PROGRESSIVE EXERCISE TO ADDRESS IMPAIRED BALANCE AND MOBILITY IN OLDER ADULTS REFERRED FOR HOME CARE PHYSIOTHERAPY SERVICES: IS IT BENEFICIAL TO TARGET VESTIBULAR CONTROL AND LOWER LIMB MUSCLE STRENGTH?

by

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Submitted in partial fulfillment of the requirements
for the degree of Master of Science

at

Dalhousie University
Halifax, Nova Scotia
September 2009

DALHOUSIE UNIVERSITY

SCHOOL OF PHYSIOTHERAPY

The undersigned hereby certify that they have read and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled "PROGRESSIVE EXERCISE TO ADDRESS IMPAIRED BALANCE AND MOBILITY IN OLDER ADULTS REFERRED FOR HOME CARE PHYSIOTHERAPY SERVICES: IS IT BENEFICIAL TO TARGET VESTIBULAR CONTROL AND LOWER LIMB MUSCLE STRENGTH?" by Denise Hollway in partial fulfillment of the requirements for the degree of Master of Science.

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DALHOUSIE UNIVERSITY

DATE: September 4, 2009

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TITLE: PROGRESSIVE EXERCISE TO ADDRESS IMPAIRED BALANCE AND MOBILITY OF OLDER ADULTS REFERRED FOR HOME CARE PHYSIOTHERAPY SERVICES: IS BENEFICIAL TO TARGET VESTIBULAR CONTROL AND LOWER LIMB MUSCLE STRENGTH?

DEPARTMENT OR SCHOOL: School of Physiotherapy

DEGREE: MSC CONVOCATION: October YEAR: 2009

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Abstract

Purpose: The primary purpose of this study was to evaluate the effect of a progressive exercise program on vestibular control of standing balance, in older adults referred for home care physiotherapy because of balance impairment. The secondary purpose was to determine if the mobility of this population can be explained by a linear relationship with vestibular control of standing balance and with muscle strength of designated lower limb muscle groups.

Subjects: Seven adults (75-89 yrs), referred for home care physiotherapy for balance impairment.

Methods: Eligible participants were recruited from the wait list of the Extra Mural Physiotherapy Program in Saint John, NB. Ability to use vestibular inputs for postural control in standing was assessed using the Clinical Test of Sensory Interaction and Balance (CTSIB), mobility was measured with the Timed Up and Go test (TUG), and lower extremity muscle strength was assessed with changes in 1 repetition maximum (1RM). Participants who had $CTSIB_{Test\ 5}$ scores of < 15 seconds were accepted into the study. Participants were randomly assigned to an 8 week intervention of progressive balance exercise targeting ability to use vestibular control and high intensity progressive resistance exercise (PRE) or high intensity PRE only. Descriptive statistics were calculated, and the primary hypothesis was tested using the Mann Whitney U-test ($\alpha = 0.05$) to compare the difference in Pre and Post exercise means for the $CTSIB_{Test\ 5}$ scores of the Resistance and Balance Exercise (RBE) Group and the Resistance Exercise (RE) group. A Spearman Matrix Correlation was used to examine factors which affect mobility.

Results: The difference in $CTSIB_{Test\ 5}$ scores of the RBE Group (median 23.3 s) was greater than the difference in $CTSIB_{Test\ 5}$ scores for the RE Group (median 0.60 s) ($W = 18.0$, $p < 0.05$). A linear relationship was found between TUG and $CTSIB_{Test\ 5}$ scores and TUG and ABC scores during Pre exercise testing ($p < 0.05$). A linear relationship was found between TUG scores and knee flexion strength during Post exercise testing ($p < 0.05$).

Conclusions: The results of this study provide preliminary evidence that the ability to use vestibular control in older adults, referred for home care physiotherapy for balance impairment, can be modified by progressive balance training and resistance exercise but not by resistance exercise alone.

List of Abbreviations Used

1RM	1 repetition maximum
ACSM	American College of Sports Medicine
BOS	base of support
COG	center of gravity
COM	center of mass
COP	center of pressure
CTSIB	Clinical Test of Sensory Integration and Balance
EC	eyes closed
EO	eyes open
ex.	exercise(s)
LE	lower extremity
MVIC	maximum voluntary isometric contraction
Nm	Newton meter
PPMCC	Pearson product moment correlation coefficient
PD	portable dynamometer
PRE	progressive resistance exercise
RBE	Resistance Balance Exercise Group
RCTs	Random Controlled Trials
RE	Resistance Exercise Group
s	second(s)
SCC	semi circular canal
SOT	Sensory Organization Test
TUG	Timed Up and Go Test

Glossary

Center of mass (COM)	The point in a body or system of bodies at which the entire mass may be assumed to be concentrated.
Center of gravity	That point in a body or system around which its mass or weight is evenly distributed or balanced and through which the force of gravity acts [1].
Balance	The ability to maintain the center of gravity (COG) over the base of support (BOS) in a variety of situations [2].
Base of Support (BOS)	Defined as the area of the body that is in contact with the support surface [3].
Center of Pressure (COP)	The center of distribution of the total force applied to the supporting surface. The COP moves continuously around the COM to keep the COM within the support base [3].
Extra Mural Physiotherapy	The Extra Mural physiotherapy (EMP) program in New Brunswick provides physiotherapy services in the patient's home with the goal to prevent the onset of impairment or to limit deterioration in function as a result of impairment. Patients can be referred to Extra Mural Physiotherapy by their physician, health care provider, family or friends. http://www.ahsc.health.nb.ca/Programs/ExtraMural/index.shtml
Fatigue	In progressive resisted exercise (PRE), indication of fatigue is monitored so that resistance can be progressed properly and to avoid injury. Loss of form, where form is described by the correct speed, range of movement, and completion of movement, without additional accessory movements during PRE, is monitored to avoid fatigue [4].
Postural Control	The ability to control and stabilize the body's position in space while manipulating the body's orientation to the demands of a specific task [2, 3].

Acknowledgements

I wish to thank Dr. Marie Earl for your patience, tenacity with computer glitches, and most of all the commitment, humor and dedication you bring to the educational process. I continue to appreciate Marie's support in the completion of this thesis.

Thank you to Dr. Elizabeth MacDonald and Dr. Marilyn MacKay Lyons for your input and guidance as thesis committee members. I appreciate your willingness to share your knowledge and I admire the dedication you bring to your work.

To my friends and family, thank you for listening and supporting me as I found my way in academic study. All of the suggestions and comments I received were welcome and helpful. I also appreciated the pleasure of your company while walking the dogs, playing bridge, kayaking, biking or sitting with me as I figured out another statistical problem.

And to my life partner, Gordon, thank you for the space and the love to finish this thesis.

Chapter1: Introduction

Background and Rationale for Research Project

Fall Risk and Community Dwelling Older Adults

Canadian statistics show that there are over 180,000 injurious falls in Canada each year in older adults, 65 years and over, accounting for over 60% of injury related hospitalizations in this age group [5]. Approximately 35-40% of community dwelling, relatively healthy, older adults fall each year, with the number of falls increasing after age 75 [6]. Almost 50% of older adults who fall experience a minor injury and up to 25% experience a serious injury such as a fracture or a sprain [5]. An injurious fall can lead to nursing home admission, with up to 40% of nursing home admissions related to a fall in the older adult population [7]. For those who do not suffer an injury, a fall can cause older adults to curtail activity and lose confidence in their mobility, both of which can contribute to decreased health, function and an increase in future falls [6].

At the regional level in New Brunswick, the impact of falls can be seen in visits to the Emergency Department resulting from a fall. For example, in 2006, the Saint John Regional Hospital, in New Brunswick, recorded over 1000 visits to its Emergency Department due to falls in the older adult population [8]. This number has steadily increased since 2002, when the number of recorded visits due to falls was 662 [8]. The majority of the falls occurred in older adults living in the community [8]. There is no clear policy to address the role of physiotherapy in the prevention of falls in community dwelling, older adults in this region. Older patients seen in the Emergency Department at the Saint John Regional and deemed to be at a high risk for falls are not consistently referred to Extra Mural Physiotherapy (EMP) or outpatient physiotherapy [9]. Older patients who are in hospital and who are at risk for falls at time of discharge may be referred to EMP; however, this is not policy [9]. Patients who are referred to EMP with high risk for falls are considered high priority and are usually seen within 2 weeks of referral, depending on the wait list. Patients who are referred to EMP for balance problems and/or lower extremity (LE) weakness are considered medium priority and are slated to be seen within eight weeks; however, this time frame is not always met due to wait list times [9].

The high rate of falls, and high injury rate, in balance impaired, community dwelling older adults makes further research, with the aim to improve postural control and reduce fall risk factors, necessary. Assessment of the ability to utilize sensory inputs and LE strength may allow for the development of effective individualized programs that result in a decrease of fall risk factors, as well as improve postural control in older adults referred for home care physiotherapy.

Sensory Input and Postural Control

Postural control is influenced by the neuromuscular, musculoskeletal and the sensory systems [3]. Loss of postural control can occur with impairment of visual, somatosensory and vestibular sensory systems, impairment of the central nervous system in processing sensory information or from a combination of both factors [3]. Impaired sensory control can affect the ability of the older adult to react to internal and external perturbations and is associated with increased fall risk in older adults [2, 3]. Murray

(2005), using the Clinical Test of Sensory Integration and Balance (CTSIB), demonstrated evidence of vestibular dysfunction in older, community dwelling, adults discharged home from an emergency department, 2 weeks post fall [10]. In the same study, a healthy, age-matched control group who had not suffered falls in the past 12 months was able to utilize vestibular inputs for balance control [10]. In fact, static balance scores of 30 seconds for healthy older adults were comparable to those found by Cohen (1993) for young adults using the CTSIB [10, 11].

Assessment of ability to utilize sensory control is usually not included in the assessment of falls in older adults, even in specialized Falls Clinics [12]. Of fourteen Fall Clinics, described in a report by the National Aging Research Institute in Australia, only three clinics utilized an assessment tool to assess ability to utilize sensory inputs [12]. There is little evidence in the literature that assessment of an individual's ability to utilize sensory inputs for postural control is included in the development of therapeutic balance training programs. Three studies were found which included assessment of ability to utilize sensory inputs for postural control and also targeted sensory inputs (including vestibular control) as part of the balance training protocol [13-15]. Only one random controlled trial (RCT[15]), with both these elements, was found in two systematic reviews which addressed the effect of exercise interventions on balance [16] and on rate of falls [17] in the community dwelling, older adult population.

Based on current evidence, assessment of the older adult to utilize vestibular inputs could 1) identify impairment of a physiological system that contributes to postural control [2, 3] and 2) improve the ability of the therapist to customize a training program suited to the individual [13, 14]. Targeting specific physiological systems with customized training interventions, tailored to the specific needs of the individual, has been found to be more effective than non specific global exercise programs in improving measures of postural control [13, 14, 18-20]. Low intensity home based exercise programs, which address generalized fall risk factors in older community dwelling adults, have had limited success in improving measures of postural control and/or decreasing numbers of falls [18-21] [22]. High intensity progressive balance training programs, which include the manipulation of sensory inputs, have been shown to improve measures of postural control in both healthy and balance impaired older adults [13-15]. Such effective progressive balance training programs have been conducted in research settings using complex instrumentation [13-15]. It is not known if progressive balance training programs, which include the manipulation of sensory inputs, can be delivered in a home care setting and be effective in improving measures of postural control.

Muscle Strength and Postural Control

LE strength is also important to consider as a potential modifiable risk factor in older adults. Lack of muscle strength, particularly of the LE, has been associated with balance impairment, loss of functional mobility and increased fall risk in older community dwelling adults [3, 23-25]. The association between decreased LE muscle strength and falls has led to the investigation of strength training to enhance functional ability including postural control [24, 26]. Hess (2005) reported an increase in LE strength and an increase in clinical measures of postural control and mobility following a high intensity progressive resisted exercise (PRE) protocol with balance impaired, older adults[26]. The PRE program followed American Academy of Sports Medicine (ACSM) guidelines and was conducted with professional gym equipment [26]. It is not known if balance impaired, older adults can achieve the same result with PRE for LE muscles, and using free (band) weights, in a home care situation.

Mobility

Older community dwelling adults who were found to have evidence of vestibular dysfunction have also been found to have evidence of decreased mobility as measured by the Timed Up and Go test (TUG) [10]. Decreased LE strength has been associated with decreased ability to negotiate commonly found gait and mobility challenges in sedentary, older community dwelling adults [27]. An improvement in the modifiable fall risk factors of a) the ability to utilize vestibular input and b) muscle strength in older community dwelling adults could lead to an improvement in mobility in this population.

Summary

The fall rate in older community dwelling adults is high and continues to rise with each decade [6]. Older adults who fall are more likely to fall again [28]. Recurrent falls are associated with increased functional dependence, decreased mobility, and increased hospital and nursing home admission [5, 7]. Investigating strategies to improve postural control through targeting modifiable risk factors may contribute to improved mobility.

The ability to utilize vestibular inputs for postural control and decreased muscle strength may be modifiable risk factors for older community dwelling adults referred for homecare physiotherapy to address increased fall risk. Therefore, the purpose of this study is to examine the influence of an individualized, home-based, progressive exercise program designed to target both the ability to utilize vestibular inputs for postural control and lower extremity muscle strength.

The primary objective of this study is to evaluate the effect of a progressive exercise program on the ability of this population to use vestibular inputs to maintain standing balance. The secondary objective of this study is to assess the factors that influence mobility in the balance impaired, home care population. The ability to utilize vestibular inputs for balance control will be examined using the Clinical Test of Sensory Integration and Balance (CTSIB); LE muscle strength will be examined using portable dynamometry (PD) and one-repetition maximum tests; Mobility will be assessed using the TUG.

Hypotheses

Primary Hypothesis

The ability to use vestibular inputs, as measured with CTSIB, will be greater in balance impaired, older adults who complete high intensity progressive exercise training for balance and lower extremity strength than in older adults who are balance impaired and who receive lower extremity strength training only.

Secondary Hypothesis

The mobility of older adults referred for home care physiotherapy will be explained by a linear relationship with the ability to utilize vestibular inputs, and with muscle strength of designated lower limb muscle groups.

Chapter 2: Review of the Literature

Modifiable Fall Risk Factors and Older Community Dwelling Adults

Community dwelling, older adults are dependent on freedom from falls and reduced fall risk to retain functional mobility and be independent in their homes and community [29]. Loss of mobility and increased fall risk are a multifactorial problem in older adults, influenced by both intrinsic and extrinsic fall risk factors [3]. Impaired postural control is a contributing factor to falls and is impacted by intrinsic fall risk factors that may be modifiable [3, 18, 30, 31]. Decreased sensory function and decreased lower (LE) strength are two such intrinsic factors that could impair postural control [3]. It is not known if targeting community dwelling, older adults, who have decreased sensory function, with a specific balance training program in their home will lead to improved postural control. The relative contribution of sensory inputs and LE strength to the mobility in this population is also not understood.

The following sections will include a review of postural control as it relates to community dwelling, older adults. An overview of the ability to utilize sensory inputs including a brief review of the vestibular system and its contribution to postural control in community dwelling, older adults will be included. The strength characteristics of this same population will also be discussed. Assessment tools that can be used to assess sensory function in postural control, muscle strength and mobility in the home care setting will be included, along with results from previously reported studies of community dwelling, older adults. Finally, a review of balance training programs and progressive resistance exercise (PRE) programs, and the results that have been reported in community dwelling, older adults, will be discussed.

Postural Control in Older Adults

Overview

Postural control can be impaired due to disease, aging and/or disuse secondary to immobility [32]. Postural control is defined as the ability to control and stabilize the body's position in space while manipulating the body's orientation to the demands of a specific task [2, 3]. Postural control in quiet stance is a reflection of the body's ability to counteract the influence of gravity and maintain the center of gravity (COG) over a relatively small base of support (BOS) [2]. Postural control in both static and dynamic situations is dependent on the ability of the body to respond to sensory, internal and external perturbations.

Postural stability is maintained when information from the somatosensory, visual and vestibular systems can be processed accurately to activate the appropriate motor response. According to the framework proposed by Judge and colleagues (1995), loss of stability is related to either 1) a failure to realize the COM has been displaced (a sensory deficit), 2) an inappropriate response to a perturbation due to muscle weakness or 3) the inability to generate an appropriate motor response [33].

Sensory Deficits and Postural Control

The visual, somatosensory and vestibular sensory systems provide information to the neuromuscular system to ensure that effective postural adjustments are executed in response to the environment [2]. In the case of the somatosensory system, a loss of peripheral neuro-receptors in the feet and ankles may make it difficult for an older adult to walk on soft or uneven ground due to a delay in muscle response to the perturbation from stepping on challenging surfaces [3]. In a longitudinal study of healthy older adults (78.5+/- 3.7 years), Baloh (2003) reported a statistically significant decrease in vibratory sense at the ankle and great toe as well as a decrease in deep tendon reflex response over an eight year period [34]. Decreased joint position sense, vibration sense and touch thresholds were found to be related to poor performance on static and dynamic tests of balance in older adults living in a retirement home (mean age 83+/-5.1years) [23, 35].

Older adults who have decreased visual fields and visual acuity have been shown to have increased postural sway when vision is removed or altered, thereby making them more likely to fall in such situations [3]. Older adults who fall have impaired visual and lower extremity somatosensory inputs as well as reduced reaction times [23, 36]. Lord (2001) studied the predictive value of testing visual impairment alone, and in combination with other measures of known physiological risk factors for falls, such as reaction time and postural sway [36]. Among older adults (mean age 83+/-5.1 years; N=148), a history of falling was associated with decreased depth perception and decreased contrast sensitivity [36]. Stepwise discriminant analysis demonstrated that impaired depth perception, reaction time and postural sway were significant and independent risk factors for falls.

The standardized canonical correlation coefficients, which demonstrate the relative importance of each variable in explaining the variance in the dependent variable of falls, were 0.49 for depth perception, 0.41 for reaction time and 0.52 for postural sway [36].

There is also evidence that older adults who fall are challenged in their ability to utilize vestibular inputs [10, 11]. In fact, 80% of patients (mean age 78.3+/-7.3 years), presenting to an emergency department, due to fall of unknown cause, were found to have difficulty with vestibular control in standing [10]. Older adults with balance impairments may rely more on vision or combined vision and somatosensory inputs than vestibular inputs for postural control [3]. It may be that balance impaired older adults are inactive and therefore do not regularly utilize vestibular inputs for postural control [3].

Another explanation for difficulty utilizing vestibular control for postural control may be related to anatomical changes related to ageing. Up to a 20% reduction of the hair cell populations in the vestibular apparatus was reported in a sample population of temporal bones of persons over 70 years [37]. To understand the significance of these findings it is useful to review the anatomy of the vestibular system and its contribution to postural control. The peripheral vestibular system consists of the membranous and boney labyrinths as well as the motion sensors of the vestibular system, the hair cells [38]. The boney labyrinth consists of three semicircular canals (SCCs), the cochlea and a central chamber called the vestibule. The membranous labyrinth is suspended within the bony labyrinth by perilymphatic fluid and supportive connective tissue. The five sensory organs are contained within the membranous labyrinth and consist of three SCCs and the two otolith organs, the utricle and the saccule. Specialized hair cells contained in the widened ends of the SCC, the ampulla, and the otolith organs, are the biological sensors that convert displacement, due to head movement, into neural firing [38]. The SCCs sense rotation of the head, with rotation in the sagittal and frontal planes detected by the anterior and posterior SCCs and rotation in the horizontal plane detected by the horizontal SCC [38]. The otoliths sense linear acceleration of the head as well as tilt of the head with respect to gravity [38]. The loss of hair cells in the sensory organs, along with the changes in the visual and somatosensory system described, may result in a reduction of the older adult's ability to maintain postural control in response to external perturbations [38].

Clinical evidence of vestibular impairment has also been related to falls in older adults. A distinct nystagmus after head shaking is generally considered pathological and demonstrates clinical asymmetry of the vestibular reflexes [39, 40]. Asymmetrical vestibular function was found to be strongly associated with older healthy adults who had a history of fall related fractures [41, 42]. Kristinsdottir (2000) reported that self described healthy older adults (mean age 73) with no history of vestibular disorder, and who had suffered a hip fracture, demonstrated higher incidence of head shake nystagmus (68%) than an age-matched control group [41]. Of the 12 subjects who had suffered a hip fracture, 9 subjects suffered a hip fracture on the same side as the slow phase side of the nystagmus [41]. In a further study of otherwise healthy, older adults (mean age 75), a higher incidence of wrist fracture was found on the slow phase side of the induced head shake nystagmus [42]. In the wrist fracture study [42], the incidence of head shake nystagmus of the fallers was found to be 37% higher than the incidence of head shake nystagmus for an age controlled group of healthy adults. The authors suggested that asymmetrical vestibular function may be an important risk factor in falls and fractures in older adults [42]. In the hip fracture study the authors also suggested that inappropriate postural responses may have been a contributing factor to the majority of falls in their study population [41].

Functionally, older adults have been found to have difficulty with postural stability when visual and somatosensory inputs are unreliable, suggesting difficulty with ability to utilize vestibular inputs [11, 35]. Lord (1994) studied the physiological characteristics of older women (65-86 years) and the relationship of these characteristics to their frequency of falling [35]. A test of static balance was included, with subjects standing on both a firm and a compliant surface with eyes open and then closed for 30 seconds [35]. Older women with a history of multiple falls had significantly decreased performances with this test of static balance than did older women who were one time fallers, or who were non fallers [35]. One time fallers and multiple fallers were significantly worse than non fallers when standing on a firm surface with eyes closed and when standing on a compliant surface with eyes both open and closed.

The ability to stand on a compliant surface with eyes closed is a measure of ability to utilize vestibular control as the participant is receiving unreliable somatosensory input and no visual input to maintain postural control. This test of ability to utilize vestibular control in static balance is found in the Clinical Trial of Sensory Integration and Balance

(CTSIB) and is known as $CTSIB_{Test\ 5}$. Older adults (N=20, mean age 78.3+/-7.3 years) discharged home from a hospital emergency department after a fall were found to have decreased ability to utilize vestibular inputs in standing balance as measured with the $CTSIB_{Test\ 5}$ [10].

Impairment in sensory systems can result from the aging process, leading to difficulty integrating sensory systems in the older adult. For example, an individual standing on a stationary platform, looking at a passing train, may feel as if they are moving due to unreliable input from the visual system. In the case of the moving train, the information from the somatosensory system and the vestibular system is reliable and given an impairment free sensory system and central nervous system (CNS), the healthy individual would disregard the unreliable visual input and no postural adjustments would be initiated [3]. Decreased inputs from the somatosensory neuroreceptors as well as decreased visual acuity may result in the older individual being unable to integrate the conflicting sensory inputs in the platform scenario, causing a large amount of sway or a loss of postural control [3]. Older healthy adults with one type of sensory impairment can compensate for the lack of sensory information due to overlapping information provided by the other two types of sensory input [2, 3, 11, 43]. Older adults with two or more sensory system impairments cannot compensate for loss of one sense with alternative senses because of the presence of too much impairment in the sensory systems needed for postural control [2, 3, 11, 43].

The ability to select reliable sensory inputs and disregard unreliable information during situations of sensory conflict, usually referred to as sensory integration, is dependent on inputs from each of the visual, somatosensory and vestibular systems [43]. The visual system provides information regarding where the body is in relation to the environment, including feedback related to body alignment and speed when walking [2, 3]. The somatosensory system provides information with regard to the orientation of body parts to one another, as well as to the support surfaces [2, 3, 44]. The vestibular system provides information with regard to the speed of movement and direction of the head, [44]. as well as the position of the head in space [2]. The three sensory systems provide overlapping information to the CNS, as each system on its own is not able to provide complete information about body position or movement to the central nervous system [43]. Determining the ability of older adults to utilize sensory inputs, as well as integrate sensory inputs in the presence of sensory conflict, may allow for an individualized balance training program to be developed for the older individual.

Muscle Strength and Postural Control

Decreased muscle mass and strength are associated with sedentary lifestyles and are signs of typical aging [45]. Statistics Canada reported in 2005 that 48% of Canadians between the ages of 65 and 75, and 60% of Canadians over the age of 75, considered themselves to be physically inactive. Only 12% of those aged 65-75 years, and those aged 75 and older , reported themselves to be physically active [46]. Injurious falls in older adults are associated with a decrease in physical activity [29]. Reduced LE extremity strength is a predictor of future falls [47] and is associated with multiple falls in older adult women [35].

At the histological level, adults may lose up to one third of muscle strength between the age of 25 and 65 years of age [48]. The structural changes that can occur in aging muscles include atrophy of muscle fibers as well as infiltration of the muscle by fat and connective tissue [45]. Changes to the neuromuscular system include an increase in motor unit size (more fibers per unit) and actual changes in muscle contractility properties with a decrease in type II fast twitch fibers [45]. Changes in muscle physiology result in a reduced ability to generate force and speed of muscle contraction [45].

Functionally, decreased strength in older community dwelling adults has been associated with decreased gait speed, decreased aerobic capacity (6 Min. Walk Test), decreased ability to rise from a chair [24], and increased fall risk [24, 25, 47]. Older community dwelling adults have been found to use a greater percentage of their maximal isometric knee strength when performing the task of rising from a chair than their younger counter parts [48]. However, Schultz (1995) reports that joint torques required for activities of daily living (ADL) are not large [48]. For chair rise, the typical peak torque required has been reported to be 20-40 Nm at the ankle, and 30-100 Nm at the knee and hip [48]. The joint torques required to restore standing balance are similar for older and younger persons, with torques of 19-30 Nm required at the ankle, 18-30 Nm required at the knee and 10-24 Nm required at the hip [48]. Indeed, healthy older community dwelling adults have larger muscle torques available than are required to counteract balance perturbations (see Appendix 1).

Older adults with a history of falling demonstrate associated decreased LE muscle strength. Lord (1994) found that older women (mean age 74 years) with a history of multiple falls had significantly decreased strength compared to one time fallers and non fallers in tests of quadriceps and ankle dorsi-flexor strength [35]. Community dwelling older women (mean age 72 years) with weak hip, knee, and ankle flexors and extensors were found to be more likely to fall after taking a step than their stronger age related counterparts [49]. Decreased hip abduction force in community dwelling women, 65 years and older, was found to be associated with impaired function in a large population based study [50]. And finally, ankle dorsi-flexors were identified as being an independent predictor of older adults (mean age 75 years) who fell in a study of community dwelling older adults [47]. The sub group of older adults who fell in the same study were found to have decreased strength in the ankle dorsi-flexors and the hip extensors compared to non fallers [47].

Motor Response and Postural Control

Postural adjustments are motor patterns activated by the neuromuscular system and musculoskeletal system depending on the rate of activation needed to counteract a balance perturbation [2]. Preparatory postural adjustments occur prior to the initiation of a voluntary movement (approximately 500 ms -1s prior to onset) [2]. The preparatory postural motor pattern is used to generate purposeful postural adjustments prior to a balance perturbation such as bracing the body with a leg, just before a heavy lever is pulled [2, 3]. Anticipatory postural adjustments occur prior to, or coincidentally with, perturbations that result from voluntary movements such as carrying or lifting objects [2, 3]. Contraction of the core muscles of the trunk to counteract the weight of lifting a heavy object is an example of an anticipatory postural adjustment, and occurs approximately 80-100 ms prior to movement onset [2].

Reactive postural motor patterns are activated after a postural perturbation in response to an external perturbation, or to make corrections during voluntary movements when preparatory or anticipatory adjustments are not used effectively [2]. The reactive motor patterns can be classified as short, medium or long latency responses. Short latency responses are reflex responses that occur 30-50 ms after a perturbation to balance [2]. These reflexes are thought to provide a stimulus that can regulate muscle force in response to an external perturbation but not actually maintain balance in functional movement [2]. The medium latency responses that comprise the muscle bursts of the ankle and hip motor strategies described below, occur approximately 100 ms after the perturbation onset, and provide corrective torques to control balance. Long latency responses are voluntary movements and can occur up to 1 second after the perturbation [2].

Two postural movement strategies that control the COM over the BOS, without creating a new BOS, are the ankle and hip strategies [2]. The ankle strategy allows the person to maintain the COM over the BOS, with the movement occurring primarily at the ankle

[44]. Torque generated at the ankle is applied to the support surface while the subsequent knee and hip torques stabilize the proximal joints [2]. The hip strategy manifests as a more rapid movement of the trunk about the hip joints, with smaller amplitude of rotational movement about the ankle. The hip strategy is more often used in response to larger perturbation or standing on a narrow base of support or in heel toe stance. A third postural movement strategy is called the stepping strategy [2]. The individual can change their BOS by stepping to make the BOS larger and therefore reposition the COG within the new BOS to prevent a fall.

Lin (2004) compared the postural motor patterns of younger adults, stable older adults and unstable older adults using external perturbations to displace the COM [51]. Both stable and unstable older adults were found to use the stepping strategy more often than younger adults who remained in place by using ankle and hip strategies [51]. Older adults, both stable and unstable, also used significantly less ankle dominated responses and more hip dominated responses compared to the younger adults [51].

Assessment Tools for Use in the Home Care Population

Assessment of Sensory Inputs in the Home Care Population

Assessment of sensory inputs that affect postural control could 1) allow the therapist to identify impairment of a physiological system that contributes to postural control [2, 3]. and 2) improve the ability of the therapist to customize a training program suited to the individual [13, 14]. The Clinical Test of Sensory Integration and Balance (CTSIB) provides reliable and valid information regarding the ability of the individual to utilize somatosensory, visual, and vestibular sensory inputs to maintain postural control [11, 52]. The CTSIB also provides information regarding the ability of the patient to adapt to intersensory conflict [11, 52]. The CTSIB requires very little equipment and is inexpensive to perform so it is well suited for use in the assessment of the home care population.

Weber (1993) examined the validity of foam posturography (CTSIB) by comparing it with moving platform posturography [52]. The Sensory Organization Test (SOT) is used to assess the postural stability of individuals using computerized moving-platform posturography. Subjects stand on a pressure sensitive moving platform which measures peak to peak anterior-posterior sway [52]. The SOT can assess six different sensory conditions, providing an opportunity to assess the contribution of visual, somatosensory and vestibular information to postural stability [52]. The first three sensory conditions are tested with the platform fixed and the final three sensory conditions are assessed with the platform sway referenced to the sway of the individual. Tests 1 and 4 have eyes open and tests 2 and 5 have eyes closed. Tests 3 and 6 have a visual surround that is referenced to body sway (vision is sway referenced) [52]. Weber (1993) determined the sensitivity of foam posturography to be 95%, and the specificity to be 90%, in relation to those who had normal moving platform posturography for Test 5. The predictive value for abnormal results for Test 5, compared to moving platform posturography, was 86.4%, and for normal results, compared to the same, was 96.4% [52]. In relation to those who had normal posturography for all tests ($CTSIB_{Test\ 1\text{-}6}$), the sensitivity of the results from foam posturography was found to be 90.5%, and the specificity was 89.7%. The predictive value for abnormal results for all tests for foam posturography compared to moving platform posturography was 86.4%, and for normal results, compared to the same, was 92.9% [52].

The CTSIB is a timed test that was developed to systematically test the influence of somatosensory, visual, and vestibular inputs in maintaining standing postural control [11, 43]. The relative test-retest and inter-rater reliability of the CTSIB has been reported to be high ($r = 0.99$, $p < 01$) [11]. The CTSIB can be performed in 10-20 minutes with experience [11, 44]. The CTSIB consists of 6 tests of altered sensory conditions. Each test is 30 seconds long with the first 3 tests performed on a firm surface and the last three tests completed on a piece of medium density, compliant foam. Three foot positions can be used in this test (feet apart, feet together, and feet in heel-toe position). Each position is tested with eyes open, with eyes closed and with using a visual-conflict dome to allow vision that is sway referenced to the individual and does not allow visual orientation clues [43].

In a study of older adults who were discharged home from the emergency department post fall, Murray (2005) found fallers performed significantly worse with test 5 of the CTSIB. The fallers were found to have a median score of 5.8 seconds and the control group of non fallers had a score of 30 seconds ($p< 0.001$) [10]. Another study, which evaluated the effect of age on the performance of adults with $CTSIB_{Test5,}$ found different results with average scores of 16.4 +/-12.6 for older adults [11]. The high standard deviation reported for this study suggests that the population was not normally distributed. It is not clear if the results for both studies can be compared due to lack of information regarding the fall history of the older adults in the latter study, [11] and lack of information regarding foot position used in both studies (different foot positions determine the difficulty of the test) [10, 11].

Assessment of Mobility in the Home Care Population

Mobility can be defined as the ability to move independently and safely from one place to another [3]. The Timed Up & Go Test (TUG) was developed by Podsiadlo and Richardson in 1991 as a measure of functional mobility in older adults [53]. The TUG test requires a subject to stand up, walk 3 m, turn, walk back, and sit down. The individual walks at a self selected pace, is able to use their regular walking aide and is able to use the arms of the chair to assist with standing or sitting.

The reliability of the TUG test was examined by Podsiadlo (1991) in a group of 60 older adults referred to a geriatric day hospital from the community [53]. The interrater and intrarater reliability of the TUG test was found to be high (ICC = 0.99 for both). Shumway Cook (2000) also found the interrater reliability of the TUG test to be high (ICC=0.98), when assessing both fallers and non fallers, in a group of community dwelling older adults (age range 65-95) [54].

Podsiadlo(1991) also examined the validity of the TUG test [53]. Correlations were found between TUG scores and the Berg Balance Score (r = -0.72), and gait speed (r = -0.55) [53]. The TUG test can be used as a screening test given the known associations between the time to complete the test and the functional level of the participant [53, 54]. The time taken to complete the TUG test is strongly correlated with levels of functional mobility [53]. Older adults who are able to complete the task in less than 20 seconds have been shown to be independent in transfer tasks involved with activities of daily living. In contrast, older adults who require 30 seconds or longer to complete the task tend to be more dependent in activities of daily living, require assistive devices for ambulation, and score lower on the Berg Balance Scale [53]. Shumway-Cook (2000) suggests that 90 % of older, community dwelling adults with no known neurological pathologies, who score 14 seconds or more with the TUG test could be classified as fallers [54]. When used to assess the mobility of older community dwelling adults, the TUG test has also been found to be sensitive for identifying older fallers (87%), and have a specificity of 87% for identifying non fallers [54]. Another advantage of the TUG test is the opportunity it provides to observe the individual during different types of mobility tasks. Preparatory and anticipatory postural adjustments used by individuals when completing movement tasks provide information regarding the postural control of the individual.

Older, balance impaired, community dwelling adults (mean age 75.5 years) demonstrated increased mobility, as measured by the TUG test, after completing an eight week moderate to high intensity progressive balance training program in a laboratory setting. A significant difference was found between pre and post test scores for TUG ($\alpha = 0.05$; pre test 14.5 +/- 8.9; post test 11.8 +/-6.2). The assessment of mobility using the TUG test in the older adult in the home care population allows for an objective evaluation as to whether modifying the ability to utilize sensory inputs with progressive balance training will influence mobility.

Measurement of Muscle Strength in the Home Care Population

Human muscle strength can be defined as the "the maximal amount of tension or force that a muscle or muscle group can voluntarily exert in one maximal effort, when type of muscle contraction, limb velocity, and joint angle are specified." [55]. Accurate and reliable measurement of strength is necessary so that treatment plans for strengthening muscles can be designed, modified and progressed based on careful muscle strength assessment [56].

Isokinetic maximal voluntary contractions are considered to be the gold standard for strength testing. The isokinetic dynamometer can provide multiple parameters such as measures of peak force, joint angle of maximum force, measures of power and endurance and a wide range of muscle contraction types including isometric, concentric and eccentric contractions [57]. Isokinetic dynamometry is expensive and not portable; therefore, other methods of strength testing, such as portable dynamometry (PD), are required for use in the home care setting [58].

Portable dynamometry can be used to measure maximal voluntary isometric muscle contraction (MVIC). The relationship between isokinetic and isometric muscle testing needs to be considered when substituting PD as a valid measurement tool for strength testing. In studies of the joint torque of knee and hip musculature of healthy older adults comparing isokinetic dynamometry with isometric dynamometry, slower velocity isokinetic peak torque values found at 12 ^{0}/s, 30 ^{0}/s, and 60 ^{0}/s were more strongly associated with MVIC than were higher velocity isokinetic peak torque values [59-61]. Isokinetic peak torque was found to decrease with increasing velocity of isokinetic contraction [59-61]. Given the strong association between MVIC results and low velocity isokinetic dynamometry, PD, used to measure MVIC, can be considered a valid measure of muscle strength in older adults.

Reed (1993) compared results obtained measuring MVIC, with a PD, with results obtained with an isokinetic dynamometer at speeds of 60 ^{0}/s in older healthy community dwelling adults [62]. Using Pearson product moment correlation (PPMCC) ($p<0.0001$), Reed (1993) found statistically significant PPMCC for peak knee extension ($r=0.74$; CI 95% 0.53-0.87) and knee flexion ($r=0.77$, CI 95% 0.58-0.86) [62]. The high PPMCC indicates that there is a linear relationship between the two strength measures. The PPMCC does not explain the high variability found in some individual results therefore, despite a high PPMCC, a systematic bias may exist [62]. Martin (2006) found a high correlation between MVIC testing, using PD, and MVIC testing, using Biodex isokinetic dynamometry, in older community dwelling adults ($r = 0.91$; $p < 0.0001$) [63]. Results demonstrated the mean peak torque of the quadriceps produced by the PD and the Biodex were 68.9 (19.6) and 83.4 (28 Nm) respectively [63]. The PD results tended to underestimate the torque compared to the Biodex by an average of 14.5 Nm (CI 95% 8.5-20.6), with this effect being seen more in the strongest subjects [63]. While the high variability in some results [62] and the underestimation of values in other results [63] indicate that PD is not a substitute for isokinetic dynamometry, the high PPMCC results indicate that PD can produce valid results for LE strength when compared to the gold standard of isokinetic dynamometry.

Portable dynamometry (PD) is used in clinical practice to measure muscle strength because of its simplicity, objectivity, and responsiveness to measuring muscle strength changes [64]. When a standardized protocol is used with PD, a reliable measure of MVIC can be found in older community dwelling adults who have fallen [64]. One challenge that has been found when using PD to measure LE muscle strength is the inability of the therapist to stabilize the PD due to the strength of the patient. The reliability of the PD measurement depends on the strength of the examiner and his/her ability to maintain the PD in position against the resistance of the patient. Kramer(1991) noted that older adult women produced hip joint torques that were 55% higher when the PD was stabilized by a belt rather than the hand of a therapist [56]. Even during a 'make' compared to a 'break' test, [56] the examiner may be overpowered by the MVIC of the patient. (A 'make' test has been found to be more reliable, [64] and is one in which the patient efforts to produce a maximum isometric contraction. A 'break' test is one in which the patient tries to beat the maximal contraction of the examiner). This disadvantage of PD has led to a great deal of variability in results especially when testing the relatively stronger LE musculature [64].

The effect of using straps and other external stabilization methods (rather than the hand held method) with PD to increase the reliability of results has been examined in several studies [56, 58, 65, 66]. An anchoring station that allowed the portable dynamometer to be stabilized by a metal framework produced reliable results ($ICC_{1,1}$ = 0.94 - 0.95) when used to measure hip extensors and hip abductors in a population of 25-35 year old healthy adults [65]. A PD mounted on a portable frame was found to have good to excellent reliability ($ICC_{3,1}$ = 0.94-0.98) when performing test-retesting of LE strength in older adults living in the community [58]. A simple solution using a strap to stabilize the PD when measuring hip abductor strength in younger and older adults was found to be reliable and produce higher joint torques when compared to the hand held method [56]. Stabilizing various commercially available portable dynamometers mounted on a portable bed also produced reliable results [66]. The reliability results of three studies using stabilized PD with a standardized approach to assess MVIC LE strength in community dwelling older adults are provided below in Table 1. The reliability results obtained indicate that portable dynamometry, using a standardized approach, is a reliable method to measure LE MVIC muscle strength in older community dwelling adults.

Table 1: Summary of Reliability Studies Using Stabilized Portable Dynamometry

Author	Study Population	Method	Intra Rater Reliability	Inter Rater Reliability	Muscles tested
Ford-Smith (2001) [58].	Community dwelling fallers- mean age 75	PD- stabilized	$ICC_{(3,1)}$ 0.61-0.90	$ICC_{(3,1)}$ 0.71-0.91	HF,HE,KE, KF, AD,AP
Kramer (1991) [56].	Healthy older women- mean age 68	PD-belt HHD	$ICC_{(2,1)}$ 0.98 $ICC_{(2,1)}$ 0.96	not provided	HA
Fenter (2003) [66].	Community dwelling women- mean age 24	PD- stabilized	$ICC_{(2,1)}$ 0.88-0.96	$ICC_{(2,1)}$ 0.9-0.95	HA

HF=hip flexors; HE=hip extensors; HA=hip abductors; KE=knee extensors; KF=knee flexors; AD=ankle dorsi-flexors; AP=ankle plantar flexors

Lower extremity muscle strength of healthy, older adults living it the community obtained using portable and fixed dynamometry has been reported in a number of studies [56-58, 63, 64, 67]. A summary of the methods and the results of these studies can be found in Appendix 1. It is likely that the varied results obtained are the results of differences in testing protocols. To compare results from PD with those produced by isokinetic dynamometry, the measurements need to be reported in units that reflect joint torque: Newton meter (Nm). It is also important that the MVIC of the muscles to be tested are measured in an antigravity position so that the torque calculation reflects the true joint torque.

Measurement of Balance Confidence in the Home Care Population

A fear of falling has been found in both fallers and non fallers in the older adult population living in the community [68]. The Activities-specific Balance Confidence (ABC) Scale is a 16 item questionnaire that evaluates perceived ability to maintain balance during routine daily activities [69]. The ABC scale has been found to correlate with self reported physical abilities (subscale of the Physical Self Efficacy Scale ($r=.63$, $p<.001$)) in adults over 65 years. The test-retest reliability of the ABC scale was found to be high over a two week period ($r = 0.92$, $p <0.001$) [69]. The standardized procedure to administer the ABC scale and a copy of the ABC can be found in Appendix 10.

Addressing Fall Risk through Progressive Balance Training

Two recent systematic reviews with meta-analyses addressing the effect of exercise on balance, [16] and on fall rate, [17] in older adults living in the community or in residential care were reviewed. A summary of the RCTs from each systematic review, with older, community dwelling adults as their target population, is included in Appendix 2. A further review of the literature was done for RCTs which included measurement of sensory inputs and manipulation of sensory inputs in the balance training program. A summary of these trials is also included in Appendix 2. The following section is a discussion of those RCTs that included the measurement of sensory inputs as an outcome measure and/or those RCTS which included manipulation of sensory inputs in the balance training intervention of the study.

Measurement of Sensory Inputs as an Outcome Measure in Progressive Balance Training

Only one study in the trials in Appendix 2 used CTSIB as an outcome measure for a balance training intervention. Maduriera (2007) used the CTSIB as an outcome measure in a 12 month exercise balance training intervention that did not include manipulation of sensory inputs. Osteoporotic older women (mean age 74 ± 4.2years) participated in balance training which consisted of 40 classes (1 session/week) with walking, stretching, and BOS and coordination balance exercises. The participants were also asked to perform the balance exercises for 30 minutes (3 sessions/week) on their own. Madureira (2007) reported no difference between the Intervention and Control Groups with the CTSIB assessment prior to the intervention. The Control Group received 'orientation to prevent falls' and treatment for osteoporosis only. Scores for CTSIB were not reported.

The number of participants who could complete each condition of CTSIB for 30 seconds was reported as the outcome for static balance. The number of participants who completed $CTSIB_{Test\ 5}$ and $CTSIB_{Test\ 6}$ was reported to be significantly different in the Intervention than in the Control Group post intervention (Chi Square, $p < 0.001$). Specific scores for CTSIB conditions were not reported.

Of the studies that manipulated sensory inputs to challenge participants to use vestibular control, none used the CTSIB as an outcome measure. However, components of the CTSIB were addressed in assessment of sensory inputs. Hu (1994) utilized a motorized platform and potentiometer to determine the ability of participants to stand for 10 seconds, with eyes open (EO) and eyes closed (EC), on a firm surface and on a sway referenced platform [14]. After a 15 day training session, including training with EC on a sway referenced platform[1] , the ability to stand on a foam surface with EC closed improved significantly. Wolfson (1996) and Rose and Clark (2000) used the Sensory Organization Test (SOT) in the instrumented version of the CTSIB (computerized posturography) to assess sensory inputs [13, 15]. Wolfson (1996) reported that older adults (mean age 80), who received balance training, including manipulation of sensory inputs using a computer generated, sway referenced force platform, 3 sessions/week, improved ability with the SOT [15]. Rose and Clark (2000) reported a significant, moderate effect size (0.44) for the change in SOT scores, after an eight week balance

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[1] Platform sway is proportionate to spontaneous sway of participant so that the ankle is moved in the planes available in the training equipment by rotation of the platform. Somatosensory inputs normally used for balance are therefore minimized by platform sway 14. Hu, M.H. and M.H. Woollacott, *Multisensory Training of Standing Balance in Older Adults:I. Postural Stability and One-Leg Balance.* Journal of Gerontology, 1994. **49**(2): p. M52-M61..

program which included manipulation of sensory inputs using a sway referenced platform with and without foam. These results demonstrate that the ability to utilize sensory inputs is modifiable in older adults with a history of falls, using complex instrumentation and equipment [13, 15]. It is interesting to note that the amount of improvement in measured standing balance increased as the balance challenges became more difficult (i.e. more than one sensory input was altered) [13]. Neither Wolfson (1996) nor Rose and Clark (2000) reported specific results for each sensory condition [13, 15]. Instead, each study reported composite balance scores for SOT results that were composed of different variables in each study [13, 15].

Measurement of Mobility an as an Outcome Measure in Progressive Balance Training

Rose and Clark (2000) also reported significant differences in TUG scores between the Intervention and Control Groups following an 8 week (2 sessions/week) balance training program which included manipulation of sensory inputs as well as BOS and coordination balance exercises [13]. TUG scores reported for the Intervention and Control Group at Pre Intervention assessment were 14.5 ± 8.9 and 12.4 ± 5.7 seconds respectively. TUG scores for the Intervention Group of 11.8 ± 6.2 seconds were found to be significantly different than those reported for the Control Group (14.5 ± 8.9 seconds) [13].

Progressive Balance Training with Manipulation of Sensory Inputs in the Home Care Setting

Rose and Clark (2000) provide a detailed description of the eight week balance training program, conducted in a laboratory setting with a computerized biofeedback system and force platform [13]. The progressive program, outlined by Rose and Clark (2000), used complex instrumentation, including computer feedback regarding the movements that older adults were asked to achieve [13]. Older adults were asked to increase the range of weight shifting or stepping while undertaking tasks such as reaching for objects of different heights and with external cueing for speed of movement [13]. Sensory manipulation and BOS tasks were progressed, as tolerated, to increase the degree of difficulty over eight weeks [13]. Older community dwelling adults, with a history falls, demonstrated improved measures of balance and mobility performance following balance training that was progressive, manipulated sensory inputs and challenged sensory integration by promoting sensory conflict [13]. It is not known if older, community dwelling, balance impaired adults can attain improved measures of balance control and mobility, when trained with manipulation of sensory inputs in a progressive balance training program and delivered in the subject’s home without complex instrumentation.

Addressing Fall Risk Factors through Progressive Resistance Exercise

Weakness of the LE is an independent risk factor for falling, however there is little evidence that programs to strengthen the LE in community dwelling adults will improve postural control and mobility [17, 18, 24, 25]. Few examples of improved balance control and mobility in community dwelling older adults, following progressive resistance exercise (PRE), were found in the literature. Hess and colleagues (2005) trained older, balance impaired, community dwelling adults with a PRE program following the American College of Sports Medicine (ASCM) guidelines, using professional gym equipment [26]. Reported results included an increase in strength for targeted muscle groups and an improvement in Berg Balance Scale and TUG scores in the Intervention Group (n=13) compared to the Control Group(n = 14) [26]. The Berg Balance Scale scores showed a significant improvement from 48.8 +/-2.4 to 51.2 +/-4.3 (p = 0.030) in the Intervention Group, while the Control Group showed no improvement [26]. The TUG scores improved from 11.5 +/-2.4 seconds to 9.7 +/-2.5 seconds after the 10 week program in the Intervention Group (p = 0.045) [26]. The Control Group did not show improvement [26].

The ACSM recommends that healthy older adults start resistance training with the basic progressive program for healthy adults [4]. The basic progressive exercise program for improving muscle strength and creating muscle hypertrophy in older untrained adults, recommended by the ACSM, is the use of both multiple- and single-joint exercises, with slow to moderate lifting velocity, for one set per exercise per muscle with 60–80% of 1 repetition maximum (1RM) for 8–12 repetitions. [4]. Depending on the goals of the older adults, as well as their physiological status, variables such as exercise selection, order, intensity, volume, rest periods, and frequency can be manipulated to suit the individual [4].

In studies that have followed the ACSM guidelines for PRE in older adults, very few adverse effects have been reported [26, 70]. Screening for contraindications as well as providing proper instruction in technique and a warm-up was included in the study that reported no adverse effects [26]. Fiatarone (1994) found that frail very old adults had a dose response to high intensity PRE (1RM protocol repeated every 2 weeks) with the exercise group showing a 113 +/- 8% improvement in muscle strength with an associated increase in spontaneous physical activity [70]. Only one person dropped out of this study due to adverse effect of exercise [70]. In a further study by Hess(2005) , no adverse events were reported following a 10 week program of high intensity PRE for balance impaired, older community dwelling adults [26]. It is not known if older adults referred for home care physiotherapy would achieve the same results with a PRE program using ACSM guidelines.

Summary

Community dwelling, older adults who fall may have difficulty utilizing vestibular inputs. Older adults may experience changes in sensory and mobility function as well as in strength capacity. Comprehensive assessment tools of sensory function in postural control and mobility have been shown to be of benefit in identifying older adults who have balance control impairments and fall risk factors. Assessment tools to measure strength have been shown to be accurate and reliable in establishing baseline measurements for PRE programs in older community dwelling adults. It may be helpful to utilize these assessment tools in order to 1) identify older adults with balance impairments, 2) understand the sensory inputs and strength characteristics of older adults to maintain postural control and mobilize in their environment and 3) design individualized interventions based on assessment findings for older adults in the community.

The results from this study of a home based, high intensity, progressive exercise program with balance impaired, older adults may provide information regarding the ability to modify fall risk factors in this population. Information regarding the ability of this population to utilize vestibular inputs following high intensity progressive balance training will inform effective balance training protocols. The ability of this population to tolerate PRE, using ACSM guidelines, will also inform the ability of the home care physiotherapists to develop effective muscle strengthening programs for balance impaired older adults. As well, understanding factors which influence mobility in the home care population may also help identify effective components in a home based progressive training protocol.

Chapter 3: Methods

A single blind randomized control experimental study was conducted. Hypotheses were tested using data collected from balance impaired, older adults, referred for home care physiotherapy, regarding their ability to use vestibular inputs to maintain standing postural control, their lower extremity strength, and their mobility.

Sample

Older adults living in the community and who were referred to Extra Mural Program (EMP) physiotherapy in Saint John, New Brunswick were recruited for this study. Inclusion and Exclusion criteria are listed below in Table 2.

Sample Size

According to Portney and Watkins [71], for a moderate to large effect size (f = 0.35) to achieve 90% power, 10 participants were needed in both the Resistance and Balance Exercise Group (RBE) and the Resistance Exercise Group (RE). Allowing for a potential 10 percent drop out rate, 12 participants were to be recruited for each group. As illustrated in Figure 1, five participants were recruited for the RBE Group and 4 participants were recruited for the RE Group over a 14 month period.

Table 2: Inclusion and Exclusion Criteria

Inclusion Criteria	***Rationale***
65 years or older	Defined as 'older adult' in this study
Ambulating at least in own home with/with out aide for 6 m; able to stand independently without aide	Safely complete TUG and CTSIB assessment
Living in community or independent retirement home	Home care based study
Able to provide informed consent	Respect autonomy; safely able to complete assessment and exercise procedures
Exclusion Criteria	***Rationale***
Unstable medical conditions including poor control of chronic medical conditions	Safety issue as uncontrolled medical conditions could put participant at risk for injury with high intensity PRE [26, 72].
MMSE < 23; moderate to severe dementia	Unable to provide informed consent and follow instructions for assessment procedures and exercise protocol
Weight bearing restrictions	Weight bearing needed for balance training; restrictions with weight bearing may indicate a condition that contraindicates balance and strength training exercises
Pain on weight bearing	Confound testing results and increase fall risk
Receiving physiotherapy at time of study	Confound research data
Acute osteoarthritis in lower extremities that limits maximal muscle contractions	Contra indication to high intensity PRE [26, 72].
Legal blindness	Unable to perform CTSIB
Diagnosis of progressive neurological condition that would influence balance or muscle strength such as Parkinson's, ALS, MS or stroke within past year	Confound research data
Abnormal VOR or evidence of nystagmus	Confound intervention effects
$CTSIB_{Test\ 5}$ > 15s	Scores <15 seconds reflect vestibular dysfunction [52].

TUG =Timed Up and Go Test
CTSIB = Clinical Test of Sensory Integration and Balance
PRE=progressive resistance exercise
VOR=vestibular ocular reflex
ALS=amyotrophic lateral sclerosis,
MS=multiple sclerosis

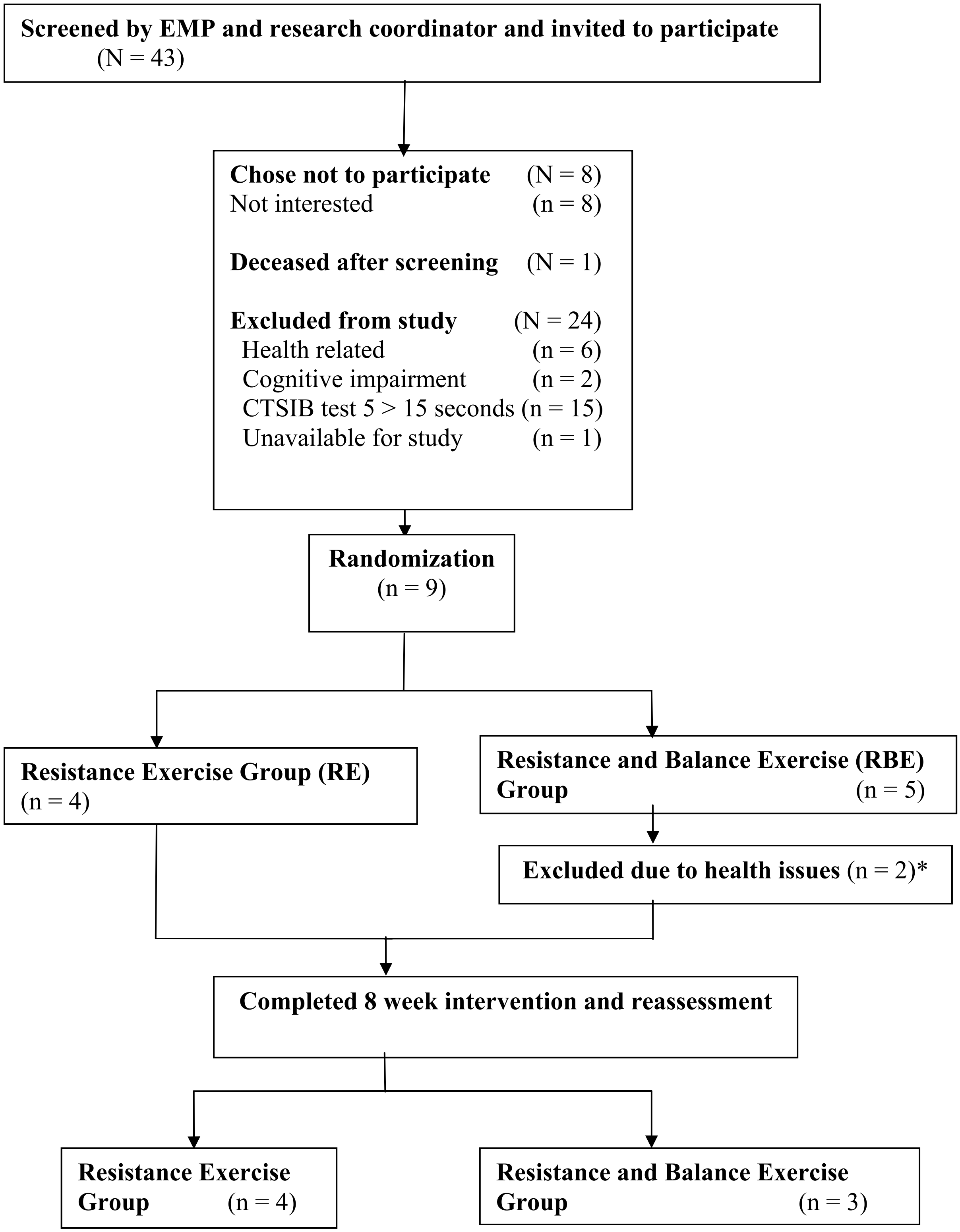

Figure 1: Flowchart of Study Participants and Participation

*One participant was excluded because of a new diagnosis of congestive heart failure. The second participant was excluded due to knee joint instability secondary to osteoarthritis. The knee instability was missed in the initial screening process and detected during the standing PRE exercise.

Recruitment Screening Procedures

Participant recruitment procedures and screening procedures are illustrated in Figure 1. The research coordinator (DH)[2] met with the EMP physiotherapists in the Saint John area to describe the study and provide the EMP physiotherapists with the inclusion and exclusion criteria for the study. The written summary of the research given to the EMP physiotherapy staff is provided in Appendix 3. The EMP physiotherapists identified appropriate patients for inclusion in this study and invited them to meet with the research coordinator to learn more about the study.

The research coordinator (DH) screened participants for age, residential status, standing and walking ability and gait aide as per the inclusion criteria. The research coordinator (DH) also administered the Mini-Mental State Exam (MMSE) and excluded participants with scores of less than 23. Participants who were excluded due to an MMSE score of less than 23 were informed, that due to problems with memory, it would not be appropriate for them to participate in this study.

A written explanation of the study and the written consent form was provided for the potential participants during the initial meeting. The written consent form is provided in Appendix 4. If the patient met the inclusion criteria described above, volunteered for the study, and signed the written consent form, a medical consent form was sent to the patient's family physician along with a summary of the study (Appendix 3). The medical consent form sent to the patient's physician is included in Appendix 5. If medical

[2] Research Coordinator (DH): Denise Hollway, a licensed physiotherapist with extensive experience with older community dwelling adults

clearance was given, the assessing physiotherapist[3] screened for balance impairment using the CTSIB (participants with scores >15 were excluded). If the participant met the criteria of CTSIB score of 15 seconds or less, the assessing physiotherapist continued with the full assessment as described below in the Data Collection Procedures section. Once the participant was successfully screened for the study, the participant was randomized into either the Resistance Exercise Group (RE Group) or the Resistance and Balance Exercise Group (RBE Group) by the research coordinator (DH). Participants were assigned to a study group by drawing from a pool with equal numbers of "RE Group" and "RBE Group" draws in the pool. The assessing physiotherapist performing the assessment and reassessments was blinded as to participant group assignment.

Once the participant volunteered for the study, the total time required for participation in the study was approximately 30 hours. The initial screening process time was 1 hour, including obtaining informed consent. Once medical clearance was obtained from the family physician, the participant met with the assessing physiotherapist who performed the Pre exercise assessment (1.5 hours). A Post exercise assessment (1.5 hours) occurred following completion of the 8 week training session.

Procedures

Data Collection Procedure

Data collection was completed by two physiotherapists trained in the assessment measures used in this study. The Pre exercise assessment session was conducted in the patient's home. Results from $CTSIB_{Test\ 5}$ testing determined if the participant was

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[3] Assessing physiotherapist: licensed physiotherapist hired for the study and trained by the research team

eligible for the study; therefore CTSIB testing was always completed first in the assessment order. After CTSIB testing, the Pre exercise assessment continued with measurement of lower extremity maximum voluntary isometric contraction (MVIC) and mobility as measured with the Timed Up and Go Test (TUG). Alternating the next assessment procedure (MVIC and TUG testing) was done by a random selection of each test from a pool containing equal numbers of “MVIC” and “TUG” options. Subject characteristics of age, cognitive status, weight, medications, co-morbidities, fall history, vision, hearing, and balance confidence were also assessed (Table 3). Standardized procedures were followed for all data collection. Refer to Appendix 6 for the data collection form used in this study. Assessment measures used in the assessment process are included in Appendixes 7-10.

Table 3: Participant Characteristics

Age	Weight
Number and type of medication	ABC score
Co-morbidities	Gait aide
Vision (ETDRS)*	Rate of falls in past 6 months
Hearing (HHIE-S)**	

* Hearing Handicap Inventory for the Elderly-Screening Version score
** Early Treatment Diabetic Retinopathy Study chart for visual acuity score

The Clinical Test of Sensory Interaction and Balance

The testing equipment used to conduct the CTSIB was a stopwatch, a 40 x 60 x7 cm medium density foam cushion, a visual conflict dome made from a Japanese lantern and a safety belt [43]. The equipment was cleaned or replaced as required between participants.

The standardized procedure used to administer the CTSIB test is included in Appendix 7. To prevent a fall, participants were closely monitored at all times by the assessing physiotherapist. Physical assistance was provided as necessary. Participants were also closely monitored to ensure that they were not experiencing pain or fatigue.

To avoid the influence of fatigue or learning on CTSIB performance, a random draw was used to determine the testing order of the firm vs. compliant surface conditions. An equal number of “firm surface testing” and “compliant surface testing” options were available in the draw. Standing surface testing order was assigned prior to testing for each individual. Three trials of each CTSIB standing test were done and were timed to the nearest 0.01 second up to a maximum of 30 seconds. A score of 30 seconds on the first trial in a test allowed the assessing physiotherapist to assign 30 seconds to the following trials in the test condition [43].

Muscle Strength Testing: MVIC testing

A Microfet[4] 2 portable dynamometer (PD) was used to obtain measures of the MVIC of hip (abduction, extension), knee (flexion, extension) and ankle (dorsi-, plantar flexion) muscles. Muscle strength measures were obtained using a standardized approach as outlined in Appendix 8. Limb positions used were intended to isolate the designated muscle groups and eliminate the effects of gravity. A portable exam table and a strap-resisted test protocol [56] were used for all muscle testing. The PD was stabilized during testing with a strap attached to a secured clamp mounted to the portable bed. A felt pad

[4] Hogan Health Industries Inc., P.O. Box 957, Draper, Utah 84020-0957

was placed between the between the PD transducer pad and the participant's limb to enhance patient comfort.

Prior to testing, the participants were instructed in proper breathing technique to avoid the Valsalva maneuver. The participants were instructed in proper technique to avoid accessory movements of the body during test trials. Each participant was given three sub-maximal trials prior to each muscle group test for the purpose of a specific warm up and to ensure proper technique. The moment arm length (MAL) was recorded (in meters) as the distance between the joint axis and the center of the PD.

The PD was zeroed before each contraction and the force pad was positioned perpendicular to the limb being tested. The test trials included a six second isometric contraction and a two minute rest as per ACSM Guidelines. Participants were instructed to build the maximal contraction over one to two seconds and then hold so that a sustained contraction was recorded (in Newtons). The six seconds were counted out loud by the assessor and participants were instructed to stop contracting when six seconds passed.

Participants were monitored for pain, fatigue, accessory movement, and strap /dynamometry placement during testing. Trends in force production were also monitored to ensure steady contraction. Testing was stopped if pain was reported and longer break periods were given if fatigue was reported. Trials were stopped if the PD and strap placement became unstable. Trials were stopped if participants did not use proper technique to avoid undue accessory movement. Trials were resumed when PD placement was stable and proper technique instructions were understood. If there was a trend toward increasing force production with each trial, trials were repeated until a plateau in force production was reached.

The peak force of each trial was recorded by the assessor. Peak force in Newtons (N) was converted to Peak Torque in (Nm) using the following formula:

Peak Torque (Nm) = Peak Force (N) x Moment Arm Length (m)

The average of the three consecutive trials was used for further analysis. Muscle strength measures were normalized to body weight for each participant during data analysis.

Muscle Strength Testing 1 Repetition Maximum (1RM)

The 1RM (one repetition maximum) was determined with band weights using the ACSM guidelines as outlined in Appendix 12. The 1RM was completed during the first training session and repeated biweekly, ending on the last week of the training intervention.

The Timed Up and Go Test (TUG)

Equipment required to complete the TUG test was a stop watch, a firm chair of standard height (44-47 cm) with arm rests [73], a tape measure, a piece of brightly marked colored tape to mark the floor, and a three meter walking space. The TUG test result is the length of time, in seconds, that it takes to rise from a standard chair with arm rests, walk 3 meters, turn, return to the chair and sit down [53]. Participants were allowed to use their regular walking aide for the test. For safety reasons, the participant was asked to wear a safety belt around their waist. The assessor provided close supervision to prevent a fall in the event the participant became unsteady during the TUG test. One practice trial was completed with a minimum of a 1 minute rest period given prior to participant completing the first timed trial. A total of three timed trials were completed with a minimum of a one minute rest period between trials. Standard procedure for the TUG test is provided in Appendix 9.

Progressive Balance and Resistance Exercise Training

The RBE Group was trained for 8 weeks with a progressive exercise program, which included manipulation of sensory inputs, in addition to Progressive Resistance Exercise (PRE) for lower extremity muscles. Participants in the RBE Group were trained by the research coordinator (DH) for up to 1 hour, 3 times per week for 8 weeks (24 hours in total). The RBE participants performed progressive balance exercise training for 30-35 minutes, two times per week and strength training 3 times per week for 25-30 minutes (i.e. 3 sessions per week, alternate days). The balance training protocol for this study was designed based on principles from the program developed by Rose and Clark (2000) [13]. A detailed description of the protocol that was used is outlined in Appendix 11, along with a sample of the first 3 levels of the balance program. While the type of computerized biofeedback used by Rose and Clark is not possible in a home care setting, manipulating support surfaces and sensory inputs is possible. The goal of the program in this study was to improve the ability of the participant to use vestibular inputs for balance control. Participants were challenged to use vestibular control for at least 2/3 of the total time devoted to balance training. Base of support (BOS) conditions, motion, (dynamic balance) and cognitive tasks were also imposed in progressive levels.

The program used by Rose and Clark (2000) consisted of each participant attending a 45 minute exercise session 2 times per week [13]. The same number of sessions per week was used in this study. Participants met with the research coordinator (DH) 3 times per week for 8 weeks, for 1 hour each session. (24 hours in total). The participants in the RBE Group received 3 sessions per week, two of which included progressive balance exercise training for 30 minutes. Strength training occurred 3 times per week for 25-30 minutes (i.e. 3 sessions per week, alternate days). The exercise completed was documented.

Progressive Resistance Exercise Training

Participants who were assigned to both the RBE Group and the RE Group began a high intensity PRE program based on ACSM guidelines (3 sessions per week, alternate days, for 8 weeks). All PRE training for the RE Group was prescribed and supervised by a research physiotherapist (AM)[5]. The research coordinator prescribed and supervised all PRE training sessions for the RBE Group. The exercise completed was documented.

The hip abductors and extensors, knee flexors and extensors and ankle dorsi -flexors and plantar flexors were trained. The training resistance for the PRE program was based on

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[5] Research physiotherapist (AM): Andrea Murphy, a licensed physiotherapist working with the Extra Mural Physiotherapy Program and who has extensive experience with the geriatric population

the participant's 1RM. The PRE program consisted of 1 set of 10 repetitions for each muscle group during each session, with 3 sessions per week for 8 weeks [4, 26].

In the first week of training, participants trained at 50 % of their 1RM to introduce good technique with the exercise and to familiarize the participants with PRE to reduce potential risk of injury. For the remainder of the program, the PRE load was set at 80 % of the 1RM, corresponding to a load that fatigues the muscle in 8 -12 reps. The intensity of the stimulus was maintained by increasing the load each week or as tolerated by the participant [26]. The ACSM guidelines recommend a 2-10% increase in load be applied when an individual can perform the current work load for 1-2 repetitions beyond the desired amount of repetitions [4]. The 1RM was reassessed every 2 weeks and in the final week to ensure the load of resistance was equal to 80% of the 1RM. Each repetition lasted 6 seconds, with the concentric phase and the eccentric phase performed at a pace that allowed proper technique to be maintained. Training sessions were conducted on alternate days. Progression of the PRE is more fully described in Appendix 13.

Statistical Analysis

Demographic information and test results were entered into Microsoft Excel[6] and then transferred to Minitab[7] statistical software for further analysis. Descriptive statistics were calculated for the variables of age, gender, ABC scores; fall history, number of medications, number of co-morbidities, and weight. Descriptive statistics were also calculated for CTSIB, MVIC, and TUG measures. Results of CTSIB were visually

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[6] Microsoft Corporation, 2002
[7] Minitab Inc.,www.minitab.com

inspected for within trial consistency. The mean of the three trials was used as the test score, as per the conventional method for the CTSIB test described in the literature [43]. The normality of the data was tested prior to hypothesis testing by visual inspection of the plotted data and by using the Anderson Darling test.

Hypothesis testing: Primary Hypothesis

Non parametric testing (Mann Whitney U-test) was used to test the primary hypothesis that balance impaired, older adults will have improved ability to utilize vestibular inputs, as measured with $CTSIB_{Test5}$,following high intensity balance and LE strength training compared to balance impaired, older adults who received LE strength training only. The change in $CTSIB_{Test5}$ after exercise was used to test the primary hypothesis (Post CTSIB Test 5 – Pre CTSIB Test 5). Alpha of 0.05 was adopted for hypothesis testing.

Hypothesis Testing: The Secondary Hypothesis

A Spearman Rank Correlation Matrix was used to examine the bivariate relationships that influenced Pre and Post assessment TUG scores. Effects of CTSIB scores, age, ABC score, co-morbidities, and number of medications were examined. Rank correlation was chosen to include all variables which may not be normally distributed and because of the ability to rank all the variables such as number of medications and co-morbidities. The variables entered in the correlation analysis were ranked from lowest to highest; therefore a low score indicated a good performance in TUG scores and a good outcome with number of medications but indicated a poor performance in CTSIB scores and poor ABC score. Relationships were considered statistically significant with an Alpha value of 0.05.

Ethical Considerations

Harms

During balance and mobility assessment there was a risk of participants becoming unsteady and falling. The assessments were done by an experienced physiotherapist who monitored participants continually. The participants wore safety belts for all tests and were able to use usual gait aides with the TUG test. The balance training was delivered by a registered physiotherapist who closely supervised participants during all aspects of the program to prevent harm. A safety belt was worn at all times by participants during progressive balance training.

The study participants were at some risk for muscle soreness during strength testing procedures and with PRE training. However, this adverse outcome was considered unlikely because the procedures include a specific warm up to teach patients appropriate technique and to prepare the muscles for maximal contraction [26]. The procedures also used recommended intensity of exercise for this age group and used close supervision for proper form to decrease the potential of adverse effects [4]. No adverse events were reported by any of the participants of this study.

Benefits

Older, balance impaired adults, who had been referred for home care physiotherapy, were invited to participate in a study conducted in their own homes. The level of care was individualized and provided 3 times per week for 8 weeks. The usual level of care in the home care physiotherapy service for balance impairment is usually 2 times per week. It was felt that the participants would benefit from higher intensity, more frequent, individualized physiotherapeutic intervention. As seen in the analysis of the study, the participants in this study did benefit from increased lower extremity muscle strength. As well, the participants in the RBE groups did have evidence of increased postural control.

Chapter 4: Results

Sample Characteristics

Descriptive statistics for the variables of CTSIB, 1RM, history of falls, medical status, age, MMSE score, Activities Balance Confidence score (ABC), Timed Up and Go test (TUG), number of medications, number of co-morbidities, Hearing Handicap Inventory for the Elderly-Screening Version score (HHIE-S) and weight are summarized for each group in Table 4. See Appendix 15 for the complete data set and qualitative analysis for each participant.

Intervention Sessions and Exercise Adherance

As seen in Table 5, participants performed balance activities with inaccurate somatosensory inputs and vision removed for a minimum of 80% of the total time devoted to balance exercises. As well, all the participants in the RBE Group achieved the maximum goal of 16 sessions (2 sessions/week x 8 weeks) of progressive balance training in this study, with no ill effects reported.

The 1RM of all participants increased for each muscle trained during the 8 weeks of the study, although resistance load did not increase each week for all muscle groups. The maximum number of PRE sessions was 24 sessions (3 sessions/week x 8 weeks), with 2 participants realizing this goal. The minimum attendance for PRE training was 75% of the total number of sessions available (Table 6). Reasons cited for non attendance in the PRE sessions were storms (physiotherapists were unable to travel), social obligations, surgery and doctor appointments. Three participants declined to participate in specific PRE exercises (standing exercises) during specific sessions citing feeling unwell or due to a preexisting condition such as arthritis in the feet (unable to tolerate weight on top of foot for dorsi- flexion training. This attitude did not persist for all sessions as the registered physiotherapists investigated medical status or made adjustments within sessions to encourage participation: i.e. contact physician /family members or adjusted positioning of weights on the foot. There were no adverse effects reported for the participants during PRE training.

Table 4: **Characteristics of Study Participants per Group**

Characteristic	Assessment Session	RE Group (n=4)		RBE Group (n=3)	
Gender Males (n) Females (n)	***Pre***	2 2		1 2	
History of falls (n)	***Pre***	3		3	
Lives alone	***Pre***	2		1	
Assisted living residence	***Pre***	1		1	
History of cardio-vascular disease	***Pre***	4		2	
History of stroke	***Pre***	1		0	
		Mean (sd)	***Median (min-max)***	***Mean (sd)***	***Median (min-max)***
AGE (years)	***Pre***	80.3 (3.9)	81.0 (75-84)	86.7 (2.7)	87.0 (84-89)
MMSE score (max =30)	***Pre***	26.5 (2.7)	27.0 (23-29)	28.0 (2.0)	28 (26-30)
ABC score (max=100)	***Pre***	41.0 (27.7)	52.3 (0*-59.4)	57.1 (28.3)	59.1 (27.8-84.4)
	Post	38.7 (29.8)	41.4 (0-71.9)	76.4 (19.7)	83.8 (54.1-91.3)
TUG (s)	***Pre***	28.2 (20.7)	21.0 (12.5-58.4)	15.8 (3.9)	13.8 (13.4-20.3)
	Post	30.1 (33.1)	16.5 (10.6-80.6)	13.1 (1.8)	12.4 (11.8-15.1)
No. of Medications	***Pre***	3.8 (1.7)	3.5 (2-6)	3.3 (2.3)	2.0 (2-6)
	Post	3.0 (0.8)	3.0 (2-4)	3.0 (1.7)	2.0 (2-5)

Table 4: (Continued) Characteristics of Study Participants

Characteristic	Assessment Session	RE Group (n=4)		RBE Group (n=3)	
		Mean (sd)	***Median (min-max)***	***Mean (sd)***	***Median (min-max)***
No. of co-morbidities	***Pre***	3.5 (1.3)	3.5 (2.0-5.0)	3.7 (1.2)	4.0 (3.0-5.0)
	Post	4.0 (1.0)	4.0 (3.0-5.0)	3.5 (1.3)	3.5 (2.0-5.0)
HHIE-S (max score=40)	***Pre*****	17.3 (11.7)	22.0 (4.0-26)	4.0 (1.0)	2.0 (0-6.0)
	Post**	16.7 (14.7)	22.0 (0-28.0)	4.7 (4.2)	6.0 (0-8.0)
Weight	***Pre***	156.3 (23.6)	147.5 (140.0-190.0)	162.3 (26.8)	155 (140-192)

No statistical differences found between the RBE Group and RE Group for the Pre exercise characteristics of: Age, MMSE, TUG, ABC, No. of co-morbidities, No. of medications and weight (Mann Whitney U- test, $\alpha = 0.05$).

*patient rated ABC at zero

* *HHIE-S: n=3 for RE Group;

MMSE: Mini Mental State Exam

ABC: Activities-specific Balance Confidence Scale

TUG: Timed Up and Go test

HHIE-S: Hearing Handicap Inventory for the Elderly-Screening Version score;

Table 5: % of Components Implemented in Total Time of Balance Protocol

Components of Progressive Balance Program		**Participants RBE Group**		
		EM24	**EM26**	**EM30**
Attendance (total # of sessions)		16	16	16
Total length of sessions (minutes)*		35	30	30
Base of Support	*Broad*	25%	90%	80%
	Narrow	75%	10%	20%
Surface	*Firm*	5%	10%	10%
	Compliant	95%	90%	90%
Vision	*EO*	10%	10-20%	10%
	EC	90%	80-90%	90%
Motion	*Static*	20%	30%	20%
	Weight Shift	80%	70%	80%
Cognitive Task	*Yes*	10%	5%	10%
	No	90%	95%	90%
Speed	*Self paced*	80%	90%	100
	Slow paced	10%	10%	0%
	Fast paced	10%	na	0%
Stepping	*Self paced*	5%	na	na

na = not applicable
* = time varied due to endurance of the participants

Table 6: PRE Training Sessions Attendance

	RE GROUP				**RBE GROUP**		
PARTICIPANT	EM02	EM03	EM33	EM34	EM24	EM26	EM30
ATTENDANCE total # of sessions (%)	24 (100)	20 (80)	19 (79)	22 (92)	24 (100)	23 (96)	18 (75)
REPETITION PER SET (1 set per session)	8-10	8-10	8-10	8-10	8-12	8-12	8-12

Muscle Strength

MVIC Data

MVIC testing was used to assess muscle strength. However, the data collection procedure was too lengthy, or the positioning on the table was uncomfortable for some participants. Therefore, as illustrated in Appendix 14, data is missing for several participants or muscle groups. No furhter analysis was completed using the MVIC data and muscle strength was evaluated using the 1RM.

1RM Data

The 1RM used in the PRE training protocol of the study provides evidence that strength progressed in this study (Table 7). During Pre exercise assessment, there were no significant differences between the 1RM of each muscle group in the RBE and the RE Groups ($p< 0.05$). Participants trained at loads ranging from 57 - 92% of the calculated 1RM after the initial week of training (Appendix 15). By inspection, the 1RM used to train each muscle increased over the training period for every muscle group (Table 7). The change in 1RM of the RBE Group was equivalent to the change in 1RM of the RE Group ($p > 0.05$) (Table 8), therefore the two groups were combined to test the hypothesis that the 1RM of each muscle increased after exercise. For each muscle group, the Post exercise 1RM exceeded the Pre exercise 1RM ($p < 0.05$). Comparing the Pre and Post exercise 1RM data for each of the muscle groups trained (N=7), demonstrated significant differences for all muscle groups ($p < 0.05$).

Table 7: One Repetition Maximum (Kg) per participant

MUSCLE GROUP		**RE GROUP**				***RBE GROUP***		
	Week	***EM02***	***EM03***	***EM33***	***EM34***	***EM24***	***EM26***	***EM30***
HIP ABD	*1*	4	5	6	6	3	3	9
	2	4	5	6	4	3	4	9
	3	8	8	7	7	5	4	10
	4	8	8	6	8	5	4	11
	5	12	12	6	8	6	7	NA
	6	12	12	6	9	6	8	11
	7	14	14	7	13	6	8	14
	8	14	NA	8	15	6	NA	NA
KNEE EXT	*1*	9	14	12	18	12	16	10
	2	12	11	12	18	12	16	11
	3	19	18	13	19	13	18	11
	4	19	18	13	19	14	18	12
	5	20	19	13	20	14	18	16
	6	20	19	13	22	15	18	NA
	7	20	20	14	23	15	18	16
	8	20	NA	14	24	16	18	18
ANKLE DF	*1*	14	20	20	20	15	20	14
	2	15	16	20	20	16	20	15
	3	19	23	23	23	18	25	15
	4	20	24	23	23	20	25	16
	5	23	25	24	24	20	27.5	20
	6	23	25	24	24	24	30	NA
	7	24	25	25	25	25	30	20
	8	25	NA	25	25	26	33	22

Table 7 (Continued): One Repetition Maximum (Kg)

MUSCLE GROUP	Week	RE GROUP				*RBE GROUP*		
		EM02	*EM03*	*EM33*	*EM34*	*EM24*	*EM26*	*EM30*
ANKLE PF	*1*	8	8	15	15	17	14	12
	2	9	8	15	15	17	14	13
	3	14	16	16	17	20	18	13
	4	15	16	16	17	20	18	14
	5	16	18	18	18	20	18	16
	6	16	18	18	19	25	18	NA
	7	17	20	19	20	27	20	13
	8	17	NA	20	22	30	22	18
HIP EXT	*1*	4	8	9	12	6	10	10
	2	5	8	9	12	7	11	10
	3	10	16	10	13	7	13	10
	4	10	16	10	14	8	14	11
	5	15	18	12	15	11	18	17
	6	16	18	12	17	12	20	NA
	7	16	19	13	19	12	20	17
	8	16	NA	14	22	NA	21	19
KNEE FLEX.	*1*	4	8	11	12	6	12	12
	2	5	8	11	12	6	13	12
	3	7	16	12	13	7	14	12
	4	8	16	12	14	8	15	13
	5	13	18	13	15	11	16	15
	6	15	18	13	15	12	17	NA
	7	15	18	14	17	14	19	15
	8	15	NA	14	19	15	19	17

NA = not available due to training schedule or patient non attendance

Table 8: Actual and % Change in 1RM following 8 week PRE Training Intervention

	RE GROUP (n=4)				***RBE GROUP (n=3)***			
MUSCLE	**Actual Change 1RM (kg)**			**% change 1RM**	**Actual Change 1RM (kg)**			**% change 1RM**
	Mean (sd)	**Median**	**Min-Max**		**Mean (sd)**	**Median**	**Min-Max**	
HIP ABD	7.5 (3.7)	9	2-10	153.3	4.3 (1.2)	5	3-5	107.7
KNEE EXT	6.3 (3.7)	6	2-11	53.8	4.7 (3.1)	4	2-8	42.0
ANKLE DF	6.5 (3.0)	5	5-11	38.5	10.7 (2.5)	11	8-13	65.0
ANKLE PF	8.3 (3.0)	8	5-12	85.8	9.0 (3.6)	8	6-13	61.0
HIP EXT	9.5 (3.1)	10.5	5-12	144.3	8.7 (2.5)	9	6-11	100.0
KNEE FLEX	7.8 (3.6)	8.5	3-11	121.3	7.0 (2.0)	7	5-9	83.3

Clinical Test of Sensory Integration and Balance (CTISB) Data

Trial Consistency

Prior to hypothesis testing, individual subject data were inspected. Because of the overall small sample size, visual observation was used to examine for trial effects during Pre and Post exercise CTSIB assessments. Individual trial data for $CTSIB_{Test\ 1\text{-}6}$ for Pre exercise trials are presented in Figures 2-7 below. Individual trial data for $CTSIB_{Test\ 4\text{-}6}$ for Post exercise assessment are presented in Figure 8-10 below. $CTSIB_{Test\ 1\text{-}3}$ for Post exercise trials were all within 30 seconds, therefore had little variability and are not presented. There did not appear to be a systematic trend toward either improvement, or decreased performance as a function of trial.

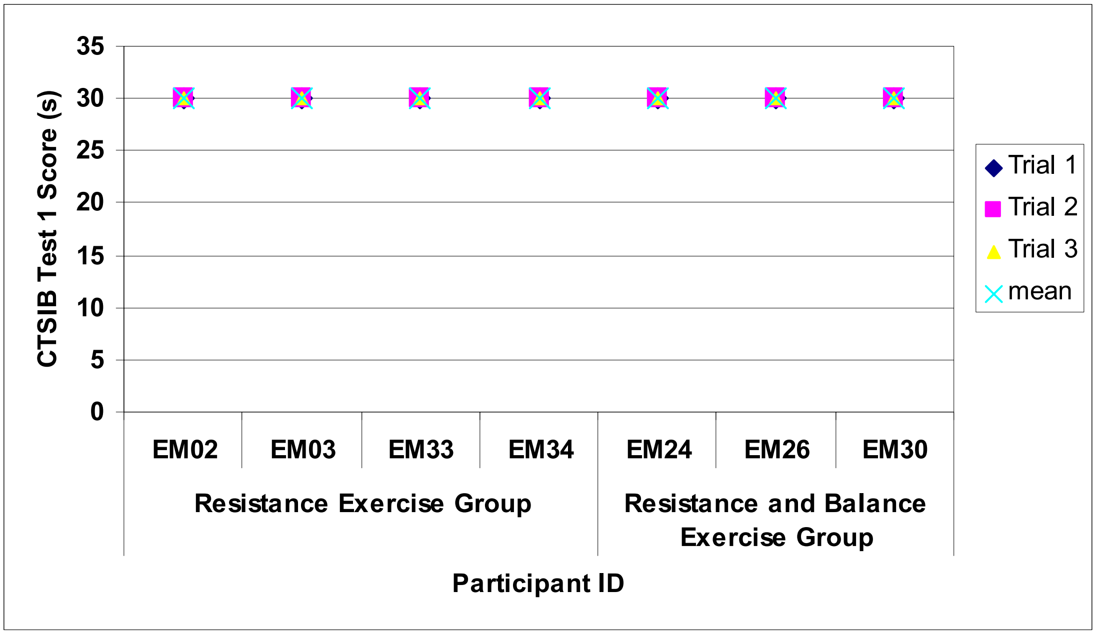

Figure 2: Pre Exercise trial data for CTSIB$_{\text{Test 1}}$

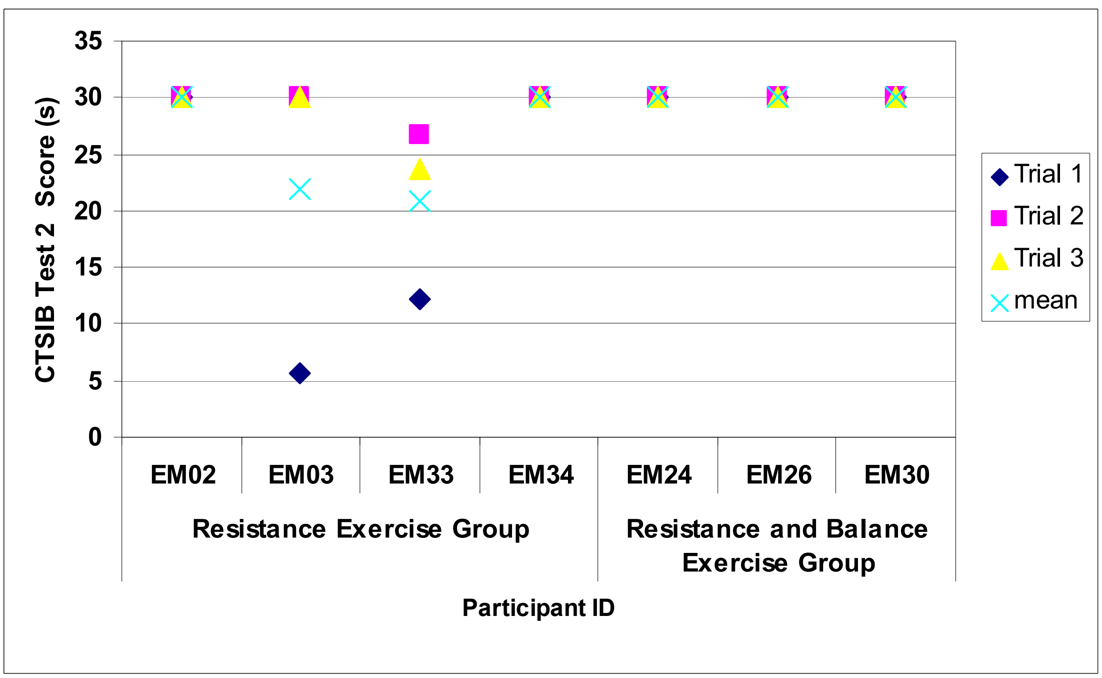

Figure 3: Pre Exercise trial data for CTSIB$_{\text{Test 2}}$

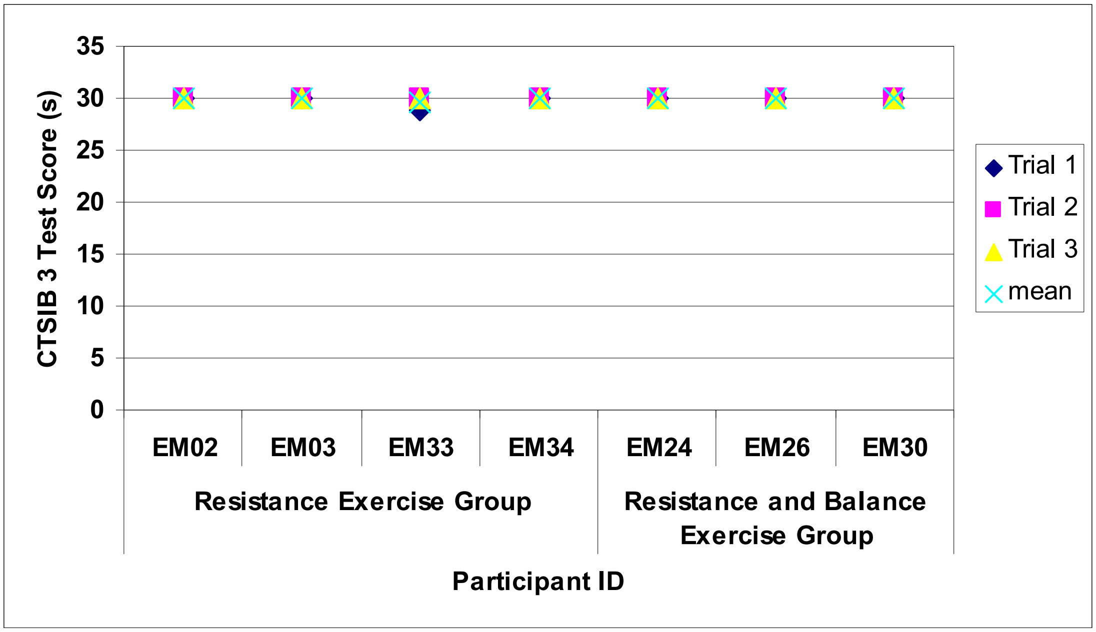

Figure 4: Pre Exercise trial data for $CTSIB_{Test\ 3}$

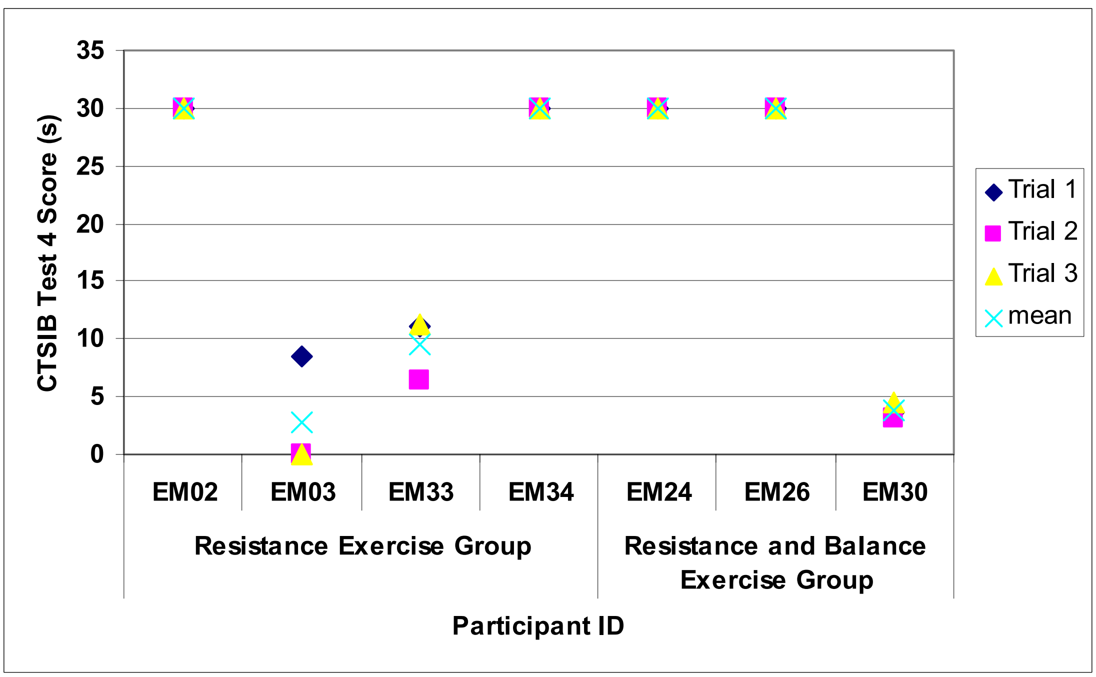

Figure 5: Pre Exercise trial data for $CTSIB_{Test\ 4}$

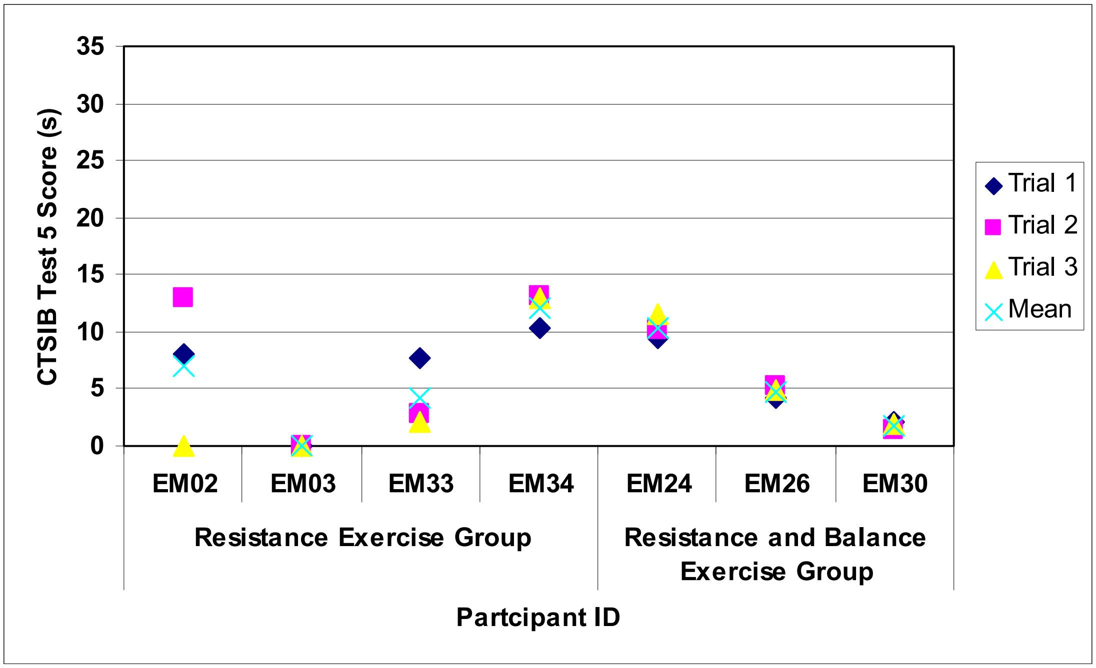

Figure 6: Pre Exercise trial data for $CTSIB_{Test\ 5}$

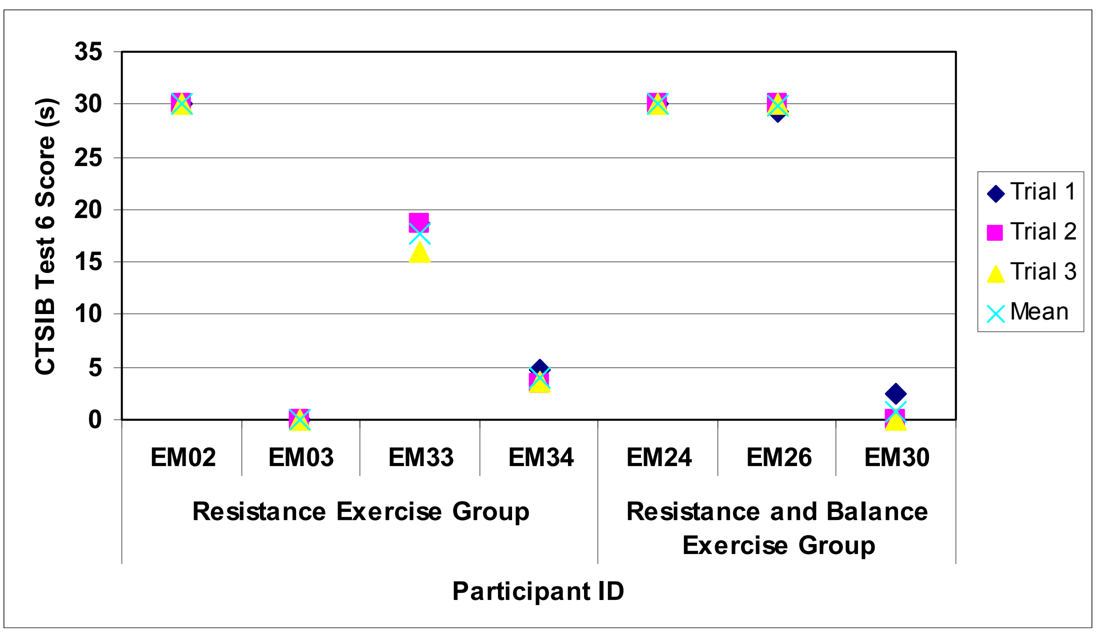

Figure 7: Pre Exercise trial data for $CTSIB_{Test\ 6}$

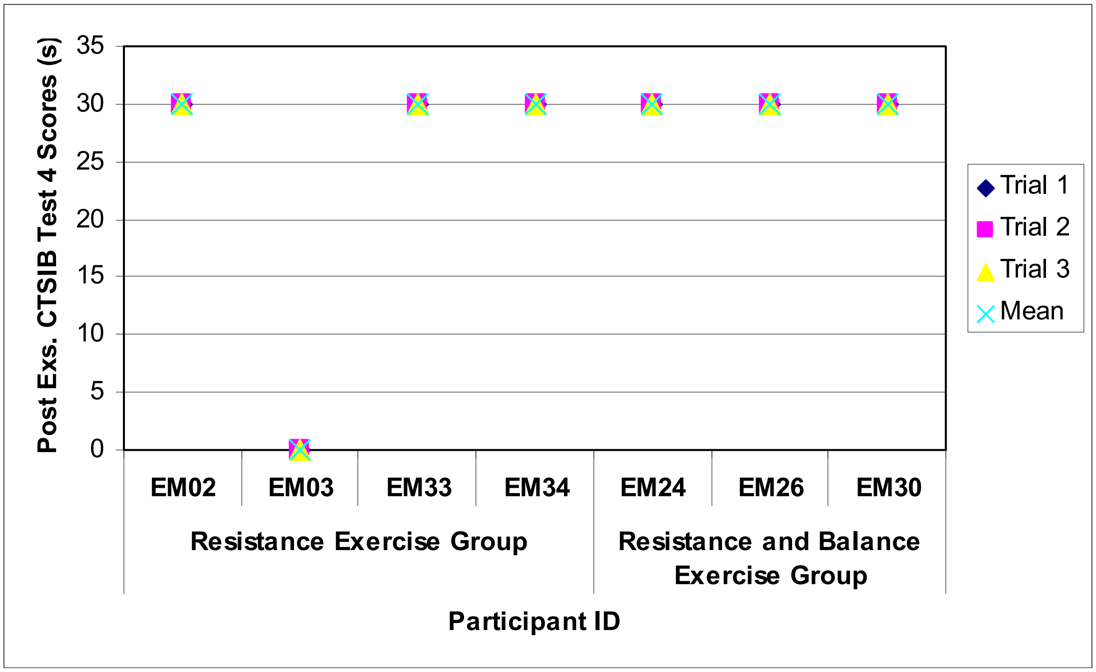

Figure 8: Post Exercise trial data for $CTSIB_{Test\ 4}$

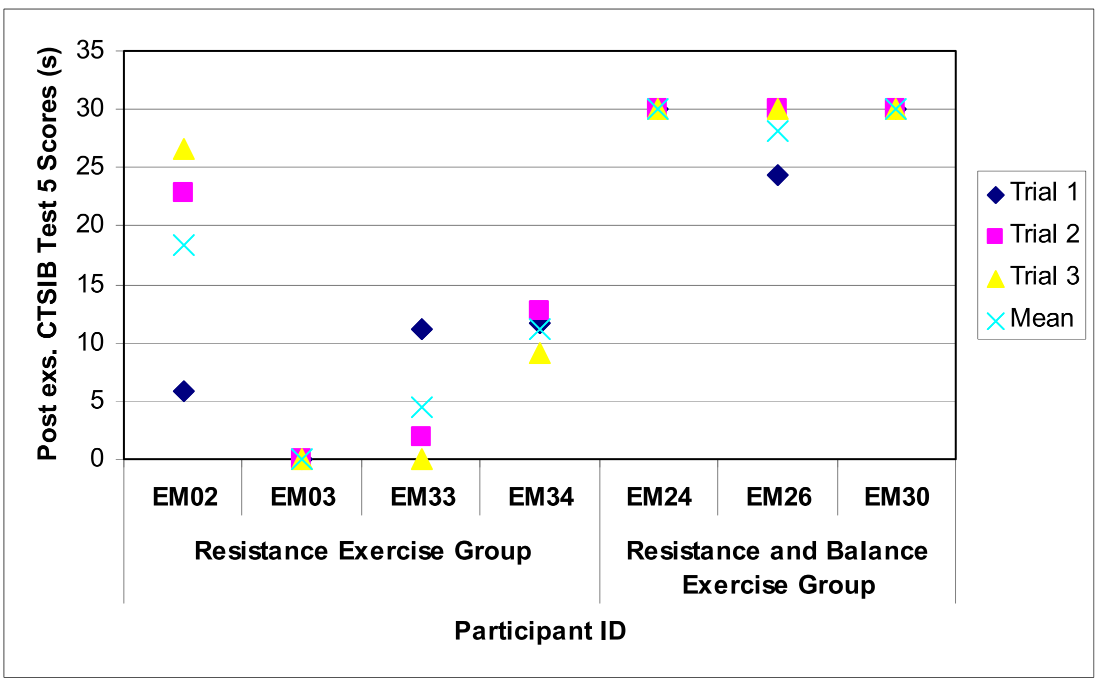

Figure 9: Post Exercise trial data for $CTSIB_{Test\ 5}$

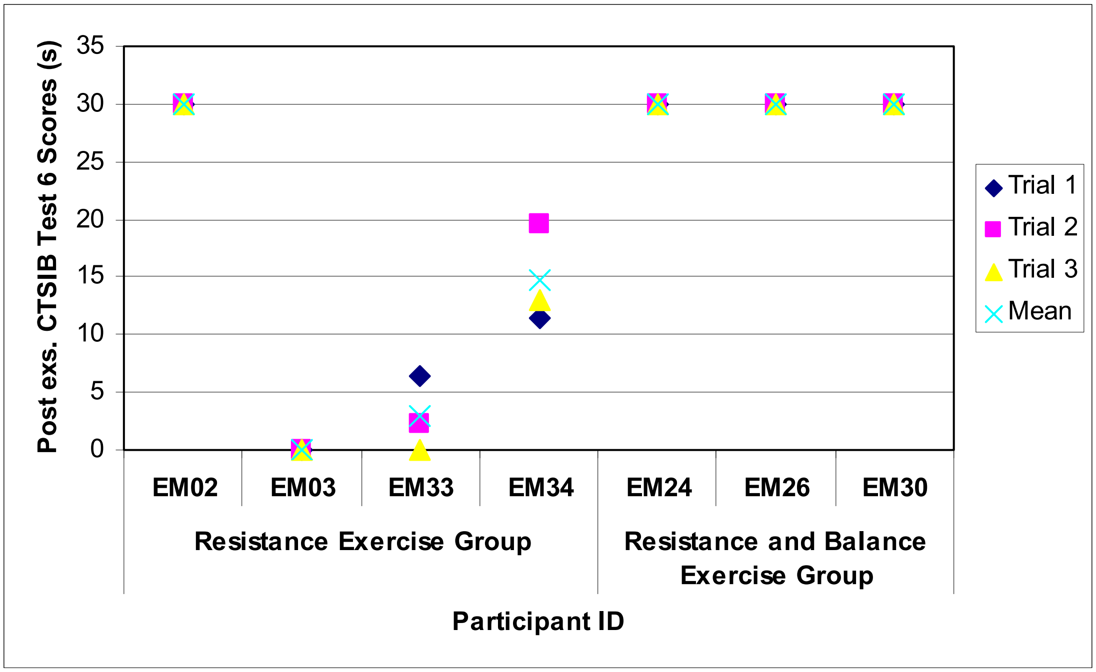

Figure 10: Post Exercise trial data for CTSIB$_{\text{Test 6}}$

Normality Testing

Prior to hypothesis testing, the normality of the data was tested by visual inspection of the plotted frequency and by using the Anderson Darling test. The plotted frequency of the data is displayed in Figure 11. Inspection of Figure 11 demonstrates the data is skewed to the left, indicating the data do not follow a normal distribution. According to the Anderson Darling test, p = 0.218, there is evidence that the data is normally distributed. However, due to the small sample size and skewed distribution, non parametric tests were chosen to test the primary hypothesis.

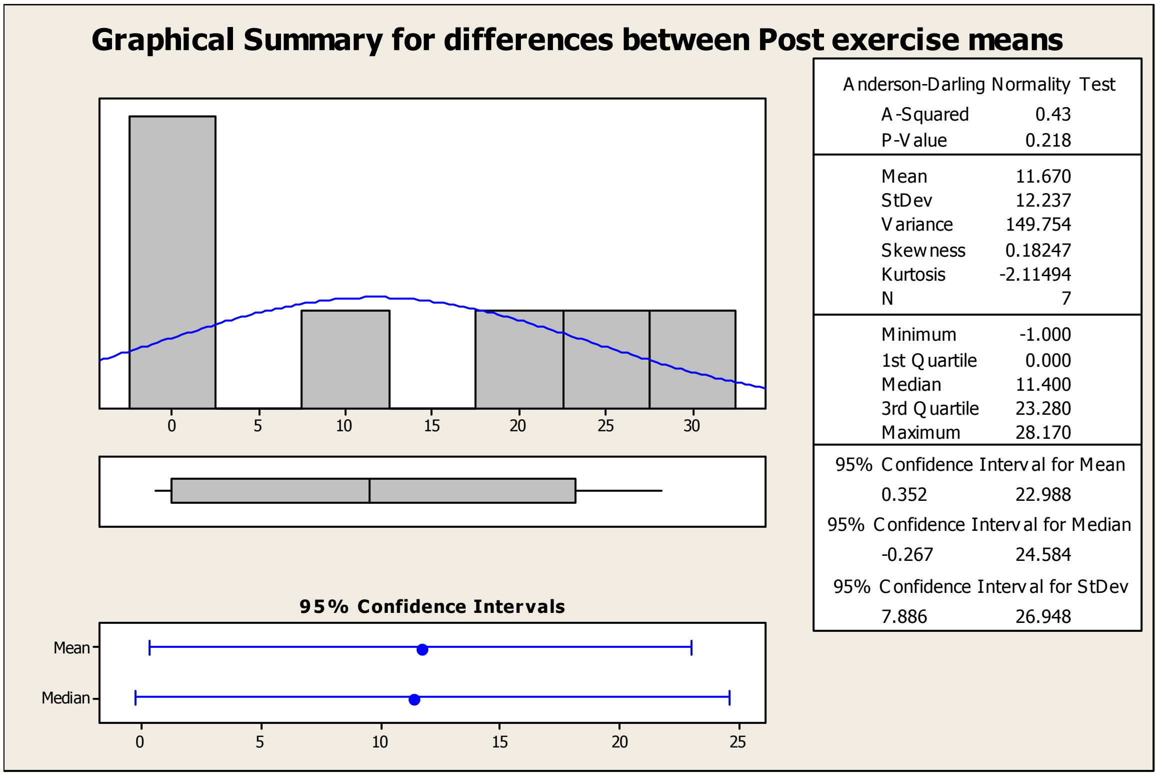

Figure 11: Mini tab output: Graphical Summary for Post Exercise $CTSIB_{Test\ 5}$ data

Summary Statistics for CTSIB: Firm Surface Conditions- $CTSIB_{Test1\text{-}3}$

The summary statistics for CTSIB scores of each group are displayed in Table 9. All the participants in the RBE Group and RE Group achieved the maximum test time of 30s during Post exercise assessment for $CTSIB_{Test\ 1}$ and $CTSIB_{Test\ 3}$. With respect to $CTSIB_{Test\ 2}$, all three participants in the RBE Group achieved the maximum score of 30 s during both Pre and Post exercise assessments. Although some participants in the RE Group had decreased scores with $CTSIB_{Test\ 2}$ during the Pre exercise assessment, all participants in the RE Group achieved a narrow range of scores close to 30 s during the Post exercise reassessment with $CTSIB_{Test\ 2}$.

Summary Statistics for CTSIB:Compliant Surface Conditions- $CTSIB_{Test\ 4\text{-}6}$

During the Pre exercise assessment, one participant in the RBE Group and two participants in the RE Group had scores below 15 seconds with $CTSIB_{Test\ 4.}$ During Post exercise assessment, all but one participant achieved 30 s with $CTSIB_{Test\ 4}$. Performance for $CTSIB_{Test\ 5}$ was similar for all participants during the Pre exercise assessment, with all scores below 15 seconds. During the Post exercise assessment of $CTSIB_{Test\ 5}$, participants in the RBE Group achieved a narrow range of scores close to the maximum score of 30 seconds. Participants in the RE Group had a wide range of scores with $CTSIB_{Test\ 5}$ during Post exercise assessment, with all 4 participants scoring below 20 seconds. There was a wide range of scores in $CTSIB_{Test\ 6}$ during Pre exercise assessment in both Groups. During Post exercise assessment, all three participants in the RBE Group scored 30 s in $CTSIB_{Test\ 6.}$ Participants in the RE Group had a wide range of scores with $CTSIB_{Test\ 6}$ during Post exercise assessment, with participant EM 02 scoring 30 s and EM03 being unable to complete the test.

Table 9: Summary statistics for CTSIB

		RE GROUP (n = 4)			*RBE GROUP (n = 3)*		
Test	**Assessment Session**	**Mean (sd)**	**Median**	**Min-Max**	**Mean (sd)**	**Median**	**Min-Max**
CTSIB1	**Pre**	30 (0)	30	30-30	30 (0)	30	30-30
	Post	30 (0)	30	30-30	30 (0)	30	30-30
CTSIB2	**Pre**	25.7 (5.0)	25.9	20.9-30	30 (0)	30	30-30
	Post	29.6 (0.7)	30	28.6-30	30 (0)	30	30-30
CTSIB3	**Pre**	29.9 (0.2)	30	29.6-30	30 (0)	30	30-30
	Post	30 (0)	30	30-30	30 (0)	30	30-30
CTSIB4	**Pre**	19.5 (12.1)	19.8	8.5-30	21.3 (15.1)	30	3.8-30
	Post	22.5 (15.0)	30	0-30	30 (0)	30	30-30
CTSIB5	**Pre**	6.7 (5.7)	7.3	0-12.2	5.7 (4.3)	4.8	1.8-10.4
	Post	8.5 (8.0)	7.8	0-18.4	29.4 (1.1)	30	28.1-30
CTSIB6	**Pre**	12.9 (13.7)	10.8	0-30	20.2 (16.8)	29.8	0.8-30
	Post	11.9 (13.6)	8.8	0-30	30 (0)	30	30-30

Primary Hypothesis

The primary hypothesis stated that the ability to use vestibular inputs, as measured with the Clinical Test of Sensory Integration and Balance ($CTSIB_{Test\ 5}$), is greater in balance impaired older adults who complete high intensity progressive exercise training for balance and LE strength, than in older adults who are balance impaired and who receive LE strength training only. The change in $CTSIB_{Test\ 5}$ scores between Pre and Post assessment for the RBE Group and the RE Group were tested using the Mann Whitney U-test for nonparametric data. The data used for this comparison can be found in Table 10. According to the Mann Whitney U-Test, the change in $CTSIB_{Test\ 5}$ scores of the RBE Group (median 23.3 s) were greater than the change in $CTSIB_{Test\ 5}$ scores for the RE Group (median 0.60) ($W = 18.0$, $p < 0.05$).

Table 10: Change in CTSIB Test 5 Scores After Exercise (Post – Pre)

Participant	**Diff RE Group**	**rank**	**Participant**	**Diff. RBE Group**	**rank**
EM 02	11.4	4	EM 24	19.6	5
EM 03	0.0	2	EM 26	23.3	6
EM 33	0.2	3	EM 30	28.2	7
EM 34	-1.0	1			
	Total rank	**10**			**18**

Secondary Hypothesis

The bivariate relationships between TUG scores, $CTSIB_{Test5}$ scores, and designated subject characteristics collected at the Pre and Post exercise assessment were analyzed using Spearman Correlation coefficients (Tables 11 and 12). Variables were ranked from lowest to highest, with a low rank indicating a good performance in the TUG, while indicating a poor performance with CTSIB measurement. Relationships were considered statistically significant with $p < 0.05$. Scatter plots to illustrate relationships found to be statistically significant, are included below in Figures 12-15.

Table 11: Pre Exercise Assessment Spearman Correlation Matrix

Pre Exercise Spearman Correlations: ranked scores for TUG, $CTSIB_{Test\ 5,}$ Age, ABC, No. of medications, No. of co morbidities, 1RM for Hip Abduction (HA)and Extension (HE), Knee Extension (KE) and Flexion (KF), Ankle Dorsi (AD)and Plantar Flexion (AP)

	TUG	CTSIB 5	AGE
CTSIB 5	**-0.786** **0.036**		
AGE	-0.541 0.210	0.126 0.788	
ABC	**-0.857** **0.014**	0.607 0.148	0.577 0.175
Meds	0.505 0.247	-0.468 0.290	-0.170 0.716
Co-Morb.	0.385 0.393	-0.385 0.393	0.194 0.676
HA	0.382 0.398	-0.273 0.554	-0.321 0.483
KE	-0.414 0.355	0.144 0.758	0.473 0.284
DF	0.040 0.932	-0.100 0.832	0.201 0.666
PF	-0.436 0.328	0.382 0.398	0.633 0.127
HE	-0.252 0.585	0.036 0.939	0.500 0.253
KF	-0.148 0.751	-0.111 0.812	0.561 0.190

	ABC	Meds	Co-Morb.
Meds	0.000 1.000		
Co-Morb.	-0.257 0.578	0.346 0.447	
HA	-0.636 0.124	-0.333 0.465	-0.421 0.347

KE	0.577	0.227	-0.093
	0.175	0.625	0.843
DF	0.219	0.543	0.235
	0.637	0.208	0.611
PF	0.218	-0.448	0.402
	0.638	0.314	0.371
HE	0.234	-0.142	-0.426
	0.613	0.762	0.341
KF	0.185	-0.058	-0.343
	0.691	0.901	0.452

	HA	**KE**	**DF**
KE	-0.110		
	0.814		
DF	-0.071	0.854	
	0.880	0.014	
PF	-0.130	0.339	0.264
	0.782	0.456	0.568
HE	0.486	0.655	0.442
	0.269	0.111	0.320
KF	0.453	0.561	0.372
	0.307	0.190	0.411

	PF	**HE**
HE	0.257	
	0.578	
KF	0.189	0.972
	0.685	0.000

Cell Contents: Spearman Rank Correlation
P-Value

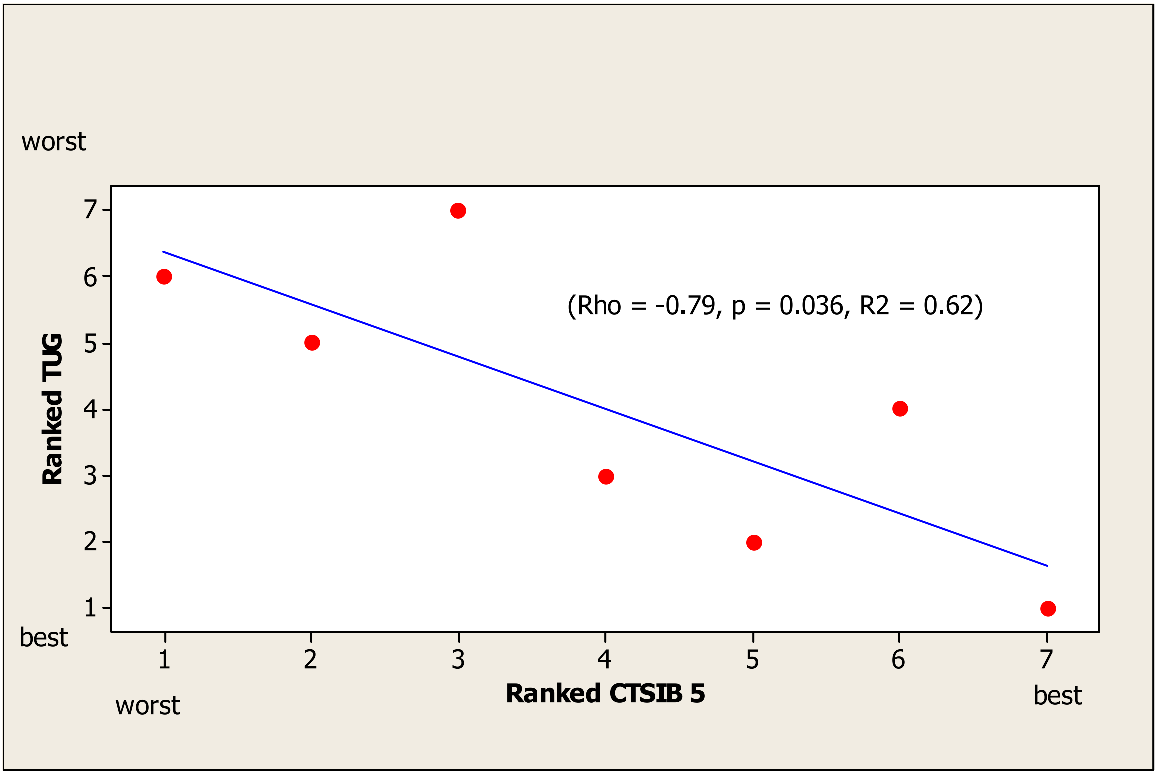

Figure 12: Scatter plot of Spearman ranked Scores: TUG vs. CTSIB 5

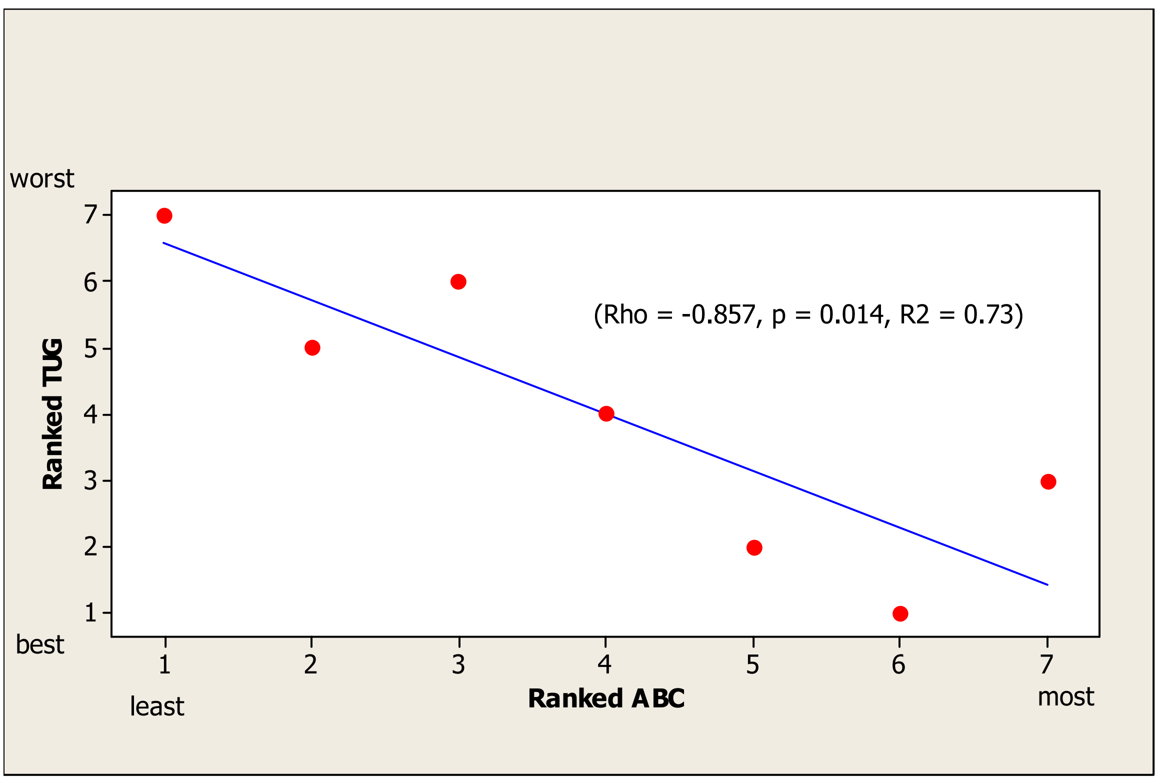

Figure 13: Scatter plot of Spearman ranked Scores: TUG vs. ABC

Table 12 Post Exercise Assessment Spearman Correlation Matrix

Post Exercise Spearman Correlations: ranked scores for TUG, $CTSIB_{Test\ 5,}$ Age, ABC, No. of medications, No. of co morbidities, 1RM for Hip Abduction (HA)and Extension (HE), Knee Extension (KE) and Flexion (KF), Ankle Dorsi (AD)and Plantar Flexion (AP)

	TUG	**CTSIB 5**	**AGE**
CTSIB 5	-0.378 0.403		
AGE	-0.739 0.058	0.609 0.147	
ABC	-0.500 0.253	**0.757** **0.049**	0.595 0.159
Meds	0.356 0.434	-0.397 0.379	-0.057 0.904
Co-Morb.	0.385 0.393	-0.019 0.969	0.194 0.676
HA	-0.168 0.718	-0.359 0.429	-0.453 0.307
HE	-0.631 0.129	-0.173 0.711	0.209 0.653
KE	-0.382 0.398	-0.303 0.509	-0.321 0.483
KF	**-0.800** **0.031**	-0.028 0.953	0.413 0.357
DF	-0.374 0.408	0.139 0.766	0.567 0.185
PF	-0.673 0.098	0.183 0.694	**0.761** **0.047**

	ABC	**Meds**	**Co-Morb.**
Meds	0.019 0.968		
Co-Morb.	-0.018 0.969	0.385 0.394	
HA	-0.374 0.408	-0.333 0.465	**-0.904** **0.005**
HE	0.036 0.939	0.028 0.952	-0.722 0.067
KE	-0.036 0.938	-0.267 0.563	**-0.841** **0.018**
KF	0.273 0.554	-0.029 0.951	-0.551 0.199

DF	0.611	0.434	0.476
	0.145	0.331	0.280
PF	0.309	-0.124	0.365
	0.500	0.791	0.421

	HA	**HE**	**KE**
HE	0.680		
	0.093		
KE	**0.867**	0.697	
	0.012	0.082	
KF	0.467	**0.917**	0.648
	0.291	**0.004**	0.115
DF	-0.630	-0.070	-0.221
	0.130	0.882	0.634
PF	-0.438	0.046	-0.185
	0.325	0.922	0.691

	KF	**DF**
DF	0.201	
	0.666	
PF	0.315	**0.712**
	0.492	**0.073**

Cell Contents: Spearman Rank Correlation
P-Value

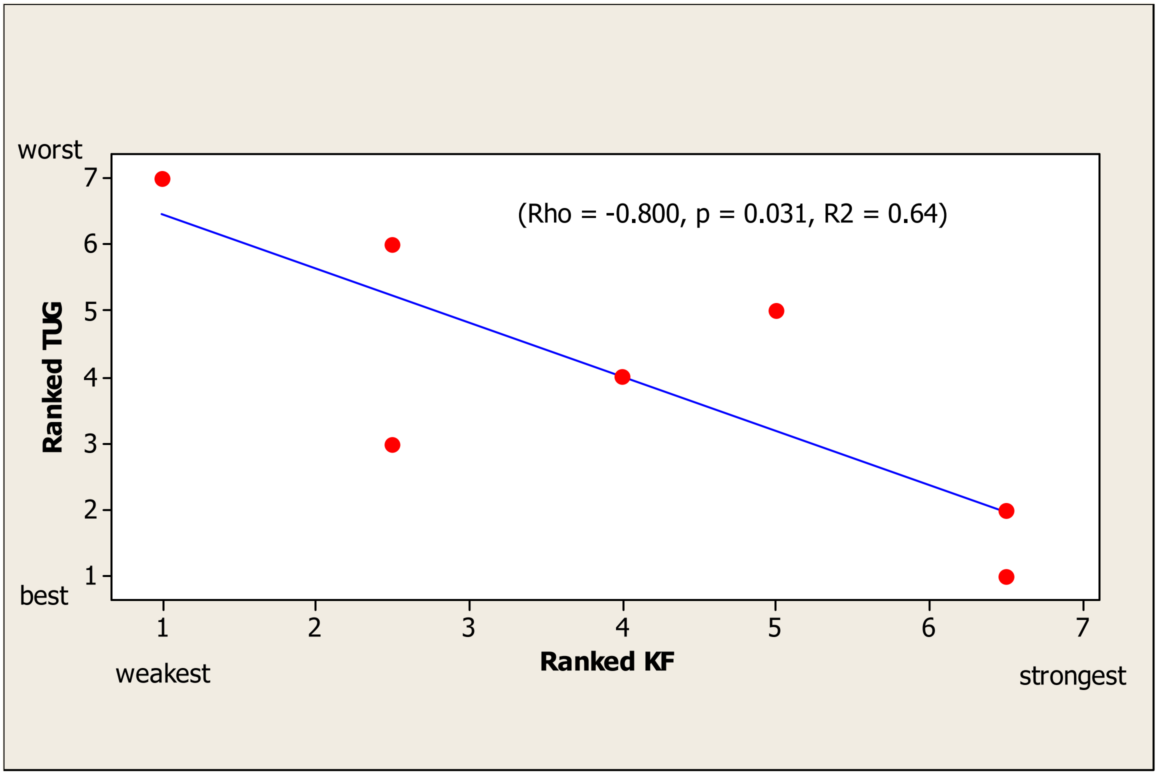

Figure 14: Scatter Plot of Spearman Ranked Scores: TUG vs. Knee Flexion

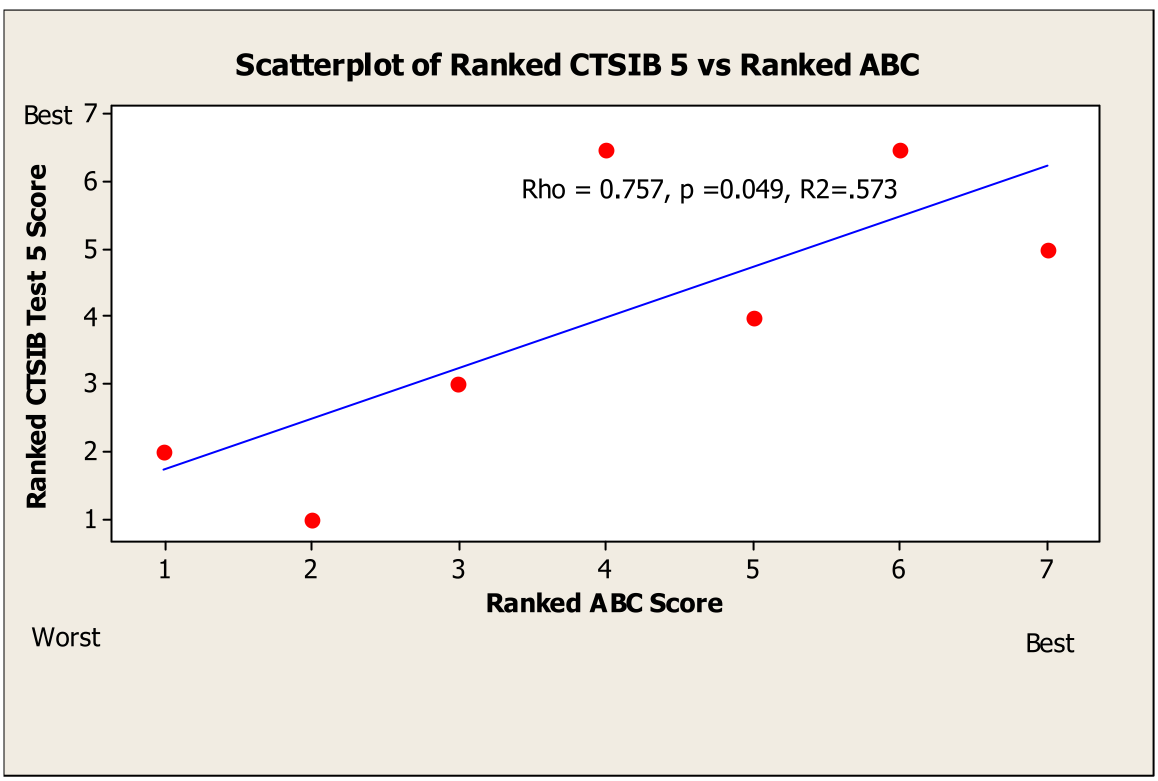

Figure 15: Scatter Plot of Spearman Ranked Scores: CTSIB 5 vs. ABC.

Chapter 5: Discussion

The primary objective of this study was to assess the Post exercise ability of adults (> 65 years) to utilize vestibular inputs for postural control, as tested with the CTSIB. The participants in this study were older, community dwelling adults, who had been referred for home care physiotherapy[8] due to increased fall risk (i.e. history of falls, decreased balance and /or LE strength). In fact > 85 % of this group reported a history of falls. The study participants demonstrated evidence of decreased mobility, as measured by TUG scores during Pre exercise assessment. All participants also had evidence of sensory impairments with CTSIB tests scores during Pre exercise assessment. The participants received high intensity progressive exercise for balance and LE strength training, or LE strength training only, in their home. The older adults who received high intensity progressive training for balance and LE strength were found to have greater ability to utilize vestibular inputs, as measured with $CTSIB_{Test\ 5}$, than those older adults who received LE strength training only. The findings regarding the ability to utilize vestibular inputs as measured with CTSIB, as well as insights gained from the other CTSIB results for this study population, have implications for clinical research and practice, as will be addressed in the discussion below.

The secondary objective of this study was to examine the factors which affect mobility, as measured by the Timed Up and Go Test (TUG). A Spearman Rank Correlation Matrix, was used to examine the bivariate relationships between TUG scores, $CTSIB_{Test5}$

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[8] Home care physiotherapy in this study was provided under the supervision of EMP physiotherapy. Eligibility for EMP physiotherapy is defined as having a functional limitation that requires physiotherapy to be provided in the natural environment of the individual.

scores, and designated subject characteristics collected at the Pre and Post exercise assessment. During Pre exercise assessment, a systematic relationship was found between mobility and ability to use vestibular inputs, and between mobility and balance confidence. A systematic relationship was found during Post exercise assessment between mobility and knee flexion strength. A systematic relationship was found between $CTSIB_{Test\ 5}$ and ABC scores during Post exercise assessment. These findings are also relevant to clinical research as explained in detail below.

Components of the Progressive Exercise Protocol

There were two intervention arms in this study. The Resisted Balance and Exercise Group (RBE) received an 8 week exercise intervention which included targeting vestibular inputs for postural control in a balance training program (2 sessions/week) and a PRE program for LE strength training (3 sessions/week). The Resisted Exercise Group (RE) received PRE for LE strength training only (3 sessions/week). The training intervention for this study was novel in three ways. First, the exercises were delivered on an individual basis by registered physiotherapist at a higher frequency than is usual in home care physiotherapy in this region [9]. Secondly, the training program was progressive and targeted both vestibular control and lower extremity strength. Many studies have utilized base of support exercises and voluntary perturbations to train balance, however very few studies have targeted sensory perturbations, and none were found that targeted the home care population on an individual basis, with this type of training [16-18]. And thirdly, the LE strength training used in this study was a progressive resisted exercise protocol based on ACSM guidelines [4]. No comparison studies were found which targeted the home care population in their own homes with PRE based on ACSM guidelines. It is notable that this population tolerated the ACSM guidelines for LE strength training without adverse effect.

Muscle Strength: Response to PRE Training

Strength improved significantly between the initial and the final week of training for each of the muscle groups trained in this study. No studies have reported using high intensity PRE and free weights in a home care setting with a balance impaired older population. However, Hess (2005) trained balance impaired, community dwelling older adults in an 8 week PRE program, using ACSM guidelines, in a community setting with professional gym equipment. Hess (2005) reported a 54 -106 % increase in the 1RM for the 4 lower extremity muscles trained [26]. Fiatarone (1994) trained frail older adults, in a long term care setting, using ACSM guidelines for PRE. Training participants with a cable and pulley system in a 10 week training program, Fiatarone (1994) reported a 26-180% increase in the 1RM for the lower extremity muscle groups trained. The change in 1RM achieved through training older adults in their home through this study, is comparable to the training effect achieved by different populations of older adults using high intensity PRE in other settings [26, 70].

CTSIB outcomes: Response to Strength Training

Increased muscle strength following PRE training may have influenced postural control of both the RBE and RE Groups. During Pre exercise assessment, three participants, two in the RE Group and one in the RBE Group, had low scores with $CTSIB_{Test\ 4}$, in comparison to $CTSIB_{Test\ 1\text{-}3}$. This pattern suggests that poor performance on the compliant surface was caused by motor impairment. At the completion of the exercise period, these participants had significant gains in 1RM for dorsi-flexion, and two of the three participants had improved performance with $CTSIB_{Test\ 4}$. Therefore, it is possible that strength gains influenced scores on $CTSIB_{Test\ 4}$.

CTSIB Outcomes: Response to Progressive Balance Training Targeting Vestibular Control

Ability to utilize vestibular inputs to maintain postural control in standing was determined by comparing the scores of $CTSIB_{Test\ 5}$ with scores from $CTSIB_{Test\ 1}$ and $CTSIB_{Test\ 4}$. During Pre exercise assessment, all participants were able to stand for 30 seconds with $CTSIB_{Test\ 1}$ and three of the seven study participants performed poorly on $CTSIB_{Test\ 4.}$ All seven study participants had low scores (< 15 s) with $CTSIB_{Test\ 5}$ during Pre exercise assessment. During Post exercise assessment in the RE Group, all participants continued to have low scores with $CTSIB_{Test\ 5}$ with normal scores for $CTSIB_{Test\ 4}$ in all but one participant. This result indicates that the participants, who received only PRE, continued to have difficulty utilizing vestibular inputs to maintain postural control in standing. For the one participant in the RE Group who continued to have difficulty with $CTSIB_{Test\ 4}$ and $CTSIB_{Test5}$, poor performance with $CTSIB_{Test\ 5}$ may be attributed to difficulty with utilizing vestibular inputs and mechanical instability. For the RBE Group, normal Post exercise scores of 30 seconds with $CTSIB_{Test\ 1,}$ $CTSIB_{Test\ 4}$ and $CTSIB_{Test5}$ indicated ability to utilize vestibular inputs for postural control in standing [10]. As such, progressive balance training which targeted vestibular control in older, balance impaired older adults was found to be beneficial in modifying ability to utilize vestibular inputs for postural control.

Mobility in the Home Care Study Population

The secondary objective of the study was to examine factors which affect mobility in the home care population, as measured by the TUG. During Pre exercise assessment using the 3 trial protocol [54], the study population, with the exception of one person, had TUG scores between 12.5 and 24 seconds. Shumway Cook (2000) reported TUG scores between 10.3-39.2 seconds for community dwelling older adults with a history of falls [54]. Shumway Cook also reported that 90% of community dwelling, older adults without neurological impairment, who scored 14 seconds or more with TUG were likely to be fallers. During Pre and Post TUG exercise assessment in this study, four participants had scores greater than 14 seconds. In fact, all but one of the study participants had had a fall prior to participating in the study.

According to Podsiadlo (1991), who used a protocol of one trial for TUG, the majority of TUG scores found in this study would describe a group of older adults who are likely to be independent with personal care and are likely to be independent with mobility on stairs. TUG scores over 20 seconds would describe older adults who were more likely to use a walking aide and need assistance when going outside [53]. In this study, all but one participant used a gait aide outside and three of the seven participants always used a gait aide for mobility. Bischoff (2003) reported a 12 second TUG cutoff as normal for community dwelling older women, with increasing TUG scores associated with decreasing mobility [74]. The range in TUG scores in this study suggest a group of older adults with some mobility challenges, especially for those participants with TUG scores approaching 20 seconds or more.

Response to Exercise

The difference in TUG scores between Pre and Post exercise assessment was not significant for participants in the RBE or the RE Groups. This result is not consistent with previously reported results using similar balance training or PRE training with community dwelling older adults with a history of falls and mobility consistent with the participants of this study [13] [26]. Rose and Clark (2000) reported significant differences in TUG scores following an 8 week (2 sessions/week) balance training program, which included manipulation of sensory inputs as performed in this study, as well as BOS stepping exercises [13]. Significant differences in TUG scores were also reported following high intensity PRE training for older, balance impaired, community dwelling adults [26]. Difference in TUG scores reported between Pre and Post exercise scores for both Rose and Clark. (1.88 seconds) and Hess (2.7 seconds) were consistent with the differences reported in this study between Pre and Post exercise TUG scores[13, 26]. It is possible that there is a systematic difference in the change between Pre and Post exercise TUG scores; however the small sample size in this study does allow this difference to be revealed.

Pre Exercise Correlation

During Pre exercise assessment, a systematic relationship was found between mobility and ability to utilize vestibular control and between mobility and balance confidence. The Pre exercise correlation between mobility and ability to utilize vestibular control is supported by Murray (2005) who reported poor mobility and decreased ability to utilize vestibular control in older adults with a history of falls [10]. The systematic relationship found between mobility and balance confidence was in keeping with poor mobility and poor balance confidence reported by Myers (1998) for home care clients [75].

Post Exercise Correlation

During Post exercise assessment, systematic relationships were found between mobility and knee flexion strength. This relationship is consistent with previous correlations found between knee flexion and the sit to stand maneuver [76]. and knee flexion and gait speed [27, 77]. Both the ability to perform the sit to stand maneuver and gait speed would be expected to influence mobility performance. It was expected that mobility would correlate with ability to utilize vestibular inputs during Post exercise assessment, however this was not observed. The cluster of $CTSIB_{Test\ 5}$ scores around 30 seconds and the small range of TUG scores during Post exercise assessment may explain this finding. It is possible that a systematic relationship exists between mobility and ability to utilize vestibular control; however the study is underpowered to demonstrate this systematic relation.

Post Exercise Correlations: CTSIB and Balance Confidence

A systematic relationship was found between ability to utilize vestibular control and balance confidence during Post exercise assessment. The Post assessment correlation of ability to utilize vestibular control and balance confidence is not unexpected. The finding is supported by Murray (2005) who reported lower scores for both ability to utilize vestibular control in standing and balance confidence for older adults identified as fallers [10].

Clinical Significance

Assessment Strategies

Using the CTSIB, older adults, eligible for home care physiotherapy, were identified as having impairment with utilizing vestibular inputs for postural control in standing. This impairment was modified by a progressive balance and strength training program. CTSIB also identified some individuals with impairment in using proprioception ($CTSIB_{Test\ 2}$) and muscle strength ($CTSIB_{Test\ 4}$) to maintain postural control in standing. The results of this study support the use of CTSIB to assess ability with sensory inputs in the home care population. This assessment can provide valuable information to the home care physiotherapist in planning and monitoring the outcome of a targeted intervention for specific sensory impairments in balance impaired older adults.

The 1RM protocol in this study was tolerated well by the home care population and the results of 1RM testing informed the PRE training protocol. This study also demonstrated that the 1RM was a feasible tool to use as an outcome measure in the home care population.

Treatment Strategies

This preliminary study demonstrated that the home care population of older adults in this study tolerated progressive high intensity balance training, with manipulation of sensory inputs, and PRE with ACSM guidelines. Balance training delivered in this manner demonstrated that ability to utilize vestibular inputs in this population is modifiable. PRE training was shown to influence ability to stand on a compliant surface in this study population. This study provides evidence that home care physiotherapists who are working with older adults at risk for falls and who meet the inclusion criteria of this study, could consider implementing high intensity balance training, with manipulation of sensory inputs, and PRE, with ACSM guidelines, for this population.

Limitations

The small sample size in this study limits the ability to generalize the primary hypothesis results to the larger home care population. In addition, a larger sample size is needed to achieve sufficient power to test the secondary hypothesis and determine the factors which affect mobility in the home care population who were eligible for this study.

The portable dynamometer could offer a potential method for obtaining sensitive, reliable, valid measures of MVIC in the home care setting, however in this study the MVIC testing protocol that was chosen was difficult to implement. The bed used was portable, but cumbersome for the assessor and the bed was difficult to fit into the living space of the participants. The bed was also uncomfortable for some participants. In addition, the protocol was time consuming. If MVIC testing is to be used in the home care setting for either practice or research, a different positioning strategy using furniture in the home needs to be considered and investigated.

While the screening process was designed to exclude persons with unstable medical conditions or degenerative progressive neurological disease, participants in this study were not specifically screened for pre-existing somatosensory losses resulting from peripheral vascular disease (PVD) and/or peripheral neuropathy. While somatosensory inputs were not specifically screened, the CTSIB testing can reveal difficulty using somatosensory inputs for balance (n.b. $CTSIB_{Test2}$ vs. $CTSIB_{Test1}$). In clinical practice, or research aimed at somatosensory control, participants who demonstrated this result would be investigated further for impairment level measures of somatosensory function.

Recommendations for Future Research

Recruitment

Recruitment of participants into the study was a limitation in this study. Recruitment for this study population was done through a third party, the Extra Mural Program in Saint John, N.B. The Extra Mural Program provides physiotherapy to older adults who are unable to attend community physiotherapy because of functional limitations. The intention of the recruitment strategy was to identify participants on the Extra Mural Program waitlist who were balance impaired and medically stable. However, few of people on the waitlist were eligible because of contraindications to the exercise protocol, or because they had co-existing degenerative conditions (i.e. Multiple Sclerosis) that would have confounded the results. The small pool of eligible participants limited the number of people who could be recruited in the intended study period. Expanding the recruitment to identify people who meet the criteria is a possible solution for future studies with the home care population. Another strategy would be to recruit from a larger pool of home care patients by conducting a multi-center trial.

Further Exploration of Vestibular Inputs for Postural Control

In this study, comparing $CTSIB_{Test\ 5}$ scores with those from $CTSIB_{Test\ 1}$ and $CTSIB_{Test4}$ was used to determine ability with vestibular inputs during postural control in standing. Ability to utilize vestibular inputs in postural control can also be determined by comparing $CTSIB_{Test\ 6}$ with scores from $CTSIB_{Test\ 1}$ and $CTSIB_{Test\ 4.}$ Difficulty standing on a compliant surface with vision available but blocked ($CTSIB_{Test\ 6}$) indicates difficulty standing when two types of sensory inputs (vision and somatosensory) are unreliable. Comparing results from $CTSIB_{Test\ 5}$ and $CTSIB_{Test\ 6}$ also indicates the ability to cope when visual inputs are unreliable ($CTSIB_{Test\ 6}$) rather than absent ($CTSIB_{Test\ 5}$). In this study, some of the participants (n = 4) had low scores (<20s) during $CTSIB_{Test\ 6}$ Pre exercise testing, while all participants had low scores with $CTSIB_{Test\ 5}$ during Pre exercise testing. Theoretically being unable to complete $CTSIB_{Test\ 5}$ may indicate difficulty with anticipatory control processes (i.e. anticipating closing the eyes, and purposefully shifting to use of vestibular inputs for balance control). Difficulty with $CTSIB_{Test\ 6}$ may indicate difficulty with sensory conflict (i.e. ignoring visual cues that do not provide accurate information about balance control). Given the difference in $CTSIB_{Test\ 5}$ and $CTSIB_{Test\ 6}$ scores during Pre and Post Exercise assessment, it appears that $CTSIB_{Test\ 5}$ and $CTSIB_{Test\ 6}$ each provide different information regarding the participant's ability to utilize vestibular inputs. This result suggests that continued use of the full CTSIB assessment, in research and in the clinical setting, rather than the modified CTSIB ($CTSIB_{Test\ 3\ and\ Test\ 6}$ not tested) is warranted [78]. As well, future studies of the ability to utilize vestibular control in standing may consider using $CTSIB_{Test\ 5}$ and $CTSIB_{Test\ 6}$ as a measure of ability to utilize vestibular control.

Further Exploration of Sensory and Motor Inputs for Postural Control

During Pre exercise assessment, $CTSIB_{Test\ 2}$ scores for two participants in the RE Group were low. $CTSIB_{Test\ 2}$ indicates difficulty standing on a firm surface with accurate somatosensory information and vision removed. Given normal scores with $CTSIB_{Test\ 1}$, low scores with $CTSIB_{Test\ 2}$ indicate difficulty using proprioception for standing balance. One participant, who had difficulty with $CTSIB_{Test\ 2}$ during Pre exercise assessment, had normal scores with this test during Post exercise assessment. However this participant had difficulty with $CTSIB_{Test\ 4\text{-}6}$ during Pre and Post exercise assessment. The training this individual received (PRE only) may have allowed for better performance with $CTSIB_{Test\ 2}$ during Post exercise assessment. Continuation of strength training beyond 8 weeks may have allowed for improved performance with the more challenging balance tests with a compliant surface ($CTSIB_{Test\ 4\text{-}6}$). It is also possible that impaired ability to use proprioception for balance should be addressed as a treatment strategy (i.e. exercises to substitute other senses). Future research with CTSIB in this population will be helpful in interpreting CTSIB scores and shaping the direction of physiotherapy intervention

Conclusion

This group of older adults referred to home care physiotherapy services for balance problems were able to complete a high intensity, individualized program of progressive exercise. All the participants were selected based on impairment with ability to utilize vestibular inputs for postural control in standing. Both exercise groups received PRE according to ACSM guidelines; however only those participants who also received progressive, high intensity balance training with manipulation of sensory inputs showed evidence that ability to utilize vestibular inputs for postural control in standing was modifiable. These findings provide evidence that vestibular control can be assessed in older adults referred to home care physiotherapy for balance problems. In addition, including individualized balance training targeting the use of vestibular inputs can improve postural control in this population.

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Appendix 1: Lower Extremity Isometric Muscle Strength in Older Adults

Table 13: Reported Values: Lower Extremity Muscle Strength in Older Adults

ISOMETRIC					
Portable Dynamometry					
Method	**Belt Resisted vs. Hand Held(HHD)**	**HHD**	**Stabilized Frame**	**HHD**	**HHD**
Author	**Kramer (1991) [56].**	**Andrews (1996) [67].**	**Ford-Smith (2001) [58].**	**Wang (2002) [64].**	**Martin (2006) [63].**
Sample	20 healthy older women; mean age 68.4	156 healthy older adults; age 70-79	25 healthy older adults; age 70-87	41 healthy older adults; mean age 76 (1.2)	20 healthy older adults; age 60-81
Units	**Nm**	**N**	**N**	**N**	**Nm**
Hip Abd.	*belt* - L 49 R 49.5 *HHD* -L 30.5 R 29.5	M 251.2 (54.0) F171.5 (40.4)		M 96.1 (39.2) F 74.5 (20.6)	
Hip Ext.			160.8 (74.5)	M 93.1 (32.4) F 67.7 (26.5)	
Hip Flex		M 162.9 (41.5) F 103.7 (26.0)	172.6 (73.6)	M 111.8 (28.4) F 77.5 (19.6)	
Knee Flex.		M 216.4 (40.8) F 136.9 (34.1)	89.2 (53.0)	M 105.9 (22.6) F 71.6 (20.6)	
Knee Ext.		M 357.1(80.4) F 225.6 (47.4)	199.1 (109.8)	M 134.4 (53.9) F 96.1 (36.3)	68.9 (19.6)
Ankle DF		M 221.5 (56.5) F 159.7 (44.0)	125.5 (64.7)	M 87.3 (29.4) F 66.7 (15.7)	
Ankle PF			160.8 (68.6)		

Table 13: (Continued) Reported Values: Lower Extremity Muscle Strength in Older Adults

ISOMETRIC				
Biodex			Portable Dynamometry	Kin Com
Method	**HHD**	**Biodex**	**HHD with Joint sensor**	**Kin Com**
Author	**Martin (2006)** [63].	**Martin (2006) [63].**	**Li (2006) [57].**	**Li (2006) [57].**
Sample	20 healthy older adults; age 60-81	20 healthy older adults; age 60-81	28 healthy adults; age 17-73 mean age 35.4(12)	
Units	**Nm**	**Nm**	**Nm**	**Nm**
Hip Abd.				
Hip Ext.				
Hip Flex			172 (42)	248 (50)
Knee Flex.				
Knee Ext.	68.9 (19.6)	83.4 (28)		
Ankle DF				
Ankle PF				

Appendix 2: Summary of Balance Training Trials

Table 14: Summary of Results for Balance Training Trials

Table 14: Summary of Results for Balance Training Trials

Author	Subjects (age range, mean or criteria in years)	Targeted impairment	Outcome Measures	Intervention	Main Result
Howe References [16]. Exercises conducted in community setting or laboratory unless otherwise indicated					
Boshuizen (2005) [79].	N = 49 (>65)	Difficulty rising from chair (<87.5 Nm knee ext. torque)	Knee ext torque; timed walking; TUG; balance stepping test; BOS balance test	EG1: Knee ext ex.:10 wk (2x/wk supervised ex.; 1x home ex.) EG2: 10 wk (1x/wk supervised, 2x home ex.)	EG1>EG2 >CG knee ext. strength and walking speed
Brouwer (2003) [80].	N =38 (67-87)	Balance confidence	LOS with force platform, ABC scale, activity level, isokinetic strength, health status	EG: 8 wk (1x/wk x 60 min); BOS training, low resistance strengthening, stretching; community based ex.	EG and CG:↑ ABC scores EG: ↑.performance LOS
Buchner (1997) [81].	N =181 (68-85)	↓balance with tandem gait ;↓KE strength	BOS balance tasks on balance boards and tandem walking; aerobic capacity; # of falls	EG:26 wks (3x/wk x 60 min); endurance and strength or strength training only	EG: no change balance & gait; ↑strength and endurance; ↓fall risk
Cress(1999) [82].	N =49 (76 ± 4)	none	FR; Timed narrow walk; timed gait; CF-PFP, SF-36 and SIP; max.O_2 consumption; strength	EG: 6mos (3x/wk x 60 min) endurance (75% max HR)and strength training	EG:↑ performance FR, strength and endurance (↑max O_2), CF-PFP EG: CF-PFP: no Δ balance aspect
Islam(2004) [83].	N =29 (76 ± 7)	none	OLS EC, LOS force platform; chair stand	EG:12-week (2x /wk x 60 min); BOS and manipulation of sensory input balance training; functional strengthening	EG: ↑ performance LOS and OLS EC , chair stand
Johansson (1991) [84].	N =34 (70) female	none	OLS (EO,EC) with neck rotation; beam walking; figure 8 walking; timed 30 m walk	EG:5 wk (2x/wk x 60 min) BOS balance ex. functional strength ex.; mobility ex.	EG: ↑ performance balance with 2 of 9 balance tests;

Table 14: Summary of Results for Balance Training Trials					
Author	**Subjects (age range, mean or criteria in years)**	**Targeted impairment**	**Outcome Measures**	**Intervention**	**Main Result**
Krebs(1998) [85].	N =132 (62-89)	SF36 scale: self report of 1+ functional impairments	Gait: kinematic and kinetic measures; LE strength	EG: 6 mos (3x/wk) home PRE with bands; 35 min video tape of ex.; telephone f/u provided after initial two visits to teach the ex.	EG: ↑ with medio-lateral gait stability;
Lichtenstein (1989) [86].	N =50 >65	none	Postural sway (EO,EC) with force platform testing	EG:16 wk (3x/wk x 60 min); BOS and coordination/reaction training, walking, stretching ex.	EG: no change in postural sway measures
Lord (1996) [87].	N =179 (60-85) female	none	Postural sway: Lord sway meter EO; hip and lumbar spine bone density; quad. strength	EG:4x10-12 wk sessions (2x/wk x 60 min) BOS, coordination and functional strength ex., stretch and relax ex.	EG:↑ performance in postural sway and quad strength
Lord (1996) [88].	N =112 (60-85)	none	Postural sway: Lord sway meter (EO,EC - firm/compliant surface) and coordinated balance test	EG: 4x10/12 wk sessions (2x/wk x 60 min) BOS, coordination and functional strength stretch and relax ex.	EG:↑ performance postural sway and coordinated balance test
Lord (2003) [89].	N =551 (62-95)	none	Postural sway: Lord sway meter, reaction time and coordinated balance test (EO,EC - firm surface); LE strength; 6 min walk time, # of falls	EG: 12 mos.(2x/wk x 60 min) BOS balance, coordination, functional strength, walking ex.	EG: no Δ in balance scores; ↑ performance with walking time and reaction times; ↓ # of falls
Lord (2005) [90].	N =620 (75-98)	PPA fall risk score	Postural sway: Lord sway meter: coordinated balance test (EO,EC firm/compliant surface), STS test	EG: 12 mos. (2x/wk x 60 min) individualized and group BOS, LE PRE , reaction time ex.	EG: no Δ in balance scores, ↑ LE strength scores

Table 14: Summary of Results for Balance Training Trials					
Author	**Subjects (age range, mean or criteria in years)**	**Targeted impairment**	**Outcome Measures**	**Intervention**	**Main Result**
MacRae (1994) [91].	N =80 (69+) female	none	Hx of falls and injuries from falls, OLS, LE strength, gait kinematic measures	EG:12 mos (3x/wk x 60 min) individualized functional strength ex., BOS and coordination ex.; walking to ↑ HR	EG: trend to decrease in falls and injuries from falls
McGarry (2001) [92].	N =22 (60 -87)	none	Berg Balance Scale, TUG, FR	EG: 6 wk (3x/wk) Get off Your Rocker Exercise Class: BOS balance ex., Swiss ball exercises	EG:↑ Berg Balance and FR scores
Nelson (2004) [93].	N =72 (77.8 ± 5.3)	2 functional impairments in initial screening process and <10 on EPESE	Tandem walk; OLS; EPESE; PPT, max. gait speed, 6 min walk, 1RM, hand grip, Geriatric Depression scale; Medical Outcome survey	EG:6 mos (3x/wk) Home progressive BOS balance and strength ex. with home visit follow up	EG:↑ performance tandem walk, OLS ↑ EPESE score; no Δ strength
Okumiya(1996) [94].	N =42 (78.9 ± 4.7)	none	FR, TUG, neurobehavioral tests	EG: 6 mos (2x/wk x 60 min)BOS, coordination, light calisthenics, weight bearing functional strength ex.	EG:↑ performance with FR, TUG
Paillard (2004) [95].	N =21 (63-72)	none	Postural sway with force platform; dynamic balance with cylindrical platform with ataxiameter; max $O_{2;}$ gait: kinematic measures	EG:12 wk (5/wk x 45-60 min) brisk walking at lactate threshold	EG:↑ dynamic balance in lateral stability EO, $O_{2\,max}$ and ↓body fat
Ramsbottom (2004) [96].	N =22 (75.6 ± 6.5)	Sedentary older adults	Static and dynamic balance with balance performance monitor, leg power with Nottingham Power Rig, TUG	EG:24 wk (2x/wk) functional strength and dynaband ex., balance and coordination ex., stretching	EG:↑ dynamic balance, leg extensor power and TUG scores
Reinsch(1992) [97].	N =230 (74.2 ± 9.2)	none	Chair stand, OLS, falls and related injury	4 groups: 1 yr: comparing ex., behavior, cognitive and control.-low intensity ex. 3x/wk x 60min); cognitive behavior and discussion control met 1x/wk x 60 min.	No Δ in outcome measures in any group

Table 14: Summary of Results for Balance Training Trials

Author	Subjects (age range, mean or criteria in years)	Targeted impairment	Outcome Measures	Intervention	Main Result
Rooks(1997) [98].	N =131 (65-95)	none	Tandem stance, OLS (EO,EC), tandem walk, neuromotor performance measures, 1RM, reaction time, functional capacity inc. stair climbing	EG:10 mos (3x/wk) LE PRE and walking group	PRE group and walking group:↑ tandem stance, OLS EO, ↑tandem walking and stair climb speed PRE group: ↑LE strength
Rubenstein(2000) [99].	N =59 (74)	1+ risk factors: LE weakness, gait/ balance impair, falls	POMA; OLS; isokinetic LE strength; STS test; 6 min walk and indoor obstacle course	EG:12 wk (3x/wk x 90 min) group PRE ex., endurance and balance ex.	EG: ↑performance POMI, gait; ↑LE strength, 6min endurance test, ↑ STS reps. no Δ POMI balance score, OLS
Shigematsu(2002) [100].	N =38 (72-87) female	none	Cardio respiratory fitness measures, OLS (EO EC), FR; grip strength an timed squat; agility measures and coordination responses	EG:12 wk(3x/wk x 6o min); warm up, dancing (inc. BOS balance exercises)	EG:↑ performance OLS EC and FR; ↑agility
Suzuki(2004) [101].	N =52 (73-90) female	none	OLS (EO EC), tandem walk, FR, hand grip, function with ADL; knee strength	EG: 6 mos:10 sessions (every 2 wks) + home ex.3x/wk x 30min; BOS, light resistance, flexibility ex.; tai chi;	EG: ↑ performance OLS, FR and knee strength, ↓ # of falls
Wolf (1997) [102].	N =72 (76.9)	Relatively inactive	COP force platform (EO,EC)	EG1:15 wk 1/wk x 60 min computer bal. training; EG2:15 wks 2xwk x 30 min Tai Chi;	EG1:↑ performance force platform measures EG2:Tai Chi:↓ fear of falls

Table 14: Summary of Results for Balance Training Trials					
Author	**Subjects (age range, mean or criteria in years)**	**Targeted impairment**	**Outcome Measures**	**Intervention**	**Main Result**
Wolfson (1996) [15].	N =110 (80.6 ± 4.5)	none	SOT, OLS, LOS; LE isokinetic torque; gait velocity	4 groups: bal., strength, bal and strength; and education (bal=manipulation sensory inputs, BOS ex.; strength =PRE) 3 mos;1 to 1instruction 3x/wk; followed by 6 mos tai chi for all groups	Bal group ↑ performance SOT Bal and Bal and strength group: ↑ performance LOS and OLS; Strength group = ↑ LE torque
Zhang(2006) [103].	N =49 (70.6 ± 4.9)	OLS 5-20s;no experience with Tai Chi;	OLS EO; trunk flexibility; 10 m walking speed; FES score	EG: 8 wk Tai Chi 7/wk x 60 min augmented by home Tai Chi ex.	EG:↑ performance OLS and trunk flexibility; ↓ fear of falling with FES score
Sherrington References [17]. Exercises conducted in community setting or laboratory unless otherwise indicated					
Bunout (2005) [104].	N =298 (70-80)	none	# of falls, gait speed with 12min walk, grip, biceps and knee ext strength, OLS	EG: 1 year (2x/wk x 60 min) Walking, functional strength and Thera band ex.	EG: no Δ fall rate;↑ biceps and quad strength; ↑ gait speed
Barnett (2003) [105].	N =123 (70-81)	1+ risk: LE weak.,↓ balance or reaction time	Knee ext, reaction time; postural sway meter (EO, EC - firm and compliant surface); coordinated balance test STS; walking speed;SF-36; fall rate	EG: 1 year x 1 hour (37 classes); education: BOS and coordination balance ex. (inc. Tai Chi ex.); functional strength and resisted Thera band ex; home ex. with diaries	EG: ↓ fall rate; ↑ performance postural sway on firm surface (EO, EC) and coordinated balance test
Campbell (1997) [21].	N =233 (>80) female	none	STS test, FR, 4 test balance scale, # of falls	EG:BOS balance and coordination ex. during stance and walking, (Otago program)	EG:↑ performance 4 test balance score and STS , ↓ rate of

Table 14: Summary of Results for Balance Training Trials					
Author	**Subjects (age range, mean or criteria in years)**	**Targeted impairment**	**Outcome Measures**	**Intervention**	**Main Result**
					falls
Campbell (1999) [106].	N =152 F (>80) female	Exercise group from Campbell (1997)	# of falls and compliance with exercise program	EG:BOS balance and coordination ex. during stance and walking (Otago program)	EG:↓ rate of falls
Campbell (2005) [107].	N =391 (84 ± 4.9)	Poor visual acuity	# of falls and cost of implementing program	4 groups (1 year): Home Safety and Otago ex.; Otago ex., Home Safety only ; social group	Home Safety: ↓ rate of falls
Carter (2002) [108].	N =93 (65-75) female	Osteoporosis and relative inactivity	Postural sway: computerized posturography; Dynamic balance: figure of 8 walk	EG:20 wk (2x/wkx 40 min): Osteofit program: BOS, stretching and resisted strength ex.	EG:↑ performance dynamic balance; no Δ fall rate
Day (2002) [109].	N =1090 (75.4 -76.5)	none	TUG, Postural sway with Lord sway meter, LOS and coordinated balance test; quad strength; time to first fall in 18mos	EG: Balance and strength group –ex. not described; Home hazard modification group and Vision modification group	Balance and strength group:↑ performance coordinated balance test and quad strength measures
Ebrahim (1997) [110].	N = 165 (66-71) female	Postmenopausal with UE fracture past 2 yrs	LE power, grip strength, step endurance testing, femoral neck and vertebral bone density	EG:2 years brisk walking 3 sessions/week on an individual basis	Walking group: small changes vertebral bone density
Green (2002) [111].	N =146 (62-80)	Stroke ≥ 1 year	River Mean Mobility index, gait speed, # of falls, Barthel Index	EG:20 wk-median # of treatments 3;actual treatment not described	EG: no long term changes
Hauer (2001) [112].	N =57 (75-90) female	Post discharge from hospital following fracture from falls	POMA,FR, modified test battery of 5 timed balance positions (EO,EC), fall rate	EG:12 wk 3x/wk:PRE and BOS and coordination ex.	EG:↑ performance POMA, FR, balance battery, ↓rate of falls

Table 14: Summary of Results for Balance Training Trials					
Author	**Subjects (age range, mean or criteria in years)**	**Targeted impairment**	**Outcome Measures**	**Intervention**	**Main Result**
Korpelainen (2006) [113].	N =160 (72.8 ± 1.2) female	Hip BMD 2 Sd below reference value	TUG, fall rate, bone density and mineral content femoral trochanter, times walking speed	EG:30 mos supervised group (60 min)and daily home ex. (20 min)of BOS and functional strength ex.	EG:↑ mineral content femoral trochanter
Latham (2003) [114].	N =243 (77-81)	Frail, post discharge from hospital	BBBS, TUG, rate of falls	EG:10 wk 3x/wk 60-80% of 1RM quad strengthening at home	EG: no diff between EG and CG
Li (2005) [115].	N =256 (72-90)	Inactive living in community	# of falls, BBS,DGI, FR,OLS (EO,EC); 50 ft. speed walk; TUG test; SAFFE	EG:6 mos. (3x/wk x 60 min): Tai chi group and stretching group	Tai Chi:↓ rate of falls;↑ performance in all outcome measures
Lin (2007) [22].	N =150 (76.8)	Fall within past 4 wks. requiring medical attention	WHOQOL-BREF,POMA, FR, fear of falling	3 groups: EG1(home exercise), EG2(Education), and EG3(home modification) 4 mos, every 2 wk visit EG1: BOS balance, functional and light weight strength ex. (3x wk home ex.)	EG1 and EG2:↑ performance WHOQOL-BREF,POMA, FR; ↓ fear of falling No significant diff b/t groups
Liu-Ambrose (2004) [116].	N =96 (75-95)	Female with low bone mass; relatively inaction	PPA, Community and Balance Mobility Scale; dorsi flexion strength, foot reaction time	3 groups: EG1(PRE), EG2(agility) and control (stretching)25 wk 2x/wk x 50 min	EG1 and EG2:↑ performance postural sway and fall risk score
Luukinen (2007) [20].	N =437 (88 ± 3)	Presence of fall risk factors: cognitive, physical, functional	STS, Tandem standing; rate of falls; chair rise, walking speed	Individual exercise plans based on baseline assessment: home and group ex.: sit. or st. as tolerated, BOS and functional strength ex.	EG groups: no significant diff. in fall rate
Madureira (2007) [117].	N =66 (74.6 ± 4.8) female	Female, osteoporosis 2.5 Sd below average	BBS, CTSIB, TUG, fall rate	EG:12 mos 60 min/wk for 40 classes BOS and coordination ex. + home ex. 3 /wk as per class ex.	EG:↑ performance BBS, $CTSIB_{Test\ 5and\ 6}$, TUG and ↓ fall rate

Table 14: Summary of Results for Balance Training Trials

Author	**Subjects (age range, mean or criteria in years)**	**Targeted impairment**	**Outcome Measures**	**Intervention**	**Main Result**
Means (2005) [118].	N =338 (73.5)	none	Functional obstacle completion, rate of falls	EG1:6 wk 3x/wk x 90 min ; balance and coordination ex. and functional strengthening	EG:↑ performance functional obstacle course; ↓ # of falls
Morgan (2004) [119].	N =294 (81.0 ± 7.6)	Hospital admission or 2 days bed rest in past month (i.e. frail)	POMA, SF-36 Functional status, fall risk and time to first fall	EG:8 wk 3x/wk x 45 min- sit/stand BOS ex.	EG: low functioning older adults ↓ fall risk; high functioning adults ↑ fall risk
Robertson (2001) [120].	N =240 (81.1 ± 4.5)	none	# of falls and # of injurious falls, costs of implementing the program	EG: BOS balance and coordination ex. during stance and walking	EG:↓ # of falls in 80+ y ; ↓ injurious falls in EG
Skelton (2005) [121].	N =81 (72.8 ± 5.9)	living at home in home, 3+ falls past yr	# of falls, fall related injuries; frequent fallers and hospitalization, death or nursing home admission	EG: 36 wk: 60 min/wk FaME ex. program: BOS , coordination and strengthening ex. + home ex. 30 min 2x/wk; Control:2x/wk low intensity ex.	EG:↓ # of falls and decreased hospitalization, death or admission to nursing home
Steinberg (2000) [122].	N =252 (> 50)	Healthy, community dwelling adults	Rate of falls, slips and trips	4 groups: Education, Education +ex., Education +ex.+ home safety, + Education +ex.+ home safety+ medical risk factors/management	EG: ↓ # of trips and falls in all groups except education
Voukelatos (2007) [123].	N =702 (60-96)	healthy, community based	Postural sway, max. lean, lateral sway and coordinated balance test all with sway meter, # of falls, time to first fall	EG: 16 wk 60 min/wk Tai Chi	EG:↑ performance with postural sway, lateral sway and coordinated balance test, ↓ risk for falls

Table 14: Summary of Results for Balance Training Trials

Author	Subjects (age range, mean or criteria in years)	Targeted impairment	Outcome Measures	Intervention	Main Result
Wolf (1996) [124].	N =200 (>70)	none	# of falls and time to first fall	EG: 15 wk 1/wk x 60 min computer bal. training with manipulation of sensory inputs or education; followed by 15 wks 2x/wk x 30 min Tai Chi for everyone	Tai Chi:↓ # of falls and fear of falling
Woo (2007) [125].	N =180 (65-74)	none	SOT (6 condition) using Balance Master; stance time OLS, semi tandem and tandem stance	EG1(Tai Chi), EG2(resisted ex. resistance band 12 mos 3x/wk	EG1 and EG2 no Δ balance measures or fall rate
Further references which include manipulation of sensory inputs (not included in Systematic reviews above)					
Hu (1994) [14].	N =23 (65-90)	none	OLS platform sensory test with potentiometer (measured AP body sway), neurological evaluation. and physical exam	EG:10 hrs (1 hr/day) within 15 days- balance training with manipulation of sensory inputs	EG: ↑static balance EO firm surface; (EO,EC) compliant surface
Rose and Clark (2000) [13].	N = 45 (75-82)	2 or more falls in past year with no know med hx. for falls	SOT (4 condition) and LOS with computerized posturography; BBS TUG	EG: 2x/wk (45 min) x 8wk; balance training with manipulation sensory input; progressive increase. of speed with biofeedback; BOS training	EG: ↑ performance SOT and LOS scores, ↑TUG and Berg scores

CG = Control Group- received education or no intervention unless otherwise indicated
EG = Exercise Group
ex. = exercise(s)
↑ performance – statistically significant within study
EC = eyes open
EO =eyes closed
BBS = Berg Balance Scale
BMD = bone mineral density
COP = center of pressure
CS- PFP = Continuous Scale - Physical Functional Performance Test
DGI = dynamic gait index

EPESE = Established Populations for Epidemiologic Studies of the Elderly –short physical performance battery
FaME = Falls Management exercise
FES = Falls Efficacy Scale
FR = functional reach test
Functional strengthening = exercises that use body weight as resistance
IADL = instrumental activities of daily living
LE = lower extremity
LOS = Limits of Stability
KE = knee extension
OLS = one leg stand
POMA = Performance Orientated Mobility Assessment
PPT = physical performance test
PPA = physiological profile assessment
PRE = progressive resistance exercise
SF36 = Short- Form 36 Health Scale Questionnaire
SIP = Sickness Impact Profile
SOT=sensory organization test:
WHOQOL-BREF = World Health Organization Quality of Life instrument

Appendix 3: Summary of Research Project for Physiotherapists and Physicians

Summary of the Research Project for Extramural Physiotherapists and Physicians

Atlantic Health Sciences Corporation
Corporation des sciences de la santé de l'Atlantique

DALHOUSIE UNIVERSITY
Inspiring Minds

An intervention study to determine if balance impaired older adults can improve ability to utilize sensory inputs with progressive sensory integration training. A secondary purpose of the intervention is to investigate the contribution of sensory inputs and lower extremity (LE) strength to mobility in this population.

Older adults living in the community are at increased risk for falls. There is evidence that older adults who fall have difficult utilizing sensory inputs and have decreased strength and mobility. Older adults with reduced ability to utilize sensory function have not been well studied. Older adults in research settings have improved balance measures after receiving balance training that manipulates sensory inputs. It is not known if providing balance training that manipulates sensory inputs in a home setting will improve balance. There is evidence that high intensity strength training in a gym setting can improve balance control in balance impaired older adults living in the community. Again it is not known if this type of strength training in a home setting will provide similar results.

The ability to utilize sensory inputs, and decreased muscle strength, can be modifiable risk factors for falls in balance impaired older community dwelling adults. The **primary purpose** of this study is to examine the influence of an individualized progressive exercise program, which manipulates sensory inputs, on the ability of this population to use vestibular inputs to maintain balance. The secondary objective of this study is to assess the relative contribution of ability to use vestibular inputs, and LE muscle strength on the mobility of this population.

The **sample** population for this study is older adults, 65 year and over, who have been referred to Extra-Mural Program (EMP) physiotherapy in Health Region 2, New Brunswick for increased fall risk (i.e. decreased balance and or LE strength). Patients who have been referred will be contacted by EMP physiotherapy to ask permission for the research coordinator to contact them regarding the study. If the patient agrees, the research coordinator will meet with the patient, fully explain the study and give the patient an opportunity to ask questions. Individuals who volunteer for the study, and who meet the inclusion and exclusion criteria below, will review the informed consent forms with the research coordinator and sign informed consent forms. After the consent form is signed, an MMSE will be done by the research physiotherapist as part of the initial screening process.

The family physician will be asked to provide medical clearance for the patients to participate in the study. The Clinical Test of Sensory Interaction and Balance (Foam and Dome Test) will be used to assess the ability of the participants to utilize sensory inputs for balance control, lower extremity muscle strength will be assessed with portable dynamometry and mobility will be assessed with the Timed Up and Go Test. Participants will be randomly assigned to a Control Group (progressive resistive exercise for lower limb muscle strength, delivered with 1:1 supervision by a research physiotherapist from the Extra-Mural Program) or to a Combined Exercise Group with progressive exercise for both balance and lower limb strength, delivered with 1:1 supervision by the research coordinator.

Assessment will be conducted in the participant's home by a member of the research team. Results of the assessments will be made available to EMP physiotherapists and physicians upon request of the participant.

Thank you for your time and assistance with this research project,

Sincerely,

Denise Hollway, Research Coordinator
Physiotherapist
Student, MSc. Rehabilitation Research- Physiotherapy
School of Physiotherapy, Dalhousie University
Phone 506-849-0245
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Inclusion Criteria	
65 years or older	Able to provide informed consent
Ambulating at least in own home with/with out aide for 6 m; able to stand independently without aide	Living in community or independent retirement home
Exclusion Criteria	
Unstable medical conditions including poor control of chronic medical conditions	Diagnosis of progressive neurological condition that would influence balance or muscle strength such as Parkinson's, ALS, MS
MMSE score of < 23 (Moderate to advanced dementia)	Acute osteoarthritis in lower extremities that limits maximal muscle contractions
Pain on weight bearing	Weight bearing restrictions
Receiving physiotherapy at time of study	Abnormal VOR or evidence of nystagmus
Legal blindness	Stroke within past year

MMSE = Mini mental State Examination; VOR=vestibular ocular reflex; ALS=amyotrophic lateral sclerosis, MS=multiple sclerosis

Appendix 4: Informed Consent Form

Atlantic Health Sciences Corporation
Corporation des sciences de la santé de l'Atlantique

DALHOUSIE UNIVERSITY
Inspiring Minds

CONSENT TO TAKE PART IN A RESEARCH STUDY
Patient Information

Study Title: Progressive Exercise to Address Impaired Balance and Mobility of Older Adults Referred for Home Care Physiotherapy Services: Is it Beneficial to Target Vestibular Control and Lower Limb Muscle Strength?

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Study Sponsor N/A

PART A

RESEARCH STUDIES

1. INTRODUCTION

You are invited to join a research study. This study is being offered by the Atlantic Health Science Corporation and Dalhousie University. We are doing this study to find out how to best care for people with problems such as yours. The information given below will help you decide if you would like to participate.

2. EXPLANTION OF WHAT YOU ARE READING

We will explain why we are doing the study and how the study that we are doing is different from usual practice. We will tell you of any inconvenience, discomfort or risk to you if you decide to participate. We will tell you of all the assessments and exercises that we will use in this study. Please read this carefully and take as much time as you like. You can show it to your family and discuss it with them. Make notes on the paper if you don't understand anything or want it explained better. After you read this paper, please ask questions about anything that is not clear to you.

3. WHAT IS A RESEARCH STUDY?

Research studies are different from usual care. Research studies help find new information to help people with problems similar to yours. In this study we want to study balance, strength and walking ability in older adults living in the community.

4. DO I HAVE TO TAKE PART IN THIS STUDY?

No! It is completely up to you if you want to participate in this study. You can discuss this with your family, friends or doctor before you make up your mind.

We will support what ever you decide. You will receive the best care possible no matter what happens. No one will be upset if you decide to not take part or if you change your mind. If you decide to participate, you can still change your mind and stop participating at any time.

5. WILL THE STUDY HELP ME?

We do not know. The purpose of this study is to collect information about the effect of a balance and strength training program on the mobility of older adults. We will be using the most current information we have from other research studies, regarding balance training and strength training, to design the study. We will assess your balance ability, leg strength and walking ability before the program and after the program. We will share the results of this assessment with you.

Part B

6. WHY AM I BEING ASKED TO JOIN THE STUDY?

You have been asked to join the study because you have been referred to Extra-Mural Program physiotherapy. You fit the description of people being included in this study: older community dwelling adults who have challenges with balance, leg strength, walking and or falling. If you decide to participate we will notify your family physician about your decision and ask for medical clearance for you to take part in the study.

7. WHY IS THIS STUDY BEING DONE?

From research we know that older people who fall may have decreased balance control, and decreased lower leg strength. These are important factors to consider in helping older adults to move about safely and avoid falls. We know that if we can assess balance control and muscle strength we can create effective training programs to help to increase balance control and increase leg strength.

There have not been many studies done that assess older adults who have balance problems and their specific ability to maintain their balance control. We developed this study to explore the effect of targeting older adults with balance problems with an individualized balance training program. We also wanted to explore the strength of older adults who have balance challenges and what happens to mobility when we train balance control and leg muscle strength. We designed this study to deliver this program in a home setting. This information will be useful to other physiotherapists and other health care providers who work with older adults with balance challenges in the home of the adult.

8. WHAT IS BEING TESTED

In this study we will test your balance control, your leg strength and your ability to walk. Testing will be done on older adults living in the community who are 65 years and older.

9. HOW IS THE STUDY BEING DONE?

If you volunteer for this study, a researcher will come to see you and review the study with you. If you agree to participate and you are able to perform some testing procedures, the researcher will ask a trained research assistant with education in physiotherapy, to further assess you by doing some balance and strength tests and asking you some questions about your balance. If you are able to do these tests for this study and your family physician gives you medical clearance, the researcher will assign you to an exercise group. You will be assigned to an exercise group by drawing from a pool that has equal numbers of “Combined Exercise Group’ and ‘Control Group’ draws in the pool. Approximately half of the participants in this study will receive a balance and strength training program and half will receive a strength training program. After you are assigned to an exercise group, you will be seen by a research physiotherapist who will start an exercise program with you

STUDY TIME FRAME	
First visit	• Study explained by research physiotherapist • Volunteer and complete first set of tests • Do not volunteer – followed by regular EMP physiotherapy • Medical Clearance letter sent to Family Physician
Second visit	• Second set of tests by trained research assistant with education in physiotherapy • Informed as to results of screening- qualify or not
Phone call to set up third visit to begin study **or** to set up regular Extra- Mural Program (EMP)physiotherapy visit	• Assigned to Combined Exercise Group or Control Group
Third visit- Exercise begins	• Exercise Groups for 8 weeks – 3 times per week • Reassessment after 8 weeks • Reassessment 6 months after Exercise Groups end

10. HOW LONG WILL I BE IN THE STUDY?

The testing procedures will take approximately 1.5 hours to complete at the beginning of the study, at the end of the study and after 6 months have passed. The exercise program of the study will last for 8 weeks.

11. CAN I BE TAKEN OUT OF THE STUDY WITHOUT MY CONSENT?

Yes, the physiotherapist or your doctor can take you off the study at any time. This would happen if your medical status changes such that you become ill and are unable to complete the testing procedures or are not able to complete the exercise program. You will be told about the reasons why you would be taken out of the study.

12. HOW MANY PEOPLE WILL TAKE PART IN THIS STUDY?

We anticipate 24 people will participate in the study.

13. WHO CAN TAKE PART IN THIS STUDY?

You may take part in this study if the answer is YES to **all** of these items:

☐ you are 65 or older

☐ you are medically stable

☐ you are willing to take part in the study, including signing this form after carefully reading it

☐ you are able to walk by yourself (using a cane or walker if needed) for 6 m

☐ you can stand by yourself without a cane or walker

HOWEVER, if the answer is YES to any of the following items, you should not take part, for your own safety:

☐ you have uncontrolled medical conditions that require you to continually have medication adjustments

☐ you have acute arthritis that limits you from putting weight on your legs or contracting your leg muscles

☐ known inner ear or balance problems due to stroke, ALS, Parkinson's, or multiple sclerosis.

☐ you are legally blind

☐ you have difficulty with memory or cognitive tasks (The research coordinator will ask you to complete a small test to demonstrate this)

All of these items will be discussed in detail with you. You will be told the reasons why they are important to this study. If you answer YES to any of the above items, the physiotherapist will conclude the session and you will be followed by an Extra-Mural Program physiotherapist who is not part of this study.

14. WHAT WILL HAPPEN IF I TAKE PART IN THIS STUDY?

SCREENING

If you volunteer for this study, we will notify your physician of your decision and obtain medical clearance from your physician regarding you taking part in this study. This is called "screening."

During "screening", the following will occur:

- Your physician will give medical consent to you being involved in this study
- You will be asked about your medications and any medical conditions that you may have.

- You will be asked to estimate the number of falls you have had in the past 6 months
- You will complete a questionnaire regarding your balance
- The assessing physiotherapist will complete a balance test (see below) to make sure you are eligible for this study.
- If you are eligible to participate in the study after the balance test, the remainder of the tests will be done.
- If you are not eligible to participate, the trained research assistant will conclude the session and you will be followed by an Extra-Mural Program physiotherapist who is not part of this study.

STUDY PROCEDURES

If it is appropriate for you to participate, and you volunteer, the following tests will be done in your home as part of the study. The testing will be done at a pace that you are able to do without fatiguing. The testing will be done at the beginning of the study, and as explained below, the testing will be repeated after a 2 month exercise program, and again 6 months after you finish the exercise program.

Balance Test: You will be tested to see how long you can stand on the floor with your eyes open, eyes closed and then with a dome over your head to block your vision. The test will be repeated again with you standing on a piece of foam. You will be given three tries to stand for a maximum of 30 seconds. You may sit down to rest between tests.

Strength Testing: Your leg strength will be tested with you lying down on a portable treatment table or sitting in a chair. You will be asked to contract your leg muscles as hard as you can for six seconds against a device (called a dynamometer) that records muscle force. You will be given three practice tries with each muscle and then each muscle will be tested three times. Again, you may rest between tests.

Mobility testing: This test is a timed test of you standing up from a chair, walking 3 meters, turning around, walking back to the chair and then sitting down. You are allowed to use your regular walking aide (cane or walker, etc.) with this test.

Vision testing: A simple vision test will be done where you read from a scale.

Questionnaires: We will ask you some questions about your hearing and your confidence with your balance.

Falls Diary: You will be asked to keep track of any falls that you might have while you are participating in the study. You will be given a calendar so that every day, you will be able to write down whether or not you fell. If you do fall, you are also asked to write down what happened when you fell. You will be shown how to use the calendar, and how to contact someone if you need any help with it.

Combined Exercise Training: If you are assigned to this group, the research coordinator who is a registered physiotherapist will work with you for 8 weeks. You will be seen 3 times per week, on alternate days, for up to an hour each day. You will be asked to do balance training for about 30 -45 minutes, during two of these sessions, and exercises to strengthen your leg muscles for 15 -20 minutes, during each session. The training will be done with supervision from an experienced physiotherapist, at a level that you can tolerate.

Strength Training: If you are assigned to this group, an experienced research physiotherapist will work with you for 8 weeks. You will be seen 3 times per week, on alternate days, for up to an hour each day. You will be asked to do exercises to strengthen your leg muscles for 15 -20 minutes, during each session. The exercise will be done with supervision from an experienced physiotherapist, at a level that you can tolerate.

Retesting: The trained research assistant, who assessed your balance and strength before you began the exercise program, will contact you to set up an appointment with you after you have completed the exercise program. The same trained research assistant will contact you again once 6 months have passed, to set up an appointment for the final reassessment session. To help keep these assessments fair, the trained research assistant who works with you during these sessions should not find out what type of exercise you completed as part of the study. So, you will be asked not to tell him/her anything about the exercises you did (the type of exercise, or the name of the therapist who did the exercise with you).

15. WHAT ARE THE RISKS IN THIS STUDY?

There will be no increased risk of injury or discomfort during the testing procedures or in the exercise training than there would be during regular physiotherapy treatment. You may notice some fatigue or discomfort in your muscles during or after completing the testing or exercise training. If you become sore or tired during the testing or exercise training, please tell the tester, because the tests should not be painful, and you are allowed to take as many rest breaks as you need.

16. WHAT ARE MY RESPONSIBILITIES?

As a study participant you will be required to:

- Follow the directions of the trained research assistant during testing

- Report any changes in your health status during or after testing to the research coordinator: **Denise Hollway,** phone # **849-0245**
- Report any serious symptoms or events that have occurred as soon as possible to the research coordinator

17. WHAT ABOUT NEW INFORMATION?

It is possible but unlikely that new information may become available about new assessment or treatment procedures for balance and strength training or mobility assessment. You will be told about any new information that might affect your health, welfare or willingness to stay in the study.

18. WILL IT COST ME ANYTHING?

Compensation
It will not cost you anything to be in this study, and you will not be paid to be in the study.

Research related Injury
If you become ill or injured because you were in the study you will continue to receive the best medical care available. What ever happens, you will always have your legal rights. The research coordinator, health care team and the hospital have their usual legal and professional responsibilities. Signing this form does not affect any of the above.

19. WHAT ABOUT MY RIGHT TO PRIVACY?

We will keep your personal information confidential. Your name will not be used in the records of the study. You will be assigned a code name. If the results of this study are presented in a meeting, or published, nobody will be able to identify you as being in the study.

Your records will be kept for seven (7) years in a secure area at the School of Physiotherapy, Dalhousie University. Only the research team will have access to your files and know your name.

Your health record may be read to ensure that we have accurate information about your health status. The following people may read your health record:

- the Research Coordinator, or the other researchers who will be conducting the study
- the Extra-Mural Program physiotherapists involved in the study

Your physician is aware of your participation in the research study and at your request, and if appropriate, may be made aware of research findings.

You may ask the research coordinator to see a copy of your personal health information related to the study. You may also ask the research coordinator to correct any information about you that is incorrect.

20. WHAT IF I WANT TO QUIT THE STUDY?

If you choose to participate and later decide to change your mind, you can stop the research study at any time. If you wish to withdraw your consent, please inform the research coordinator. All data, up to the date you withdraw your consent, will remain in the study record. A decision to stop does not affect your health care.

21. DECLARATION OF FINANCIAL INTERESTS

The members of the research team have no financial interest in the outcome of this study. The Principal Investigators and Research Coordinator are not paid to conduct this study.

22. WHAT ABOUT QUESTIONS OR PROBLEMS?

For further information about the study, call Dr. Marie Earl or Denise Hollway.

- Dr. Marie Earl is in charge of this study at Dalhousie University, and she may be reached at (902) 494-2633.
- The research coordinator is Denise Hollway and she can be reached at 506-849-0245.

If you experience side effects from the study or other medical problems, please let the research coordinator know immediately. If you can't reach the research coordinator please speak to you family physician.

23. WHAT ARE MY RIGHTS?

After you have signed the consent form, you will be given a copy of it.
Neither the Atlantic Health Sciences Corporation nor the Principal Investigator can guarantee or assure that the stated risk or other unknown consequences will not occur. In the event that injury, illness or disability results and you believe it is directly related to participation in this study, the Atlantic Health Sciences Corporation requests that you contact the AHSC Patient Representative, at (506) 648-6714.

"If you have any difficulties with, or wish to voice concern about, any aspect of your participation in this study, you may contact Patricia Lindley, Director of Dalhousie University's Office of Human Research Ethics

Administration, for assistance (902) 494-1462, patricia.lindley@dal.ca"

In the next part you will be asked if you agree (consent) to join this study. If the answer is "yes", you will need to sign the form.

PART C

24. CONSENT FORM AND SIGNATURES

I have read all the information about this study which is called:
Progressive Exercise to Address Impaired Balance and Mobility of Older Adults Referred for Home Care Physiotherapy Services: Is it Beneficial to Target Vestibular Control and Lower Limb Muscle Strength?

I have been given the opportunity to discuss the above study. All my questions have been answered. I am satisfied with the answers.

I agree to allow the people described in the consent form above to contact my family physician ____________________to obtain medical clearance.

This signature on the consent form means that I agree to take part in this study.

______________________ ________________ ____/____/______
Signature of participant Name (printed) day/month/year

______________________ ________________ ____/____/______
Witness to participant's signature name (printed) day/month/year

______________________ ________________ ____/____/______
Signature of Investigator Name (printed) day/month/year

______________________ ________________ ____/____/______
Signature of person conducting Consent discussion Name (printed) day/month/year

If this consent process has been done in a language other than that on this written form, with the assistance of a translator, please indicate:

Language _____________ ______________________ _____________
Signature of translator date

I will be given a copy of this consent form

Thank you for your time and patience

Participants Initials___________

Appendix 5: Physician Medical Consent Form

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DALHOUSIE UNIVERSITY
Inspiring Minds

Denise Hollway, Physiotherapist
Graduate Student, School Of Physiotherapy, Dalhousie University
3014 Rothesay Road
Rothesay, NB, E2E 5V4
(505)849-0245

Date

Dear
I am a registered physiotherapist who is conducting a research study as part of the requirements for a Master of Science in Research in Rehabilitation at Dalhousie University. Under the supervision of Dr Marie Earl, I am conducting the following study**: Progressive Exercise to Address Impaired Balance and Mobility of Older Adults Referred for Home Care Physiotherapy Services: Is it Beneficial to Target Vestibular Control and Lower Limb Muscle Strength?**

Your patient __________________was referred to Extra Mural physiotherapy for assistance with_______________. _______________ meets the criteria for inclusion in this study and has volunteered for this study. I have done the initial screen of this patient which includes the MMSE: score_____. I have attached a summary of the study, including the inclusion and exclusion criteria, for your information

For ethical purposes, medical clearance from the participant's physician is required. I have provided a check list of representative conditions that would exclude your patient from participating in this study. Please indicate if your patient has any of the exclusion criteria listed below.

Exclusion Criteria
□ Moderate to severe dementia
□ Unstable or poorly controlled medical condition
□ Significant restrictions with weight bearing (WB) activities (includes significant pain with WB)
□ Acute osteoarthritis of the lower extremity
□ Legal blindness
□ Dx of progressive neurological condition including Parkinson's, ALS, MS
□ Nystagmus or abnormal VOR (vestibular ocular reflex)
□ Stroke within past year

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p.2 Date:

In the absence of exclusion criteria listed above do you agree to your patient ___________________ participating in this study? Please check one statement and sign.

I do agree to this patient's participation in this study □

I do not agree to this patient's participation in this study □

Physician Signature_________________________________

Please contact me at the above telephone number or address if you require any further information

I have enclosed a stamped, self addressed envelope for ease of return of this letter to me. Thank you for your time and your consideration,

Denise Hollway

Appendix6: Data Collection Form

Atlantic Health Sciences Corporation
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Data Collection Form

Participant ID________________ ☐ M ☐ F Date:________________

Age:______________ Height:____________ Gait Aide________________

Co-morbidities____

____

Medications ____

____

Vision______________________ Hearing ___________________________

ABC score___________________________________

MMSE score_________________________________

Strength Testing (PD results)			Limb tested ☐ right ☐ left		
Muscle Action	Moment arm length (cm)	Peak Force Trial 1	Peak Force Trial 2	Peak Force Trial 3	Mean
Hip Abd					
Hip Ext					
Knee Flex					
Knee Ext					
Ankle DF					
Ankle PF					

Sensory Integration Testing (CTSIB Results)								
Condition	Trial 1		Trial 2		Trial 3		Observed Amount of Postural Sway	
Foot Position	Apart	Together	Apart	Together	Apart	Together	Apart	Together
1-EO, firm surface								
2-EC, firm surface								
3-visual conflict, firm surface								
4 – EO, compliant surface								
5 – EC, compliant surface								
6 – visual conflict, compliant surface								

Mobility Testing (TUG results)
trial 1_________________________ seconds Date Tested _______________
trial 2_________________________ seconds Date Tested _______________
trial 3_________________________ seconds Date Tested _______________

Mobility aide used ____

Fall History (pre study)

Exhibit 17–7 Example of a Fall History Form

How many falls have occurred in the past week? ____ past month?_____ past year? _____
When was your last fall? ______________________________
Describe the recovery from the fall incident: ______________________________

Describe how the fall occurred:

Sudden/gradual ______________________________

____

Activities at the time of fall ______________________________

Direction of fall ______________________________

Recovery attempts ______________________________

Patient description of cause ______________________________

Categorize fall as extrinsic cause/intrinsic cause/both:

Extrinsic: Trip/slip/bump/environmental hazard (see list in Exhibit 17–5)
Intrinsic: Dizziness/weakness or fatigue/other (see list in Table 17–5)

Source: Data from J. Chandler and P. Duncan, Balance and Falls in the Elderly: Issues in Evaluation and Treatment in *Geriatric Physical Therapy*, A. Guccione, ed., pp. 237–251, © 1993, Mosby Year-Book, Inc.

Appendix 7: Standard Procedure: Clinical Test of Sensory Interaction and Balance

Standard Procedure - Clinical Test of Sensory Interaction and Balance (CTSIB)

Instructions to the participant prior to testing:

"The purpose of this test is to test your ability to stand during 6 different balance tests. For the first test, you will be standing on the floor with your feet shoulder width apart with your eyes open. For the second test your eyes will be closed and for the third test you will wear a dome that blocks your vision. You can be in your stocking feet or be in your bare feet for all of the trials. For the next fourth test you will stand on a large piece of foam with your feet shoulder width apart with your eyes open. For the fifth test you will stand on a piece of foam with your eyes closed and for the sixth test you will wear a dome over your head block your vision while standing on the piece of foam. You will be asked to complete each test three times. Each trial will last up to 30 seconds. If you can hold your balance for 30 seconds then you will be asked to repeat that trial with your feet together. You will be allowed to rest between trials for at least 30 seconds. To ensure that you are safe, there will be someone standing next to you as a spotter in case you lose your balance. We will require you to wear a safety belt for the whole test. Please tell us if you would like to stop for any reason."

Instructions during testing:

"Stand with your arms folded across your waist with your hands above your elbows, and look straight ahead. Hold this position until I tell you to stop"

Instructions to the tester:

1. Repeat the above instructions, having the participants close their eyes for Tests 2 and 4, wearing the visual conflict dome for Tests 3 and 6, and standing in the center of the foam for Tests 4 through 6.
2. Rotate the foam platform 90^0 and flip it over between trials
3. Record the time, to the nearest 0.01seconds, that the participant is able to maintain their balance during each trial. Stop timing if the participant's hands move, knees

bend, heels or toes lift off the floor or if the participant takes a step to correct their balance.

4. If the participant is able to maintain the position for 30 seconds, record their score as 30 seconds for any subsequent trials of that test.
5. If the participant is able to complete the first trial for 30 seconds with their feet apart, have them repeat the trial with their feet together.
6. The final score will be the average of the three scores for each test.

Appendix 8: Standard Procedure: MVIC Strength Test

Standard Procedure for MVIC Strength Test

Instructions to participant:

"The purpose of this test is to record the force that you can produce with the muscles in your legs. I will be taking measures of the muscles that move your hip, your knee and your ankle. I will go through a practice run with you for each movement so you can warm up the muscles I am testing. I will go through three practice runs with you for each muscle being tested. I will then test each muscle three times. For each test, I would like you to push as hard as you can against the instrument for 6 seconds. I will tell you when to start and when to stop pushing by saying 'go' and 'stop'. It is important that you breathe properly during the muscle testing by taking a deep breath in before you push and breathing out as you push. I don't want you to hold your breath as you are pushing. You can rest for as long as you wish between tests. Please let me know if you have any pain or discomfort during the test, because the tests should not be painful"

Instructions to the tester:

- Record the moment arm length (to the nearest 0.1 cm), from the jont axis to the centre of the paddle on the dynamometer
- The total hold time for each contraction is 6 seconds including the ramp time. Encourage the participant to build up to their maximal contraction and hold for 6 seconds. Record the peak force, to the nearest 0.1 Newton that is produced.
- Provide three practice set of sub maximal trials for each muscle group being tested.
- Perform three test trials with at least 2 minutes between each trial. Rest time can be longer depending on the needs of the participant.

- During the trial encourage the participant to breath properly
- Encourage proper technique with a ramp build up and monitor accessory movement of the body.
- Monitor dynamometer and strap placement during the trials to ensure that moment arm length is the same for all three trials.
- Encourage the participant to report and pain or fatigue between trials.

Table 15: Strength Testing Protocol for Lower Selected Extremity Muscles

Muscle Action	**Patient Position**	**Limb Position**	**Dynamometer Placement**	**Stabilization**
Hip Abduction (HA)	Supine	0^0 hip and knee flexion	Proximal to lateral femoral condyle	Dynamometer secured to limb with seatbelt and anchored to bed. Participant's pelvis stabilized with seat belt
Hip Extension	Side lying with test limb superior	0^0 hip and knee flexion	Posterior thigh at the level of the femoral condyles (superior to popliteal fossa)	
Knee Flexion	Side lying with test limb superior	90^0 hip flexion, 90^0 knee flexion	Posterior leg – proximal to ankle joint	Dynamometer secured to limb with seatbelt and anchored to bed. Participant's pelvis stabilized with seat belt
Knee Extension	Side lying with test limb superior	90^0 hip flexion, 90^0 knee flexion	Anterior leg-proximal to ankle joint	
Ankle Dorsi Flexion	supine	0^0 hip and knee flexion, 0^0 plantar flexion	Dorsum of foot proximal to Metatarsal phalangeal joints	Dynamometer secured to limb with seatbelt and anchored to bed. Participants knee stabilized with strap
Ankle Plantar Flexion	supine	0^0 hip and knee flexion, 0^0 plantar flexion	Sole of foot proximal to Metatarsal phalangeal joints	Participant slides down to foot of bed. Dynamometer placed between sole of foot and board. Knee stabilized with strap.

Appendix 9: Standard Procedure: Timed Up and Go Test

Standard Procedure –Timed Up and Go Test

Instructions to the participant:

"The purpose of this test is to time the length of time that it takes for you to get up from this chair, walk to the mark on the floor, turn around, come back to the chair and then sit down. For this test you may wear your regular foot wear and use your regular walking aide. You will not be given any physical assistance with this test however someone will be near you to prevent you from falling. For added safety, you are required to wear a safety belt for this test. You will be given a practice run with this test that is not timed to familiarize you with this test. You will be allowed to rest for 1 minute between the practice test and the timed test"

Instructions to the tester:

- Allow the participant to practice the test and rest for at least 1 minute. When the participant is ready, complete one timed trial of the test.
- Start timing when the participant initiates sit to stand movement and stop timing when the participant's back come to rest against the back rest of the chair.
- Record the time taken to complete the TUG test to the nearest 0.01 second
- Repeat the last two steps for a total of 3 times trials

Appendix 10: Assessment Tools

i) Standard Procedure: The Activities-specific Balance Confidence Scale

Instructions to the tester:

Participants should be queried concerning their understanding of instructions, and probed regarding difficulty answering specific items.

Instructions to participants prior to testing:

"For each of the following, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady from choosing one of the percentage points on the scale form 0% to 100%. If you do not currently do the activity in question, try and imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or hold onto someone, rate your confidence as it you were using these supports. If you have any questions about answering any of these items, please ask."

Instructions for Scoring:

The ABC is an 11-point scale and ratings should consist of whole numbers (0-100) for each item. **Total the ratings (possible range = 0 – 1600) and divide by 16 to get each subject's ABC score.** If a subject qualifies his/her response to items #2, #9, #11, #14 or #15 (different ratings for "up" vs. "down" or "onto" vs. "off"), solicit separate ratings and use the <u>lowest</u> confidence of the two (as this will limit the entire activity, for instance the likelihood of using the stairs.)

- 80% = high level of physical functioning
- 50-80% = moderate level of physical functioning
- < 50% = low level of physical functioning [75].

- < 67% = older adults at risk for falling; predictive of future fall [126].

The Activities-specific Balance Confidence (ABC) Scale [127].

For each of the following activities, please indicate your level of self-confidence by choosing a corresponding number from the following rating scale:

0% 10 20 30 40 50 60 70 80 90 100%

not confidence completely confident

"How confident are you that you will not lose your balance or become unsteady when you…

…walk around the house? ____%

…walk up or down stairs? ____%

…bend over and pick up a slipper from the front of a closet floor ____%

…reach for a small can off a shelf at eye level? ____%

…stand on your tiptoes and reach for something above your head? ____%

…stand on a chair and reach for something? ____%

…sweep the floor? ____%

…walk outside the house to a car parked in the driveway? ____%

…get into or out of a car? ____%

…walk across a parking lot to the mall? ____%

…walk up or down a ramp? ____%

…walk in a crowded mall where people rapidly walk past you? ____%

…are bumped into by people as you walk through the mall?____%

… step onto or off an escalator while you are holding onto a railing? ____%

… step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? ____%

…walk outside on icy sidewalks? ____%

ii) Hearing Handicap Inventory for the Elderly-Screening Version (HHIE-S)

The HHIE-S has been reported to be a valid and reliable tool to detect hearing impairment in the older adult. The following are the 10 questions from the HHIE-S [128].

1. Does a hearing problem cause you to feel embarrassed when meeting new people?
2. Does a hearing problem cause you to feel frustrated when talking to members of your family?
3. Do you have difficulty hearing when someone speaks in a whisper?
4. Do you feel handicapped by a hearing problem?
5. Does a hearing problem cause you difficulty when visiting friends, relatives, or neighbors?
6. Does a hearing problem cause you to attend religious services less often than you would like?
7. Does a hearing problem cause you to have arguments with family members?
8. Does a hearing problem cause you difficulty when listening to TV or radio?
9. Do you feel that any difficulty with your hearing limits or hampers your personal or social life?
10. Does a hearing problem cause you difficulty when in a restaurant with relatives or friends?

The HHIE-S scores are yes, 4 points; sometimes, 2 points; or no, 0 points, to each question about a particular handicap. Scores range from 0 (no handicap) to 40 (maximum handicap) [128].

iii) Mini-Mental State Examination (MMSE)

The MMSE is a reliable and valid screening tool for cognitive impairment with community dwelling, hospitalized and institutionalized older adults [129]. The instructions as well as the exam are provided below.

Instructions For Administration of Mini-Mental State Examination

Orientation

1. Ask for the Date. Then ask specifically for parts omitted, eg, "Can you also tell me what season it is?" Score one point for each correct answer.
2. Ask in turn, "Can you tell me the name of this hospital?" (town, county, etc.) Score one point for each correct answer.

Registration

Ask the patient if you may test his/her memory. Then say the names of 3 unrelated objects, clearly and slowly, about one second for each. After you have said all 3, ask the patient to repeat them. This first repetition determines his/her score (0-3) but keep saying them until he/she can repeat all 3, up to 6 trials. If all 3 are not eventually learned, recall cannot be meaningfully tested.

Attention and Calculation

Ask the patient to spell the word "world" backwards. The score is the numbers of letters in correct order (eg, DLROW=5; DLRW=4; DLORW, DLW=3; OW=2; DRLWO=1).

Recall

Ask the patient if he/she can recall the 3 words you previously asked him/her to remember. Score 0 – 3.

Language

Naming:	Show the patient a wristwatch and ask him/her what it is. Repeat for pencil. Score 0 – 2.
Repetition:	Ask the patient to repeat the sentence after you. Allow only one trial. Score 0 – 1.
3-stage command:	Give the patient a piece of plain blank paper and repeat the command. Score 1 point for each part correctly executed.
Reading:	On a blank piece of paper print the sentence, "Close your eyes," in letters large enough for the patient to see clearly. Ask him/her to read it and do what it says. Score 1 point only if he actually closes his eyes.
Writing:	Give the patient a blank piece of paper and ask him/her to write a sentence for you. Do not Dictate a sentence; it is to be written spontaneously. It must contain a subject and verb and be sensible. Correct grammar and punctuation are not necessary.
Copying:	On a clean piece of paper, draw intersecting pentagons, each side about 1 in., and ask him/her to copy it exactly as it is. All 10 angles must be present and 2 must intersect to score 1 point. Tremor and rotation are ignored.

iv) Early Treatment Diabetic Retinopathy Study (ETDRS) Charts.

The ETDRS charts are recommended as standardized charts to use in clinical studies measuring visual acuity [130].

ETDRS CHART 1

Near Visual Acuity Test

MODIFIED ETDRS WITH SLOAN LETTERS
For testing at 40 cm (16 inches)

Chart 1
Snellen Distance Equivalent
Diopters of Add for 1 M

Letter Size (metric)		at 40 cm		at 20 cm	
8.0 MM	N C K Z O	20/400	20D	20/800	40D
6.4 MM	R H S D K	20/300	15D	20/600	30D
5.0 MM	D O V H R	20/250	12D	20/500	25D
4.0 MM	C Z R H S	20/200	10D	20/400	20D
3.2 MM	O N H R C	20/150	8D	20/300	15D
2.5 MM	D K S N V	20/125	6D	20/250	12D
2.0 MM	Z S O K N	20/100	5D	20/200	10D
1.6 MM	C K D N R	20/80	4D	20/150	8D
1.25 MM	S R Z K D	20/60	3D	20/125	6D
1.0 MM	H Z O V C	20/50	2.5D	20/100	5D
.8 MM	N C D O K	20/40		20/80	4D
.6 MM	V H C N O	20/30		20/60	3D
.5 MM	S V H C Z	20/25		20/50	2.5D
.4 MM	O Z D V K	20/20		20/40	
.3 MM	N C K H D	20/15		20/30	

Instructions: the 40cm test distance requires a maximum add of +2.50. If the patient cannot see the top line, move test distance to 20cm with a maximum add of +5.00. (Similarly if a 10cm test distance is required, the maximum add is +10.00)

Record test distance and letter size from the left column. Examples: 40/4M, 20/4M

The columns on the right provide: reference to Snellen distance equivalent for two test distances; diopters of add for 1M print size for two test distances.

v) Fall History

A fall history examining intrinsic and extrinsic reasons for a fall is included below [44]. In this study we will ask participants about their fall history for the 6 months prior to the study.

Exhibit 17–7 Example of a Fall History Form

How many falls have occurred in the past week? ____ past month?_____ past year? _____
When was your last fall? ______________________________
Describe the recovery from the fall incident: ______________________________

Describe how the fall occurred:
Sudden/gradual ______________________________
____
Activities at the time of fall ______________________________
Direction of fall ______________________________
Recovery attempts ______________________________
Patient description of cause ______________________________

Categorize fall as extrinsic cause/intrinsic cause/both:

Extrinsic: Trip/slip/bump/environmental hazard (see list in Exhibit 17–5)
Intrinsic: Dizziness/weakness or fatigue/other (see list in Table 17–5)

Source: Data from J. Chandler and P. Duncan, Balance and Falls in the Elderly: Issues in Evaluation and Treatment in *Geriatric Physical Therapy*, A. Guccione, ed., pp. 237–251, © 1993, Mosby Year-Book, Inc.

vi) Fall History Diary

Protocol for Participant Fall Diary

Instructions to the participant:

"We are providing you with a daily calendar for the next 6 months. Each day, please record every slip, trip or fall. Send us a completed calendar at the end of each month, using the pre addressed and pre stamped envelopes that we have given you. The physiotherapist who is working with you during your exercise sessions will assist you with completing the calendars."

Instructions to the research physiotherapists:

1) The Fall Diary and addressed envelopes will be kept in a folder for ease of access for the participant. On your first visit give the folder to the participant and demonstrate how to fill out the Fall Diary using the calendars provided. Encourage the participant to fill in the calendar at the end of each day.
2) Fill in participant ID on each calendar month
3) Mark the start of the exercise program on the appropriate calendar month by circling the date of the first session in pen and writing 'start' beside the date.
4) Mark the end of the exercise program on the appropriate calendar month by circling the date of the last session in pen and writing 'last' beside the date.
5) Each exercise session ask the participant to show you how they are filling out the calendar.
6) Offer assistance if the participant is not completing the calendar as per the instructions.
7) Ensure that the calendar is being mailed during the 8 week exercise session. Each calendar is sent in at the end of the calendar month.
8) Remind the participant to continue to send the calendars in for the full 6 month period once the 8 week exercise session is complete.

Falls Diary **Participant ID:**______________________________

As part of the assessment of your treatment we are asking you to record the number of times you trip/slip, or fall. Please record the number of times you fall each day, on this calendar. At the end of each day, mark the number of falls, or a "0" if you did not fall at all that day. A fall is defined as losing your balance so that you come to rest on a lower surface. The lower surface can be the floor or an item of furniture such as a bed or chair. If you save yourself from falling by grabbing a near-by object or another person, this also counts as a fall. If you trip or slip but save your balance without assistance or without grabbing a near-by object, this does not count as a fall. Please record the number of times you trip or slip without falling each day, on this calendar. At the end of each day, mark the number of slips or trips, or a "0" if you did not trip or slip at all that day.

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
		1 Falls:__________ Slips or Trips: ___________	2 Falls:__________ Slips or Trips: ___________	3 Falls:__________ Slips or Trips: ___________	4 Falls:__________ Slips or Trips: ___________	5 Falls:__________ Slips or Trips: ___________
6 Falls:__________ Slips or Trips: ___________	7 Falls:__________ Slips or Trips: ___________	8 Falls:__________ Slips or Trips: ___________	9 Falls:__________ Slips or Trips: ___________	10 Falls:__________ Slips or Trips: ___________	11 Falls:__________ Slips or Trips: ___________	12 Falls:__________ Slips or Trips: ___________
13 Falls:__________ Slips or Trips: ___________	14 Falls:__________ Slips or Trips: ___________	15 Falls:__________ Slips or Trips: ___________	16 Falls:__________ Slips or Trips: ___________	17 Falls:__________ Slips or Trips: ___________	18 Falls:__________ Slips or Trips: ___________	19 Falls:__________ Slips or Trips: ___________
20 Falls:__________ Slips or Trips: ___________	21 Falls:__________ Slips or Trips: ___________	22 Falls:__________ Slips or Trips: ___________	23 Falls:__________ Slips or Trips: ___________	24 Falls:__________ Slips or Trips: ___________	25 Falls:__________ Slips or Trips: ___________	26 Falls:__________ Slips or Trips: ___________
27 Falls:__________ Slips or Trips:___	28 Falls:__________ Slips or Trips:___	29 Falls:__________ Slips or Trips:___	30 Falls:__________ Slips or Trips:____	31 Falls:__________ Slips or Trips:__		

If you have any questions or concerns, please call Denise Hollway at 506-650-1321 At the end of the month, please use the stamped, addressed envelope we gave you, to mail this page to: Denise Hollway, 3014 Rothesay Rd, Rothesay, NB, E2E 5V4

Appendix 11: Protocol for Progressive Balance Training Program

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PROGRESSIVE BALANCE TRAINING CHART
Participant ID:

Introduction

The main purpose of this program is to improve the ability of the participant to use vestibular inputs for balance control. Base of support (BOS) conditions, motion, (dynamic balance) and cognitive tasks are also imposed in progressive levels.

Participants wear a safety belt to do the exercises, and the therapist provides **stand-by supervision** i.e. the therapist guards the participant without physical contact, except in response to loss of balance.

The program is divided into progressive levels. The first two levels of the Progressive Balance Exercise will include sitting, to allow the participant to become accustomed to the various components of the program in a more stable base of support position. Each level outlined below is the outline for an individual session with the participant. The components of the program are described below.

The participant will be asked to work on each sensory task, outlined in the table below, for 30 seconds without losing balance (defined as taking a step to maintain center of mass over the base of support) for up to 3 trials for each task. To challenge participants to use vestibular inputs, participants will be asked to perform eyes closed tasks on a compliant surface at least two times more often than tasks done with eyes open on a compliant surface. Progression is based on the ability of the participant to achieve continuous 30 s with each EC task within a session. It is anticipated that it may take 2-3 sessions for a participant to completely progress from one level to the next level. Appropriate rest time will be given within the balance exercises with 10-15 minutes allocated for rest and teaching per 35 minute session.

Components of the Progressive Balance Exercise Program

Sensory perturbations [EC and compliant support surface] promoting use of vestibular inputs, are imposed on balance tasks that vary in terms of:

1. Fixed Base of Support (Fixed) conditions will be included in each session as tolerated , progressing from:
    - 1.1. Broad BoS = 2 foot stance, shoulder width apart
    - 1.2. Narrow BoS = 2 foot stance, feet together;
    - 1.3. Narrow 2 foot tandem stance (R & L anterior);
    - 1.4. Narrow Single foot stance (R & L)
2. Motion tasks will be included in each session as tolerated, progressing from:
    - 2.1. Static Posture/Stance (no additional movement)
    - 2.2. Weight Shift
        - 2.2.1. Lean
            - 2.2.1.1. Symmetrical
                - 2.2.1.1.1. amplitude = max vs. submax

PROGRESSIVE BALANCE TRAINING CHART
Participant ID:

- 2.2.1.1.2.
- 2.2.1.1.3. pace = natural, slow, fast
- 2.2.1.2. Asymmetrical (Trunk Rotation)
  - 2.2.1.2.1. amplitude = max vs. submax
  - 2.2.1.2.2. pace = natural, slow, fast
- 2.2.2. Upper Limb Reaching/Lifting
  - 2.2.2.1. Symmetrical
    - 2.2.2.1.1. amplitude = max vs. submax
    - 2.2.2.1.2. pace = natural, fast, slow
    - 2.2.2.1.3. reach for objects
      - 2.2.2.1.3.1. vary height of objects
      - 2.2.2.1.3.2. , increase weight of objects
  - 2.2.2.2. Asymmetrical (Trunk Rotation)
    - 2.2.2.2.1. amplitude = max vs. submax
    - 2.2.2.2.2. pace = natural, fast, slow
- 2.3. Stepping
  - 2.3.1. Single step (R & L)
    - 2.3.1.1. direction
      - 2.3.1.1.1. AP and lateral
      - 2.3.1.1.2. circle stepping
    - 2.3.1.2. amplitude = max vs. submax
    - 2.3.1.3. pace = natural, slow, fast
  - 2.3.2. Walking (level ground, compliant, imposed instructions….)
    - 2.3.2.1. amplitude = max vs. submax
    - 2.3.2.2. pace = natural, slow, fast
    - 2.3.2.3. perturbed walking
      - 2.3.2.3.1. navigate with obstacles
      - 2.3.2.3.2. stopping, starting and turning
    - 2.3.2.4.
- 3. Dual Cognitive Task
  - 3.1. None imposed
  - 3.2. Counting
  - 3.3. Basic Math (Subtract by constant e.g. 5, 3, 7)

* target stepping –stepping to a target with specific foot placement
**max step/lean – the max amount a participant can lean or step without losing their balance (defined as taking a step to avoid falling). With stepping, a % of max will be calculated with each progression
***pacing- physiotherapist gives verbal feedback to increase/decrease speed and accuracy

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PROGRESSIVE BALANCE TRAINING CHART
Participant ID:

Table 16: Progressive Balance Training Program – Level 1-3

Instructions:
Surface: Confirm surface type used by circling
Vision: Circle EO/EC as this type of vision is used with surface
Time: Indicate repetitions and time for each activity; 30 s = ceiling for each repetition
Maximum Step: Maximum step the participant can take and maintain balance – will be assessed starting in Week 3

Level 1

Date:		SENSORY				TIME	
Motion	**Cognitive Task**	**Surface**	**Vision**		**Base of support**	**30 min**	
						EO	**EC**
Static	None imposed	Dyna disc sit-compliant	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s
Static	None imposed	Standing compliant surface	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s
Weight shift - submax - natural pace - symmetrical lean	None imposed	Dyna disc sit-compliant	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s
Weight shift - submax - natural pace - asymmetrical lean	None imposed	Dyna disc sit-compliant	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s
Weight shift - submax - natural pace - symmetrical lean	None imposed	Standing compliant	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s

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PROGRESSIVE BALANCE TRAINING CHART
Participant ID:

Level 2

Date:		SENSORY				TIME	
Motion	**Cognitive Task**	**Surface**	**Vision**		**Base of support**	**30 min**	
						EO	**EC**
Weight shift - submax - slow pace - symmetrical lean	None imposed	Stability ball-sitting Compliant	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s
Weight shift - submax -slow pace - symmetrical lean	None imposed	Standing Compliant	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s
Weight shift - submax - slow pace - asymmetrical lean	None imposed	Standing Compliant	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s
Weight shift - submax - fast pace - asymmetrical lean	None imposed	Stability Ball Compliant	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s
Weight shift - submax - fast pace - asymmetrical lean	None imposed	Standing Compliant	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s
					Total Time	**10 min**	**20 min**

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PROGRESSIVE BALANCE TRAINING CHART
Participant ID:
Level 3

Date:		SENSORY				TIME	
Motion	**Cognitive Task**	**Surface**	**Vision**		**Base of support**	**28.5 min**	
						EO	**EC**
Weight shift -max lean - natural pace - symmetrical lean	None imposed	Standing Compliant	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s
Weight shift -max lean - natural pace - asymmetrical lean	None imposed	Standing Compliant	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s
Weight shift -max lean - natural pace - UE Reaching symmetrical	None imposed	Standing Compliant	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s
Weight shift -max lean - natural pace - UE Reaching asymmetrical	None imposed	Standing Compliant	EO	EC	Broad	30 s	2 x 30 s
			EO	EC	Narrow	30 s	2 x 30 s
			EO	EC	Narrow tandem	30 s	2 x 30 s
			EO	EC	Narrow single foot	30 s	2 x 30 s
Stepping - single step -50-70%max - natural pace -specific targets	None imposed	Standing Compliant	EO	EC	Broad	30 s # of steps	2 x 30 s # of steps
			EO	EC	Narrow	30 s # of steps	2 x 30 s # of steps
Stepping - single step -50-70%max - slow pace -specific targets	None imposed	Standing Compliant	EO	EC	Broad	30 s # of steps	2 x 30 s # of steps
					Total Time	**9.5 min**	**19 min**

Appendix 12: Protocol to Determine 1RM

Determine 1RM
One Repetition Maximum (equipment: Free weights)

Explain and demonstrate the protocol to participants for familiarization before testing.

1. Explain which muscle groups are involved in the test. NOTE. Tester will point to muscle locations as part of explanation.
2. Demonstrate the movement with accompanying verbal explanation.
3. Position participant in the standardized position and teach the specific movement. NOTE. Monitor for undesirable accessory movements, inadequate stabilization, pain or discomfort. Record the initial position.
4. Remind about correct breathing technique. e.g. "Take a breath in to prepare for the lift, and breathe out as you push the weight steadily upward." "Breathe in as you lower the weight steadily."
5. Perform several lifts at low or zero resistance to establish familiarity with movement and correct lifting technique. Encourage and monitor technique at all times; encourage feedback on pain and discomfort, charting as appropriate.
6. Set initial resistance at a level slightly above that of the warm-up resistance (i.e. 2-4 kg). This will vary between participants according to their perceived or observed effort during the warm-up.
7. Perform 1 movement with good technique.
8. Ask performer to rate how hard they perceived the movement to be on a rating of perceived exertion (RPE) scale of 6 (very, very easy) to 20 (most I could possibly do). NOTE. Tester will also monitor difficulty of the movement by observing the speed and effort at which it is performed by the participant.
9. Rest 1 minute for RPE scores below 12, rest 2 minutes for RPE scores above 12.
10. Add 5 to 10lb (2.25–4.5kg) depending on the RPE. (In this study, 1-2 kg was added with each progression).
11. Repeat process to momentary muscular failure (i.e., they cannot continue) or to volitional fatigue (i.e., they do not wish to continue).
12. Record maximum weight lifted. NOTE. When failure occurs, it may be appropriate in certain cases to remove some of the added weight and attempt another maximum effort at a slightly lower resistance.

Appendix 13: Protocol for Progressive Resistance Exercise Program (PRE)

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PROGRESSIVE STRENGTH TRAINING (PRE)

Table 17: Weekly Charting Form for PRE Training Program

WEEKLY CHARTING FORM
Instructions:
1RM: record max. weight
%1RM: record weight used
Number of Repetitions: 8-10 repetitions to fatigue

Warm up exercise:

- **10 15 reps without weight**
- **2 min rest prior to RM set**

Participant's ID: **Muscle Group:**

Week 1	Resistance	%1RM	Number of reps.
	1RM	50%	1 set; 8-10 reps
Session Date (dd/mm/yy)	Test 1RM		
A)			# of reps:R L
B)			# of reps:R L
C)			# of reps:R L
Notes:			
Week 2	1RM	80%	1 set; 8-10 reps
Session Date (dd/mm/yy)			
A)			# of reps:R L
B)			# of reps:R L
C)			# of reps:R L
1RM this week -Add 2-10% from max weight from last week session Notes:			
Week 3	1RM	80%	1 set; 8-10 reps
Session Date (dd/mm/yy)	Re-test 1RM		
A)			# of reps:R L
B)			# of reps:R L
C)			# of reps:R L
Notes:			

Participant's ID: **Muscle Group:**

Week 4	**1RM**	**80%**	**1 set; 8-10 reps**
Session Date (dd/mm/yy)	**Add 2-10% from last session Week 3**		
A)			**# of reps:R L**
B)			**# of reps:R L**
C)			**# of reps:R L**
1RM this week -Add 2-10% from max weight from last week session Notes:			
Week 5	**1RM**	**80%**	**1 set; 8-10 reps**
Session (dd/mm/yy)	**Re-test 1RM**		
A)			**# of reps:R L**
B)			**# of reps:R L**
C)			**# of reps:R L**
Notes:			
Week 6	**1RM**	**80%**	**1 set;10 reps**
Session (dd/mm/yy)			
A)			**# of reps:R L**
B)			**# of reps:R L**
C)			**# of reps:R L**
1RM this week -Add 2-10% from max weight from last week session Notes:			
Week 7	**1RM**	**80%**	**1 set;10 reps**
Session (dd/mm/yy)	**Re-test 1RM**		
A)			**# of reps:R L**
B)			**# of reps:R L**
C)			**# of reps:R L**
Notes:			
Week 8	**1RM**	**80%**	**1 set;10 reps**
Session (dd/mm/yy)	**Re-test 1RM**		
A)			**# of reps:R L**
B)			**# of reps:R L**
C)			**# of reps:R L**
Notes:			

Appendix 14: MVIC Data

Table 18: Peak Torque Produced during MVIC testing per Participant

Muscle Group	Assessment Session	*Resistance Exercise Group*				*Resistance and Balance Exercise Group*		
		EM02	***EM03***	***EM33***	***EM34***	***EM24***	***EM26***	***EM30***
HIP ABD.(RT)	***Pre***	17.22	21.26	**nc♠**	42.58	17.06	22.99	2.89
	Post	17.22	35.24	**nc♠**	75.89	24.11	22.26	28.77
KNEE EXT(RT)	***Pre***	**nc♣**	33.28	7.07	40.50	12.85	29.30	15.07
	Post	17.77	33.28	20.41	50.93	22.68	35.98	21.52
ANKLE DF (RT)	***Pre***	4.80♦	8.20	6.22	25.80	5.33	15.39	9.98
	Post	5.95	18.75	7.40	29.92	5.95	16.77	12.09
ANKLE PF(RT)	***Pre***	11.97♦	12.99	18.34	35.13	6.20	32.11	26.63
	Post	19.48	**nc♣**	24.55	33.86	16.90	33.43	25.51

nc = not collected
♠ = unable to manage exam table
♣ = lack of time
♦ = left side collected in Pre assessment; results blended as no difference in ROM detected in Post assessment exam and ankles trained bilaterally

Table 19: Summary Statistics for Peak Torque (Nm) Produced During MVIC testing

Muscle group	Assessment Session	Resistance Exercise Group				
		Mean (sd)	**Median**	**Min.**	**Max.**	**n=4**
HIP ABD	***Pre***	27.02 (13.62)	21.26	17.22	42.58	3
	Post	42.76 (30.06)	35.24	17.22	75.89	3
KNEE EXT.	***Pre***	26.95 (17.59)	33.28	7.07	40.50	3
	Post	30.60 (15.16)	26.84	17.77	50.93	4
ANKLE DF	***Pre***	13.41 (10.77)	8.2	6.22	25.8	4
	Post	15.51 (11.19)	13.08	5.95	29.92	4
ANKLE PF	***Pre***	22.15 (11.55)	18.34	12.99	35.13	3
	Post	25.96 (7.29)	24.55	19.48	33.86	3

Min. = minimum
Max. =maximum

Table 19: (Continued) Summary Statistics for Peak Torque (Nm) Produced During MVIC testing

Muscle group	Assessment Session	Resistance and Balance Exercise Group				
		Mean (sd)	**Median**	**Min.**	**Max.**	**n=3**
HIP ABD	***Pre***	14.31 (10.32)	17.06	2.89	22.99	3
	Post	25.05 (3.35)	24.1	22.26	28.77	3
KNEE EXT.	***Pre***	19.07 (8.93)	15.07	12.85	29.3	3
	Post	26.73 (8.04)	22.68	21.52	35.98	3
ANKLE DF	***Pre***	10.23 (5.04)	9.98	5.33	15.39	3
	Post	16.18 (10.17)	14.43	5.95	29.92	3
ANKLE PF	***Pre***	21.65 (13.65)	26.63	6.2	32.11	3
	Post	27.42 (7.99)	29.47	33.86	33.86	3

Min. = minimum
Max. =maximum

Appendix 15: Demographic and Assessment Data

Table 20: Individual Descriptive Characteristics of Study Participants

Table 20: Individual Descriptive Characteristics of Study Participants

			RE Group				RBE Group		
		Session	**EM02**	**EM03**	**EM33**	**EM34**	**EM24**	**EM26**	**EM30**
Age (years)			75	80	82	84	87	89	84
CTSIB (s)	***CTSIB1***	***pre***	30	30	30	30	30	30	30
		post	30	30	30	30	30	30	30
	CTSIB2	***pre***	30	21.9	20.9	30	30	30	30
		post	30	30.0	28.6	30	30	30	30
	CTSIB3	***pre***	30	30	29.6	30	30	30	30
		post	30	30	30	30	30	30	30
	CTSIB4	***pre***	30	8.5	9.6	30	30	30	3.8
		post	30	0	30	30	30	30	30.0
	CTSIB5	***pre***	10.5	0.0	4.2	12.2	10.4	4.8	1.8
		post	18.4	0.0	4.4	11.1	30.0	28.1	30.0
	CTSIB6	***pre***	30	0	17.8	3.7	30	29.8	0.8
		post	30	0	2.9	14.7	30	30.0	30.0
TUG (s)		***pre***	18.3	23.7	58.4	12.5	13.4	13.8	20.3
		post	17.2	15.9	80.6	10.6	12.4	11.8	15.1
MMSE		***pre***	26	23	28	29	26	28	30
		post	np	np	np	np	np	np	np
ABC Scale (max. = 100)		***pre***	55.6	49.0	0.0	59.4	59.1	84.4	27.8
		post	71.9	36.0	0.0	46.9	83.8	91.3	54.1

Table 20: Individual Descriptive Characteristics of Study Participants

			RE Group				RBE Group		
		Session	**EM02**	**EM03**	**EM33**	**EM34**	**EM24**	**EM26**	**EM30**
Vision (letter size)		***pre***	nc	nc	20/50	20/60	20/60	20/60	20/250
		post	20/100	nc	20/50	20/60	20/60	20/60	20/125
HHIE-S (max. handicap = 40)		***pre***	nc	4	22	26	2	0	6
		post	0	nc	28	22	8	0	6
Weight (lbs)		***pre***	nc	nc	140	140	155	192	140
		post	155	190	143	140	155	185	140
Falls (past year)		***pre***	0	1	not sure/ yes	1	1	1	5
		post	0	0	5+	5	0	2	5
No. of co-morbidities		***pre***	3	4	5	2	5	4	3
		post	3	4	5	2	5	4	3
No. of medications		***pre***	3	6	4	2	2	6	2
		post	3	3	4	2	2	5	2
Gait Aide		***pre***	cane	cane outside	wheeled walker	cane	cane outside	cane outside	cane
		post	cane	cane outside	wheeled walker	cane	cane outside	cane outside	cane
1 RM Muscle Group (Kg)	***HIP ABD***	***pre***	4	5	6	6	3	3	9
		post	14	14	8	15	6	8	14
	KNEE EXT	***pre***	9	14	12	18	12	16	10
		post	20	20	14	24	16	18	18

Table 20: Individual Descriptive Characteristics of Study Participants

				RE Group				RBE Group	
		Session	**EM02**	**EM03**	**EM33**	**EM34**	**EM24**	**EM26**	**EM30**
	ANKLE DF	***pre***	14	20	20	20	15	20	14
		post	25	25	25	25	26	33	22
	ANKLE PF	***pre***	8	8	15	15	17	14	12
		post	17	20	20	22	30	22	18
	HIP EXT	***pre***	4	8	9	12	6	10	10
		post	16	19	14	22	12	21	19
	KNEE FLEX	***pre***	4	8	11	12	6	12	12
		post	15	18	14	19	15	19	17

Table 21: Summary of Pre and Post Intervention Status of Participants

PARTICIPANT	SUMMARY
EMO2	***PMHX**:* Lt. THR with subsequent # femur, stroke>1 year ago, heart disease, Rt. ankle fused ***Medications:*** indapamide, lisinopril, aspirin ***Pre-Exercise status:*** evidence of impaired vestibular status; decreased mobility; decreased balance confidence ***Intervention:*** PRE protocol 3 sessions/week x 8 weeks ***Response to Rx*****:** CTSIBTest 5 score remains below 20 s; increase in 1RM for all muscle groups; min change TUG score; increased balance confidence
EM03	***PMHX:*** diabetes, HTN, MI>5 years, TURP, Lt. lobectomy Ca of lung ***Medications:*** verapamil, zopoclone, ventalin,atavan, advair,Tylenol 3 Pre-Exercise ***Pre-Exercise status:*** evidence of impaired vestibular status; decreased somatosensory function; decreased mobility; decreased balance confidence ***Intervention:*** PRE protocol 3 sessions/week x 8 weeks ***Response to Rx:*** CTSIB Test 4-6 scores = zero with participant unable to tolerate compliant surface; increase in 1RM for all muscle groups; >5 s decrease TUG score; decreased balance confidence
EM33	***PMHX:*** breast Ca, shingles, glaucoma, HBP ***Medications:*** gabopenten, lisinopril, timotic,tranatan , ibuprofen ***Pre-Exercise status:*** evidence of impaired vestibular status; decreased LE muscle strength; decreased mobility; decreased balance confidence ***Intervention:*** PRE protocol 3 sessions/week x 8 weeks ***Response to Rx:*** CTSIB Test 4 normal score, CTSIB 5 remained <15 s, CTSIB noticeably decreased; increase in 1RM for all muscle groups; >30 increase in TUG score
EM34	***PMHX:*** previous amputation Lt Arm for Ca (>25 years), HTN ***Medications:*** HCTZ, aspirin, ***Pre-Exercise status:*** evidence of impaired vestibular status; decreased balance confidence ***Intervention:*** PRE protocol 3 sessions/week x 8 weeks ***Response to Rx:*** CTSIBTest 5 and 6 scores remained below 15 s; increase in 1RM for all muscle groups; <2 s decrease TUG score

Table 21: (Continued) Summary of Pre and Post Intervention Status of Participants

PARTICIPANT	SUMMARY
EM24	***PMHX:*** Lt THR, hypothyroidism, previous pharynx obstruction resulting in continued SOB,HBP, Lt. cataract surgery 4 mos. ago ***Medications*:** synthroid, atacand ***Pre-Exercise status:*** evidence of impaired vestibular status; decreased balance confidence ***Intervention:*** Progressive balance and PRE protocol 3 sessions/week x 8 weeks ***Response to Intervention***: CTSIB Test 5 score increased to 30 s; increase in 1RM for all muscle groups; 1 s change TUG score; increased balance confidence
EM26	***PMHX:*** stable ischemic heart disease, pacemaker 2001, bilateral TKR 2001 ***Medications:*** lasix, nitro spray, aspirin, capoten, dilitazem, lipitor ***Pre-Exercise status:*** evidence of impaired vestibular status; ***Intervention:*** Progressive balance and PRE protocol 3 sessions/week x 8 weeks ***Response to Intervention***: CTSIB Test 5 score increased to 30 s; increase in 1RM for all muscle groups; 2 s decrease TUG score
EM30	***PMHX:*** depression, high cholesterol, allergies, LT. cataract surgery during 8 week intervention ***Medications:*** antidepressant, zocor, rantidine ***Pre-Exercise status:*** evidence of impaired vestibular status; decreased mobility; decreased balance confidence ***Intervention:*** Progressive balance and PRE protocol 3 sessions/week x 8 weeks ***Response to Intervention***: CTSIB Test 5 and Test 6 score increased to 30 s; increase in 1RM for all muscle groups; >5 s decrease TUG score; increased balance confidence

Appendix 16: PRE Training Load per week (% 1RM)

Table 22: Training Load per Week per Participant (RE Group)

MUSCLE	Week/Load	*EM02*		*EM03*		*EM33*		*EM34*	
		Kg	*% 1RM*	*Kg*	*% 1RM*	*Kg*	*% 1RM*	*Kg*	*% 1RM*
HIP ABD	***1***	3	75	2	40	3	50	3	50
	2	3	75	3.7	74	4	67	4	100
	3	6	75	6	75	4	57	5	71
	4	6	75	6	75	4	67	6	75
	5	10	83	9	75	4	67	6	75
	6	10	83	9	75	4	67	7.3	81
	7	11	79	10	71	5	71	10	77
	8	11	79	NA	NA	6	75	12	80
KNEE EXT	***1***	4.3	48	6.3	45	6	50	9	50
	2	9	75	8.3	75	9	75	14	78
	3	14	74	14	78	10	77	15	79
	4	15	79	14	78	10	77	15	79
	5	16	80	15	79	9.5	73	16	80
	6	16	80	15	79	10	77	17	77
	7	17	85	16	80	11	79	18	78
	8	17	85	NA	NA	11	79	19	79

MUSCLE	Week/Load	*EM02*		*EM03*		*EM33*		*EM34*	
ANKLE DF	***1***	6.3	45	10	50	10	50	10	50
	2	12	80	12	75	16	80	16	80
	3	15	79	18	78	18	78	18	78
	4	16	80	18.3	76	18	78	18	78
	5	18	78	20	80	19	79	19	79
	6	18	78	20	80	19	79	19	79
	7	19	79	20	80	20	80	20	80
	8	20	80	NA	NA	20	80	20	80

MUSCLE	Week/Load	*EM02*		*EM03*		*EM33*		*EM34*	
		Kg	*% 1RM*	*Kg*	*% 1RM*		*Kg*	*% 1RM*	*Kg*
ANKLE PF	***1***	4.7	59	4	50	7	47	7	47
	2	7	78	5.3	66	12	80	12	80
	3	11	79	12	75	13	81	13	76
	4	12	80	12	75	13	81	13	76
	5	13	81	14	78	14	78	14	78
	6	13	81	14	78	14	78	15	79
	7	14	82	16	80	15	79	16	80
	8	14	82	NA	NA	16	80	17	77

Table 22: (Continued) Training Load per Week per Participant (RE Group)

HIP EXT	*1*	3.5	88	4	50	4	44	6	50
	2	4	80	4.7	59	7	78	9	75
	3	8	80	12	75	8	80	10	77
	4	8	80	12	75	8	80	11	79
	5	12	80	14	78	9	75	12	80
	6	12.7	79	14	78	9	75	13	76
	7	13	81	15	79	10	77	15	79
	8	13	81	NA	NA	11	79	17	77
KNEE FLEX	*1*	2	50	4.7	59	5	45	6	50
	2	4	80	5.3	66	8	73	9	75
	3	5	71	12	75	9	75	10	77
	4	6	75	12	75	9	75	11	79
	5	10	77	13	72	10	77	12	80
	6	12	80	13	72	10	77	12	80
	7	12	80	14	78	11	79	13	76
	8	12	80	NA	NA	11	79	15	79

Table 22: (Continued) Training Load per Week per Participant (RBE Group)

MUSCLE	Week/Load	*EM24*		*EM26*		*EM30*	
		Kg	*% 1RM*	*Kg*	*% 1RM*	Kg	*% 1RM*
HIP ABD	***1***	1	33	1.3	43	4	44
	2	2	67	3	75	4	44
	3	4	80	3	75	8	80
	4	4	80	3	75	9	82
	5	5	83	5	71	NA	NA
	6	5	83	6	75	9	82
	7	5	83	6	75	11	79
	8	5	83	NA	NA	NA	NA
KNEE EXT	***1***	8	67	8	50	5	50
	2	10	83	13	81	7	64
	3	9.7	75	14	78	7	64
	4	9.7	69	12	67	9.7	81
	5	12	86	12.3	68	13	81
	6	12	80	13	72	NA	NA
	7	12.3	82	13	72	13	81
	8	12.3	77	14	78	14	78

Table 22: (Continued) Training Load per Week per Participant (RBE Group)

ANKLE DF	***1***	7	47	10	50	7	50
	2	12	75	16	80	12	80
	3	14	78	20	80	12	80
	4	16	80	20	80	13	81
	5	18	90	22	80	16	80
	6	20	83	24	80	NA	NA
	7	20	80	25	83	16	80
	8	21	81	26	79	18	82

Table 22: (Continued) Training Load Per Week per Participant (RBE Group)

MUSCLE	Week/Load	*EM24*		*EM26*		*EM30*	
		Kg	*% 1RM*	*Kg*	*% 1RM*	*Kg*	*% 1RM*
ANKLE PF	***1***	8	47	7	50	6	50
	2	13	76	11	79	10	77
	3	16	80	14	78	10	77
	4	17.3	87	14	78	11	79
	5	18	90	14	78	13	81
	6	20	80	14	78	NA	NA
	7	21	78	16	80	12	92
	8	24	80	18	82	14	78
HIP EXT	***1***	3	50	5	50	5	50
	2	4	57	9	82	8	80
	3	5	71	11	85	8	80
	4	6	75	11	79	9	82
	5	9	82	14	78	14	82
	6	10	83	16	80	NA	NA
	7	10	83	16	80	14	82
	8	NA	NA	17	81	15	79

Table 22: (Continued) Training Load per Week per Participant (RBE Group)

KNEE FLEX	***1***	3	50	6	50	5.7	48
	2	5	83	10	77	10	83
	3	6	86	11	79	10	83
	4	8	73	12	80	10	77
	5	9	82	13	81	12	80
	6	10	83	14	82	NA	NA
	7	11	79	15	79	12	80
	8	12	80	15	79	14	82