line during each step. |
| 4 | Perform 2 cycles as described in level 3 in from 12 to 15 seconds.   |
| 5 | Perform 2 cycles in less than 12 seconds in a continuous, rhythmical fashion with coordinated direction changes immediately after verbal cue.          |

## 8) Walking & Looking

- i) To be performed looking right
- ii) To be performed looking left

**Starting position:** Standardized starting position. (See set-up diagram for placement of visual target)

### **Instruction to Patient:**

Walk at your usual pace to the end of the line. I will tell you when to look at the circle. Keep looking at it while you walk past it. I will then tell you when to look straight ahead again. Try not to veer off course while you walk.

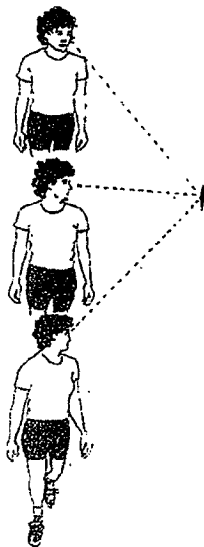
**Instruction to Therapist:** Score client as defined in the guidelines, irrespective to the underlying limiting impairments e.g: decreased neck or trunk rotation.

1. At the 2 m mark, ask the patient to “Look at the circle”.
2. Cue the patient to “Keep looking at the circle” as they look back over their shoulder until they reach the 6 m mark.
3. At the 6 m mark, ask the patient to “Look straight ahead and continue walking until the end of the line.

Stand in a location where the patient’s ability to maintain fixation can be assessed, that is, beside the target. Thus a second person may be needed to walk with the patient to ensure safety.

It is acceptable to continue to remind the patient of where they should be looking at each segment.

To score in the opposite direction, repeat task starting from opposite end of the line.



**Grading:**

- |   |   |
|---|---|
| 0 | Unable to walk & look i.e. Has to stop to look, or requires assistance or upper extremity support at any point during the test.   |
| 1 | Able to continuously walk and initiate looking but loses visual fixation on circle at or before 4 meter mark.   |
| 2 | Able to continuously walk & look, but loses visual fixation on circle after 4 meter mark ie. While looking back over the shoulder   |
| 3 | Able to continuously walk & fixate upon the circle between the 1 and 6 m mark. But demonstrates a protective step.  |
| 4 | Able to continuously walk & fixate upon circle between the 2 and 6 m mark, but veers off course at any time during task.  |
| 5 | Able to continuously walk & fixate upon circle between the 2 and 6 meter mark, maintains a straight path, in a steady & coordinated manner, time $\leq 7$ seconds.<br>NOT acceptable: inconsistent or reduces speed or looking down at feet |

## 9) Running with Controlled Stop ⌚

**Starting position:** Standardized starting position.

**Instruction to Patient:**

Run as fast as you can to the end of the track. Stop abruptly with both feet on the finish line and hold this position.

**Instruction to therapist:**

Begin timing when the initial foot leaves ground. Stop timing when both feet reach the finish line. It does not meter whether the feet land consecutively or simultaneously on both the finish line.

<b>Grading:</b>	
0	Unable to jog (with both feet off ground for brief instant), rather demonstrates fast walking or leaping from foot to foot.
1	Able to jog in any fashion, time > 5 seconds.
2	Able to jog in any fashion, time >3.0 sec but ≤ 5 sec, but is unable to perform a controlled stop with both feet on the line i.e. Uses protective step or excessive equilibrium reactions.
3	Able to jog in any fashion, time >3.0 sec but ≤ 5 sec, and perform a controlled stop with both feet on the line. NOT acceptable: excessive equilibrium reactions
4	Able to jog in any fashion, time >3.0 sec but is unable to perform a controlled stop with both feet on the line i.e. Uses protective step(s) or excessive equilibrium reactions
5	Able to jog in a coordinated and rhythmical manner and perform a controlled stop with both feet on the line, time ≤ 3.0 sec NOT acceptable: excessive equilibrium reactions

## 10) Forward to Backward Walking ⌚

**Starting position:** Standardized starting position

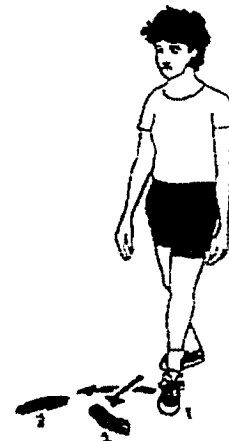
**Instructions to Patient:**

Walk forward to the half way mark, turn around and continue to walk backwards until I say "Stop". Try not to veer off course. Walk as quickly as you can, yet at a speed that you feel safe.

**Instructions to Therapist:**

Start timing when patient's foot leaves the ground. Stop timing when both feet cross the 8 meter finish line. The patient is to turn at the 4 meter mark. It is acceptable for the subject to turn in any direction s/he chooses. When counting the steps required to turn 180 deg.: i) the first step in the turn is angled away from the forward trajectory, ii) the last step in the turn completes the 180 deg. turn and is oriented toward the starting line, initiating backwards walking.

It is also acceptable to pivot on one foot rather than stepping around.



**Grading:**

0	Unable to complete task i.e. Requires assistance or upper extremity support
1	Able to complete task independently, but must stop to maintain/regain balance at any time during this task.
2	Able to complete the task without stopping but must significantly reduce speed i.e. Total time is >11 sec, AND/OR required 4 or more steps to complete the turn.
3	Able to complete task with time $\leq 11$ sec and/or veers from straight path during backwards walking.
4	Able to complete task in a continuous motion, time $\leq 9$ sec, and/or uses protective step(s) during or just after turn
5	Able to complete task in a continuous motion with brisk speed, time $\leq 7$ sec and maintaining a straight path throughout.

## 11) Walk, Look & Carry

- i) To be performed looking right
- ii) To be performed looking left

**Starting position:** Standardized starting position, but carrying a plastic grocery bag in each hand by the handle, with a 7 ½ lb. =3.4 kg weight inside the bag. (See set-up diagram for placement of visual target.

**Instruction to Patient:** Walk at your usual pace to the end of the line carrying the grocery bags. I will tell you when to look at the circle. Keep looking at it while you walk past it. I will then tell you when to look straight ahead again. Try not to veer off course while you walk.

**Instruction to Therapist:**

Same instructions as in Item 8 walking and looking. Patient to carry only one grocery bag if unable to perform bilaterally due to motor control problems of the upper extremity. Indicate on the score sheet is patient carried only one bag.

**Grading:**

0	Unable to walk & look i.e. Has to stop to look, or requires assistance or upper extremity support at any point during the test.
1	Able to continuously walk and initiate looking but loses visual fixation on circle at or before 4 meter mark.
2	Able to continuously walk & look, but loses visual fixation on circle after 4 meter mark i.e. While looking back over the shoulder
3	Able to continuously walk & fixate upon the circle between the 1 and 6 m mark. But demonstrates a protective step.
4	Able to continuously walk & fixate upon circle between the 2 and 6 m mark, but veers off course at any time during task.
5	Able to continuously walk & fixate upon circle between the 2 and 6 meter mark, maintains a straight path, in a steady & coordinated manner, time ≤ 7 seconds. NOT acceptable: inconsistent or reduces speed Looking down at feet

## 12) Descending Stairs

**Starting position:** Quiet standing at the top of the staircase (min. 8 steps). Depending on the patient's skill in the stairs, may begin by descending from the first or third step at the bottom of the flight.

**Instruction to Patient:** Walk down the stairs, try not to use the railing.

**Instruction to Therapist:**

Depending on patient's skill on stairs, may use a cane as in level 1 and 2.

<b>Grading:</b>	
0	Unable to step down 1 step OR requires the railing or assistance
1	Able to step down 1 step with/without use of cane NOT acceptable: use of railing (from this level onwards)
2	Able to step down 3 steps in any pattern with/without the use of a cane i.e. Step to pattern with/without cane or reciprocal pattern with cane
3	Able to step down 3 steps in a reciprocal pattern, without cane OR able to step down a full flight in a step-o pattern, without cane. NOT acceptable: use of cane (from this level on)
4	Able to step down a flight in a reciprocal pattern but awkward, uncoordinated
5	Able to step down a flight in a reciprocal pattern in a rhythmical and coordinated manner

### BONUS

Using therapist's discretion and for those patients who have achieve level 4 or 5, add 1 bonus point id the patient can descend the stairs while carrying a weighted basket. (laundry basket with 2 lb. weight in it). The basket should be held at waist level to obstruct vision.

Acceptable to look down the flight once at the top of the stairs. Instruct the patient, "try not to look at you feet".

If the patient us unable to hold the basket with one or both arms, their maximal score is a "5".

NOT acceptable: to look at feet during descent

### 13) Step Ups x 1 Step Ⓞ

- i) To be performed leading with the right leg
- ii) To be performed leading with the left leg

**Starting position:** Standardized starting positioning from the step at bottom of stairs.

**Instruction to Patient:**

- i) Step up and down on this step as quickly as you can until I say "Stop". The pattern is Right-Left UP and Right-Left Down. Try not to look at your feet.
- ii) Step up and down on this step as quickly as you can until I say "Stop". The pattern is Left-Right Up and Left-Right Down. Try not to look at your feet.

**Instruction to Therapist:**

Start timing when the patient's foot leaves the ground. Stop timing after the completion of 5 cycles. A cycle is one complete step up and down.

**Grading:**

0	Unable to set up independently, requires assistance and/or railing to ascend
1	Able to step up independently, but unable to step down independently i.e. requires railing and/or assistance to descend
2	Able to step up & down (1 cycle) independently without railing or assistance. Acceptable to look at feet.
3	Able to complete 5 cycles. Acceptable to demonstrate uncoordinated or inconsistent speed/rhythm. NOT acceptable: to look at feet
4	Able to complete 5 cycles in 7 to 10 seconds. Acceptable as in Level 3 NOT acceptable: as in level 3
5	Able to complete 5 cycles in $\leq 6$ sec, in a rhythmical & coordinated manner NOT acceptable: to look at feet inconsistent speed/rhythm


## Appendix 2 – Mini Mental State Examination

<b>Mini-Mental State Examination (MMSE)</b>
---

Patient's Name: \_\_\_\_\_

Date: \_\_\_\_\_

**Instructions: Score one point for each correct response within each question or activity.**

Maximum Score	Patient's Score	Questions
5		"What is the year? Season? Date? Day? Month?"
5		"Where are we now? State? County? Town/city? Hospital? Floor?"
3		The examiner names three unrelated objects clearly and slowly, then the instructor asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible.
5		"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, ...) Alternative: "Spell WORLD backwards." (D-L-R-O-W)
3		"Earlier I told you the names of three things. Can you tell me what those were?"
2		Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.
1		"Repeat the phrase: 'No ifs, ands, or buts.'"
3		"Take the paper in your right hand, fold it in half, and put it on the floor." (The examiner gives the patient a piece of blank paper.)
1		"Please read this and do what it says." (Written instruction is "Close your eyes.")
1		"Make up and write a sentence about anything." (This sentence must contain a noun and a verb.)
1		"Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.)  
30		TOTAL

**Interpretation of the MMSE:**

Method	Score	Interpretation
Single Cutoff	<24	Abnormal
Range	<21	Increased odds of dementia
	>25	Decreased odds of dementia
Education	21	Abnormal for 8 <sup>th</sup> grade education
	<23	Abnormal for high school education
	<24	Abnormal for college education
Severity	24-30	No cognitive impairment
	18-23	Mild cognitive impairment
	0-17	Severe cognitive impairment

**Interpretation of MMSE Scores:**

Score	Degree of Impairment	Formal Psychometric Assessment	Day-to-Day Functioning
25-30	Questionably significant	If clinical signs of cognitive impairment are present, formal assessment of cognition may be valuable.	May have clinically significant but mild deficits. Likely to affect only most demanding activities of daily living.
20-25	Mild	Formal assessment may be helpful to better determine pattern and extent of deficits.	Significant effect. May require some supervision, support and assistance.
10-20	Moderate	Formal assessment may be helpful if there are specific clinical indications.	Clear impairment. May require 24-hour supervision.
0-10	Severe	Patient not likely to be testable.	Marked impairment. Likely to require 24-hour supervision and assistance with ADL.

**Source:**

- Folstein MF, Folstein SE, McHugh PR: "Mini-mental state: A practical method for grading the cognitive state of patients for the clinician." *J Psychiatr Res* 1975;12:189-198.



## Appendix 4 – Health Status Questionnaire

**Health Status Questionnaire**

Participant's Name: \_\_\_\_\_

Height (cm): \_\_\_\_\_

Weight (kg): \_\_\_\_\_

Date of Birth (dd/mm/yy): \_\_\_\_\_

Sex (M / F)

Have you fallen in the past six months? YES \_\_\_\_\_ NO \_\_\_\_\_

Do you have any of the following medical conditions?

	YES	NO
An illness of the nervous system such as Parkinson's or Huntington's.		
Heart disease or a past heart-attack or stroke.		
Diabetes		
Injury to your upper-body in the past 6 months.		
Injury to your lower-body in the past 6 months.		
Loss of sensation (peripheral neuropathy)		
Arthritis in your lower body.		
Severe back pain.		
Uncorrectable problems with your vision.		

Do you currently take any medication ?

If yes, for which condition?

Current (1) &amp; Future (2) activities :

Appendix 5 – Consent Form



uOttawa

Université d'Ottawa  
École des sciences de  
l'activité physique  
(Secrétariat scolaire)

University of Ottawa  
School of Human  
Kinetics  
(Academic Secretariat)

## Consent Form

### Balance-board training for seniors

Name of researcher (Supervisor): Yves Lajoie, PhD.

Institution, Faculty, Department: University of Ottawa, School of Human Kinetics, Health Sciences

Telephone number: (613) 562-5800 ext. 4273

Email address: ylajoie@uottawa.ca

Name of researcher (Masters Student): Bruce Contant

Institution, Faculty, Department: University of Ottawa, School of Human Kinetics, Health Sciences

Telephone number:

Email address: contantb@sympatico.ca

I, \_\_\_\_\_ agree to participate in this research conducted by Bruce Contant, a masters student studying at the University of Ottawa, faculty of Health Sciences, school of Human Kinetics. The project is under the supervision of Yves Lajoie, Ph.D.

#### PURPOSE OF THE STUDY:

The purpose of this research is to know more about how training with a wobble-board affects the balance of seniors. I understand that the aim of this study is to verify the improvement of certain characteristics of my balance following a supervised training on a wobble-board. The researchers want to demonstrate that balance training can improve ankle sensation, improve posture and decrease the attention level required to perform balance challenging activities.

#### ELIGIBILITY:

To participate in this study, I must be between 65 and 75 years old. I must be free of any joint related health problem due to arthritis or past injury. I must be free of any heart conditions. Lastly, I must not suffer from any vision problems that cannot be corrected by wearing glasses.

☎ 613 562-5853  
☎ 613 562-5149

125 Université / University  
Ottawa ON K1N 6N5 Canada

www.uOttawa.ca

## PARTICIPATION:

My participation will consist of testing and training sessions over a 12 week period. The sessions will be divided into 3 evaluation sessions and 24 supervised wobble-board training sessions. The following table summarizes the twelve week study. If I am randomly selected to participate in the control group, I will not participate in the training portion.

<u>Research Timeline</u>	
Week 1	Questionnaires, Evaluation, Training
Weeks 2 – 7	Training
Week 8	Training and Evaluation
Week 12	Evaluation

### Questionnaires

1. Health questionnaire. To determine if the evaluations or training sessions could pose any potential health risks to you, the participant.
2. Mini-mental state evaluation. To ensure that you are mentally compatible for this study.

### Evaluation

1. Reaction time. Responding to a beep while sitting on a chair.
2. Postural sway. Standing without shoes on a flat device that will measure my balance and center of pressure.
3. Attentional demand. Measurement of reaction time while standing.
4. Ankle proprioception. This will test the sensation in my ankle by placing my foot on a device while sitting and by moving my foot in various directions as instructed.
5. Balance tests. I will be scored on thirteen balance tests that include: walking, climbing stairs and bending down to pick something up while walking. During this test I will wear a safety belt. I will also be filmed for further analysis, which will be kept completely confidential.

### Balance-board training

1. I will perform 8 different exercises on the wobble-board lasting approximately 16 minutes (not including a light warm-up and stretching).
2. Training will be guided and supervised by the researcher.
3. I will have a chair on each of my sides to be used as a safety device.

**RISKS:**

I understand that I may feel tired during or following an exercise session due to the physically demanding nature of the training. I understand the researcher will allow me to take breaks as needed when I feel tired. I realize that I will not be judged if I cannot perform all the exercises requested by the researcher.

I realize that all the participants in this study will not be at the same skill level during the training session. I therefore may feel inferior to the others if I have difficulties with the exercises and develop a certain lack of self-confidence. However, I know that the researchers will encourage all the participants equally and that I will not be judged if I have difficulties executing certain movements.

I know that that training on a wobble-board is balance challenging and that there is a risk of falling. I will have two safety supports, one on my right and one on my left to prevent me from losing my balance and falling. I may continually use these supports if I desire to.

**BENEFITS:**

During the study, I will have a chance to improve my balance and my posture if the exercises are executed properly and if I attend all of the sessions. This may help prevent a falls or injuries related to the loss of balance.

This study will also be beneficial for the advancement of balance and posture training. The researchers will be able to determine which characteristics of balance have been improved by wobble-board training and which board-type is most effective. This knowledge will help trainers, physiotherapists and other health specialists prescribe exercises designed to improve balance.

**CONFIDENTIALITY AND DATA KEEPING:**

I have the assurance from the researchers that the information I will share with them will remain strictly confidential and will be used for research only. The videotapes will be kept in a locked filing cabinet located in a private laboratory at the University of Ottawa for a period of 5 years and will then be destroyed. The collected data will be kept on a computer that will be accessible only to the researchers and the supervisor under the protection of an access code. The only people who will have access to videotapes and data are the researchers Bruce Contant, Andréanne Montigny and the supervisor Mr. Yves Lajoie.

**ANONYMITY:**

The anonymity will be protected by using terms such as: "the participant," or "the subject." No names will be mentioned on any reports or documents related to the study. If required, the researchers will use numbers to differentiate between the participants.

**COMPENSATION:**

There is no monetary compensation for participating in this study. For my participation in this study, I will benefit from the advantages of training with a health professional.

**VOLUNTARY PARTICIPATION:**

I realize that I may withdraw from this study at any time, even if I had agreed to participate; without providing any reason, without consequence. If I withdraw, my data will be destroyed.

The researchers may appear to be in a position of authority towards me as trainers in my centre; I should not feel intimidated by this authority. The researchers will do everything possible to minimize the effects of that authority by treating every participant in an equitable manner.

**INFORMATION ON THE RESULTS:**

Once the study is concluded and results have been analysed, I will be contacted by telephone. The researcher will offer to provide me with information based on my balance assessment. Should I wish to receive my results in writing, the researcher will provide me with the results in person at my center.

**MORE INFORMATION ABOUT THIS STUDY:**

If I have any other questions or require more information about the study itself, I may contact the researcher or his/her supervisor at the numbers mentioned hereinabove.

If I have any questions with regards to the ethical conduct of this study, I may contact the Protocol Officer for Ethics in Research, University of Ottawa, Tabaret Hall, 550 Cumberland Street, Room 159, Ottawa, ON K1N 6N5, tel.: (613) 562-5841 or [ethics@uottawa.ca](mailto:ethics@uottawa.ca).

**CONSENT:** I, \_\_\_\_\_, the undersigned, agree to participate in the above research study. The study has been explained to me, I have had the opportunity to ask questions about my involvement and to receive additional details that I wanted to know about the study. I understand that by accepting to participate, I am in no way waiving my right to withdraw from the study at any time.

I have been given a copy of this form.

Participant's signature name: *(Please print)* \_\_\_\_\_

Participant's signature: \_\_\_\_\_ Date : \_\_\_\_\_

## Appendix 6 – Certificate of Ethical Approval



Université d'Ottawa · University of Ottawa


Cabinet du vice-recteur  
à la recherche

Office of the Vice-Rector,  
Research

**COMITÉ D'ÉTHIQUE DE LA RECHERCHE  
EN SCIENCES DE LA SANTÉ ET SCIENCES**

**ATTESTATION D'APPROBATION ÉTHIQUE**

La présente attestation certifie que le Comité d'éthique de la recherche en Sciences de la Santé et Sciences de l'Université d'Ottawa a examiné la demande d'approbation éthique pour le projet intitulé *The Effectiveness of Two Types of Wobble-Board to Improve Elderly Balance over an 8-Week Training Intervention* (dossier H 03-05-10) présentée par Andréanne Montigny et Bruce Contant qui sont supervisés par le Dr Yves Lajoie, de l'École des sciences de l'activité physique, Faculté des sciences de la santé. Le Comité d'éthique a déterminé que la demande respectait les principes éthiques établis par l'Énoncé de politique des trois conseils et par les règles de procédure des Comités d'éthique de l'Université d'Ottawa. Le Comité d'éthique a donc accordé une catégorie 1a (approbation) à ce projet. La présente attestation est valide pour un an à partir de la date indiquée ci-dessous.

  
Rita D'Alessandro

Responsable de l'éthique en recherche  
Pour le Dr Daniel Lagarec, Président du CÉR en  
Sciences de la Santé et Sciences

21 avril 2005

Date

**COPY**

550, rue Cumberland  
Ottawa (Ontario) K1N 6N5 Canada

550 Cumberland Street  
Ottawa, Ontario K1N 6N5 Canada

(613) 562-5270 • Téléc./Fax (613) 562-5271

### Appendix 7 – Contribution of Collaborators

This project was written and conceived by Bruce Contant in close collaboration with Yves Lajoie, the thesis supervisor. Technical support was offered by Yves Lajoie. The collection of data was due to the participation of Patrick Bériault and Bruce Contant, both of whom also administered the training sessions. Data analysis was completed by Bruce Contant.