The effects of strength and balance training using a Rock-it Board in an ageing population

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I declare that the work presented in this thesis is, to the best of my knowledge and belief, original and my own work, except as acknowledged in the text and reference pages.

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Abstract

Background: Strength and balance programs are a well-established training method in preventing falls in people over the age of 65 years. However, there is limited research investigating the effects of strength and balance training using a stability training device, and no research to date using a Rock-it Board.

Aim: The purpose of this research was to evaluate whether the use of a Rock-it Board stability training device could improve strength and balance in older people, which could potentially reduce the risk of a fall.

Method: This study used a randomised parallel-group design trial with an experimental and control group. The experimental group consisted of five females (mean ± SD, age 77 ± 3.4 years, 70.9 ± 9.7 kg and 160.2 ± 4.6 cm) and two males (mean ± SD, age 75.5 ± 3.5 years, 78.9 ± 7.9kg, 167.8 ± 0.4 cm). The control group consisted of seven females (mean ± SD, age 64.3 ± 4.7 years, 68.0 ± 6.2 kg and 161.86 ± 4.4 cm). The experimental and control groups completed pre-intervention exercise testing consistent with the OEP. The tests used were the Romberg Test, Timed Up and Go Test, Functional Reach Test, Sit to Stand Test, Left and Right Knee Extension Force Test and a Stair Climb Test. The experimental group exercise sessions' training comprised one session twice a week of 50 minutes for four weeks. Due to a nationwide lockdown, training was continued for two additional weeks before post-testing could commence. The training, designed to improve strength and balance, consisted of a warm-up and then seven dynamic balance exercises based on movements from the OEP adapted to be used with a Rock-it Board stability training device. The control group participants were asked to maintain their habitual exercise routines but refrain from additional organised training during the six weeks.

Results: The results showed significant improvements for the experimental group in the Romberg Test (p=0.023) and the Timed Up and Go Test (p=0.03). The Romberg Test showed a magnitude of improvement in the experimental group of 36.7 %, with a large effect size (d) of 1.05. The Timed Up and Go Test showed a magnitude of improvement in the experimental group of –6.3 % with a moderate effect size (d) of 0.68. Other measures suggested that the invention improved the performance of the participants; however, none of these measures achieved significance.

Conclusion: The major finding of this study is that six weeks of dynamic balance training using a Rock-it Board improved several measures of balance and stability in older individuals. The improvements in test performance may be associated with improvements in strength and potentially neuro-muscular function. Since falls rarely commence from a static position, this study recommends that older individuals would benefit from more active and dynamic training interventions over static strength-based training programmes.

Keywords: falls prevention, Otago Exercise Programme, strength, balance, older people, stability training device.

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List of Abbreviations

ACC- Accident Compensation Corporation

ADL- Activities of Daily Living

COP- Centre of Pressure

FES- Falls Efficacy Scale

FOF- Fear of Falls

FRT- Functional Reach Test

OEP- Otago Exercise Programme / Otago Falls Prevention Programme

TUG- Timed Up and Go

RIB- Rock-it Board

WHO- World Health Organisation

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Chapter One: Introduction

1.1 Background

Falling over is increasingly inevitable in older adults. One in three community-dwelling people aged 65 years fall once every year (Campbell et al., 1990; Tinetti et al., 1988). As we age, the body undergoes substantial physiological changes. The ability to self-correct during a fall diminishes due to the significant reduction in lower limb strength and overall balance. Aartolahti et al. (2020) suggested that decreased physical activity may accelerate sarcopenia-related factors such as loss of strength and muscle mass. These effects have demonstrated a rapid decline in reaction times and a significant reduction in reactive coordination. The ability to self-correct a potential fall relies strongly on lower limb strength. Aartolahti et al. (2020) has also identified that longitudinal studies have shown that the rate of lower limb strength loss is approximately 2.5-4% per year after the age of 75 years of age. Given the nature of our everyday activities as humans, we function in more of a dynamic environment. The nature of falling is a dynamic movement which may pose more of a falls risk to older individuals. Therefore, promoting lower limb strength and balance training is vitally important and may prevent falls prevention in people over the age of 65 years.

Physical activity and exercise have been shown to promote healthy ageing and prevent mobility limitations through a series of studies known as the Otago Exercise Programme (OEP) (Campbell et al., 1999; Campbell et al., 1997; Campbell, 2003). The OEP is an evidence-based, home-based exercise programme that is individually tailored to the strength and balance retraining in older adults over the age of 65 years. This programme promotes a growing need for older adults to maintain a recreationally active lifestyle. The OEP is designed to strengthen lower leg limbs to prevent and reduce fall-related injuries. The OEP states that people over the age of 65 are more susceptible to falls and fall-related injuries (Campbell et al., 1997).

Since the OEPs initial development in 1997, the OEP has been extended to become the basis of multifaceted exercise programmes for older adults. The OEP has been extended to different modes of exercise such as yoga training, the use of free weights and an OEP DVD programme. Gillespie et al. (2012) identified that exercise interventions comprising of multifactorial exercises achieved a significant reduction in the rate and risk of falling. The essence of the OEP is to increase strength, stability and balance training in older adults to prevent the rate and risk in which injury can occur.

The various modes of exercise that can be developed from the OEP platform create open-ended opportunities for experimental studies to be investigated. The use of stability training devices with OEP correlates strongly with those suggestions of (Gillespie et al., 2012) and (Aartolahti et al., 2020) regarding multi-modes of physical activity and exercise. The Rock-it Board (RIB) is a locally produced stability training device in Hawkes Bay. The RIB is a half-moon shape board made from layered plywood. The Balance Board model is approximately 89cm long and 32cm wide with a curve the makes the tips of the board stand 15cm tall. The RIB is predominantly used as a rocking device to create a rocking movement. The manufacturers advocate for the use of their product in fall prevention; however, its effectiveness has not been scientifically substantiated. The majority of the research investigating falls prevention in older adults primarily focuses on new interventions and other types of training. This study focuses on using the OEP as a base for the development of similar exercises in a modified dynamic training program using a RIB. The idea is to create a new falls prevention training regime using the ideas that have been trialled and tested and extensively validated by the OEP.

1.2 Thesis Rationale and Significance

The OEP is a series of predominately static conditioning activities readily available for participants who choose to engage in the program. It is aimed to be a convenient way for older people to partake in physical exercise from the comfort of their own homes. However, as the literature shows, people over 65 are at risk of often falling in dynamic rather than static scenarios. Current research focuses on falls prevention programs from a static standpoint instead of a dynamic one; however, falls seldom commence from a static position. Tinetti et al. (1988) have stated that many older people fall during dynamic movements of habitual daily activities, like walking or rising from a chair or a bed. There is a lack of research investigating how the risk of falls may be reduced by implementing dynamic strength and balance training programmes. With the ready availability of the consumer product, the RIB, further research regarding strength and balance training on stability training devices is needed to understand if the possibility of a reduction in falls risk is achievable.

1.3 Research Aim

This research experiment aims to evaluate whether the use of a RIB stability training device can improve strength and balance in older people, which could potentially reduce the risk of a fall. This will be achieved by creating a series of dynamic exercises using the RIB training device that may enable older adults to reduce their risk of falls and maintain a recreationally active lifestyle.

Chapter Two: Literature Review

2.1 Preface

Accidental falls are a significant global public health issue among older people, particularly regarding cost and long-term consequences (Davis et al., 2016). New Zealand's Accident Compensation Corporation (Accident Compensation Corporation, 2021) released data in 2021, which showed that active falls and fall-related injuries cost over $787 million a year. Approximately 30% of individuals falling are over 65 years old, and ≈40% of these people are 85 years or older (Accident Compensation Corporation, 2021). In addition, considering the increasing numbers in this older age demographic and the increased risk of falls with age, it is acknowledged that theoretical and clinical driven investigations in falls prevention are becoming increasingly important (Hadjistavropoulos et al., 2011). Research has demonstrated that approximately one in three community-dwelling people aged 65 years or over suffer one fall each year, resulting in serious injuries that can lead to increased morbidity, permanent hospitalisation and decreased quality of life (Oliveira et al., 2020). The risk and consequences of falling escalate in line with an individual's identified risk factors. Appeadu and Bordoni (2022) identified numerous risk factors that precipitate falls. These include, but are not restricted to, poor medical history, impairment in balance, reduced muscle strength, reduced vision, and polypharmacy, along with walking gait difficulty, depression, cognitive difficulties and long-term degenerative diseases. Thomas et al. (2019) showed that a decline in physical performance and cognitive capabilities with increasing age causes progressive muscle strength, coordination, and balance impairment. With age, the decline in physical performance and cognitive abilities causes muscle strength, coordination, and balance impairment, exposing people to a higher risk of falls and an increased fear of falling. The impact of a fall on an older individual can be a life-changing event with ongoing consequences to the physiological and psychosocial aspects of an individual's life. Martins et al. (2018) identified that falls could increase social isolation. Thus, due to one fall, there may be a decrease in confidence and restriction on participation in physical activity, which leads to functional decline and ultimately a greater risk of more falls. Reducing serious falls in an ageing community has potential financial, physiological, psychological and social benefits. This literature review will investigate the impact of falls, strategies used to prevent falls, and the potential of using stability training for older adults to prevent that initial fall, which can prompt a cycle of decline.

2.2 Physiology of Falls

Maintaining balance requires a delicate relationship between afferent sensory inputs and efferent (motor neuron) systems. The afferent system includes vestibular, visual and somatosensory inputs. In contrast, the efferent system maintains a postural balance as it generates effective postural corrections in response to the body's movement (Horlings et al., 2008). Deficiencies in either the afferent or efferent control systems can cause proprioceptive loss and impaired balance control, resulting in a fall—however, Horlings et al. (2008) concluded that whilst both efferent and afferent systems are vital in reducing the risk of a fall, issues within the efferent system seems to represent a more significant risk factor due to increased patterns of muscle weakness and loss of balance. The efferent sensory input receptors are neurons (nerve fibres) responsible for carrying signals from the brain and the peripheral nervous system to initiate an action. The peripheral nervous system controls the voluntary movement of skeletal muscles and the autonomic efferent division, which regulates body responses. Evidence from cross-sectional studies from Bloem et al. (2001) and Adkin et al. (2003), highlighted the importance of the efferent response systems on their observations of falls and postural instability in patients with age-related spinal deficits. Their research identifies increased lower limb muscle weakness as a vital risk factor in falls. The relationship between lower limb muscle weakness and the risk of injurious fall was further highlighted in a study by Aartolahti et al. (2020), in which the lower limb strength loss rate was quantified between 2.5-4% per year after 75 years. A reduction in lower limb strength also decreases muscle mass and Type II muscle fibres. Gschwind et al. (2013) stated that the decrease in Type II muscle fibres causes a decline in muscle power, otherwise known as age-related sarcopenia. Age-related sarcopenia has a detrimental effect on the aged population because reactive muscle power in the lower limbs is an essential prerequisite for reactive postural balance in response to external perturbations.

A recent review from the World Health Organisation (WHO) (2021) estimated that ≈37.3 million falls occur yearly that are severe enough to require medical attention. These figures demonstrate the need for other preventative strategies in falls prevention. In a Cochrane review, Sherrington et al. (2020) reported that results from over 108 trials estimated that falls were reduced by 34% when engaged in training programmes that challenged balance, strength, resistance and functional exercise. Sherrington et al. (2020) suggested that programmes that challenge balance need to be a minimum of 12 weeks for long-term benefits of potentially reducing the risk of a fall. Sherrington et al. (2020) also recommended that high dosage exercise or training sessions consisting of three or more hours per week that specifically targeted balance and function should be adopted. High dosage exercise to reduce the risk of falls also supported the idea that it may benefit the brain centres that support executive control. Langhammer et al. (2018) suggested that executive control allows the cognitive pathways to operate smoothly in performing activities of daily living. With increased age, people over 65 suffer progressive vision loss, vestibular sense, proprioception, muscle strength and reaction time (Sturnieks et al., 2008). The opportunity to reverse ageing declines as the integration of sensory information is limited. The chance to improve proprioception may come with implementing strength and balance programs that support improvements in the efferent nervous system. These improvements would make the body more responsive to its position relative to its surroundings, thus enabling appropriate motor responses to control body movement.

2.2.1 Static versus Dynamic Balance

The literature shows that people over 65 years of age are often at risk of falling in more dynamic instead of static scenarios. Static balance is defined as maintaining the centre of mass vertically over the support base with minimal movement. Dynamic balance is defined as maintaining an upright body position during locomotion (Stack & Sims, 2009). A common static measure used in analysing falls risk is posturography. Posturography is a technique used to measure bodily oscillations from a Centre Of Pressure (COP). The authors de Negreiros Cabral et al. (2020) found that static posturography does not improve predictions of fall risk factors against other functional measurements. The research also stated that falls usually occur under dynamic conditions, especially when performing activities of daily living. This evidence suggests that static measurement tools have limited use in falls risk prediction, indeed, it advocates that falls testing and training would benefit from moving in a more dynamic direction. It is not uncommon for interventions to use dynamic scenarios when improving static balance. Hagedorn and Holm (2010) found significant improvements in static equilibrium when training on unstable surfaces with eyes open and shut. Thus, the dynamic integration exercise benefits both static and dynamic balance. Tinetti et al. (1988) and Berg et al. (1997) have stated that many older people fall during dynamic movements of habitual daily activities, like walking or rising from a chair or a bed. This research concludes that since falls are dynamic in nature, research is better focused on dynamic measures. Furthermore, improvements in dynamic balance are associated with the reduction of falls.
In a study by Coelho-Junior et al. (2018), the physical capabilities of older dependent community-dwelling women were measured using the Timed Up and Go (TUG) Test because the test has been widely used in clinical practice to measure the biological function and mobility in older adults. From this study, Pearson's correlation results indicated that TUG performance was significantly associated with lower limb strength (i.e. sit-to-stand), balance (i.e. one leg stand), power (i.e. countermovement jump) and mobility (i.e. usual and or maximal walking speeds). The statistical analysis showed that in the sample of 468 community-dwelling women, lower limb muscle strength (sit-to-stand) demonstrated the strongest correlation between the variables and TUG (0.53). While this study did not directly assess the risk of falls, similar measures are often used in falls prevention studies.

Hagedorn and Holm (2010) and Grabiner et al. (2012) suggest that dynamic balance training on unstable surfaces, eyes open and shut does improve functional balance and mobility in older adults, therefore contributing to a significant difference in postural sway- a precursor to a fall. Rogers et al. (2001) defined posture as the controlled detection of disturbances to the centre of gravity and the initiation responses to return the body to a stable position. In a subsequent study, Rogers et al. (2001) stated that advanced age is associated with increased postural sway. Individuals who have sustained multiple falls demonstrate more postural sway than age-matched peers. The commonly used measure of postural sway is the Romberg Test, a useful test to determine the integrity of the dorsal column pathway of the brain and spinal cord, which controls proprioception. Using a Romberg Test, Grabiner et al. (2012), found that a fall-specific training programme (i.e. forward-directed stepping response to backwards-directed postural perturbations) can reduce the number of falls ($p<0.001$; odds ratio =0.13), which improved after task-specific training protocol. In a similar research paper, Gschwind et al. (2013) recommended using the Romberg Test as a balance assessment tool to measure static steady-state balance in a study to improve balance strength/power and psychosocial health in older adults.

The Gschwind et al. (2013) study reflected those of Hagedorn and Holm (2010) by looking at balance from a dynamic standpoint. Gschwind et al. (2013) looked at the effects of a fall prevention programme investigating intrinsic fall risk factors (i.e. balance, strength and power) training that aligns with four balance domains. The domains were measured using the Romberg, Functional Reach Test, Timed Up and Go Test and the Stair Climb Power Test. This study showed that a multiple component group exercise and home-based exercise program reduced the rate of falls and fall risk (rate ratio 0.71, 95% confidence (CI) in people over the age of 65). The concept of balance existing in four domains is supported by Shumway-Cook et al. (1997). They identified balance as static, dynamic steady-state (i.e. maintain a steady position in sitting, standing and walking), proactive (i.e. anticipation of a predicted disturbance), and reactive (i.e. compensation of a disturbance). It might be considered that previous literature has combined concepts of reactive, proactive and dynamic balance; however, the distinctions are important to consider in any review of the literature. One study looking at reactive balance has suggested that leg dominance may play a role in the reactive moment when a fall can occur; Young et al. (2013) looked at leg preferences associated with stepping responses in older adults, mainly looking at recovery strategies. The study investigated how leg preference following a waist pull perturbation affected balance recovery strategies. The results discussed that older adults used a cross over step and cross behind approach, which was determined by the perturbation effect. Asymmetrical trends in stepping responses were also discussed by Young et al. (2013) indicating a previously unrecognised precipitating factor for falls; despite this investigation, the physiological mechanisms of leg preference in maintaining balance remain to be determined (Young et al., 2013). Granata and Lockhart (2008) indicated that asymmetries in dynamic stability might be associated with fall-risk status in older adults and represent a previously unrecognised fall risk factor. Whilst there is an understanding that previous researchers have observed asymmetries in dynamic balance stability, there is a gap in the literature regarding the importance of leg dominance in falls prevention.

In a systematic review with meta-analysis of diagnostic balance tests assessing falls in older adults, Kozinc et al. (2020), stated that a systematic assessment of fall risk is crucial to reduce the incidence of falls in older people. The study identified that while tests that measure body sway characteristics such as the Romberg are essential, other screening tools to predict falls must be explored. In line with Gschwind et al. (2013), the review by Kozinc et al. (2020), valued the importance of measuring the four balance domains and discussed further tests commonly used in assessing the function of older adults, namely, the TUG and Functional Reach Test (FRT).

The TUG has previously been introduced. The FRT is a single-task dynamic test used to assess the anteroposterior stability in which the maximal distance one can reach forward beyond arm's length while maintaining a fixed base of support in a standing position (Duncan et al., 1990). The review by Kozinc et al. (2020) showed that the TUG reported low sensitivity (30%) and high specificity (74%).

Similarly, a Functional Reach Test reported low sensitivity of 30 % and high specificity of 92%. The inconsistency of these measures suggests that these diagnostic tests should not be used as individual predictors of falls but instead as a collective testing battery. Hageman et al. (1995) suggested that functional reach often determines dynamic balance. However, as FRT decreases with age independently of dynamic balance, using this tool alone potentially skew's data that only rely on one measure. Collectively this research suggests that any strength and balance program should incorporate multiple measures of dynamic balance to reduce the risk of falling.

2.3 Social & Psychological Effects of Falls

Tinetti et al. (1990) completed a research paper based on Fear of Falling (FOF) and low self-efficacy in elderly persons. They described FOF as "an ongoing concern about falling that ultimately limits the performance of daily activities in an individual's life" (Tinetti et al. 1990, p.243). The concept of Fear of Falling has appeared in other papers; Cumming et al. (2000), defined FOF as a general concept that described low fall-related efficacy (low confidence in avoiding falls) and being afraid of falling. Whilst participants in a study by Tennstedt et al. (1998) indicated they did not describe themselves as being "afraid of falling" but rather were "worried" about falling. Fear of Falling is a human construct that researchers have attempted to measure. The most commonly used tool is the Falls Efficacy Scale (FES), designed by Tinetti et al. (1990). The scale provides a measure of FOF by looking at fall-related self-efficacy, or a person's ability to avoid falling while performing activities of daily living (ADL) (e.g., cleaning the house and getting dressed).

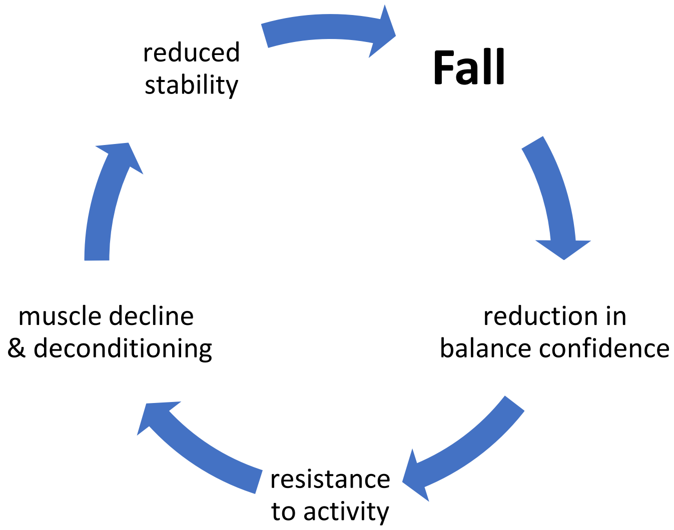
In a study by Choi (2016), it was hypothesised that there is an important relationship between falls and activities of daily living (ADL). In the study, six activities of daily living were measured: bathing, eating, dressing, walking across a room, getting in and out of bed, and toileting (Choi, 2016). A key finding from this study was that individuals who fell multiple times in the prior two years experienced a 17% higher risk of falls when attempting a new ADL compared to individuals with no falls in the previous two years. This risk of falls associated with activities of daily living aligns with a recommendation from the Multiple Sclerosis Falls Prevention Research. Cattaneo et al. (2014), suggested that people tend to fall during activities of daily living and recreation that involve transitions between body positions during walking and turning. The most common transitions that prompted falls were turning, walking, and stair climbing.

The FES is a 10-question scale that asks the individual questions about ADL (e.g. how confident are you performing daily grooming tasks?). Subjects rate each question with a number from 1-10 as to how well they can perform the task. Many authors have used this scale to quantify FOF or fall-related efficacy. It has been used most commonly with older people in a community-dwelling setting, often to assess the safety of their daily living environment. In a study by Liu et al. (2021), the independent effects of completing daily tasks were measured using the FES to assess the FOF in older adults. Using the FES, Liu et al. (2021) was able to identify that 20-60% of community-dwelling older adults have a FOF, and 20-55% report limited daily activities due to the fear of falling. This longitudinal study also identified that 30-50% of independently living older adults fear falling whether or not they have had a previous fall. The study questioned participants using telephone interviews and found the relationship between previous falls, fear of falling, and limitation of daily activities, which can be used as a prediction FOF. FOF has the potential to encourage community-dwelling older people to lead a more sedentary lifestyle. According to studies by both Scheffer et al. (2008) and Lee et al. (2018), the FOF in older individuals was anxiety associated, which encouraged the individuals to avoid any form of daily activity or social interaction. The fear of falling and falling was shown to have adverse effects on the mental capability in people over the age of 65 years of age. Supporting the findings of Scheffer et al. (2008), Lee et al. (2018) and Jankovic (2015) also stated that FOF has developed as a result of a fall from an organic cause. The subjects reported a loss of balance during a freezing phenomenon, labelled as a motor block in gait motion. These dramatic changes to an individual's lifestyle due to the fear of falling can have a detrimental effect physically or psychologically and socially. The relationship between motor block gait motion and balance training is yet to be explored. Still, it could be suggested that dynamic training to enhance daily activity may reduce motor gait block.

Fear of Falls (FOF) can lead to a more sedentary and reclused lifestyle. Alghwiri and Whitney (2011) found that a sedentary lifestyle with subsequent deconditioning creates a decremental cascade leading to frailty, social seclusion and an increased risk of future falls. In similar research, Curl et al. (2020), stated that the increased risk of falls dramatically increases social avoidance and reduced confidence in the individual's ability to complete simple tasks such as going outdoors. A 6-month longitudinal study of older community-dwelling adults by Hadjistavropoulos et al. (2011) also identified a negative spiral towards frailty, decreased independence and ultimately injury. Hadjistavropoulos et al. (2011) looked at mechanisms that described the cycle of avoidance (see Figure 1). The process consists of five steps: a fall, balance confidence (efficacy), resistance to activity, muscle decline/deconditioning, and reduced stability. Thus, the behavioural component of FOF and falls efficacy can lead to a repetitive cycle of avoidance which has further social impacts. An earlier study by Legters (2002), stated that between 25-33% of fearful individuals avoid activity because of fear of falling.

Figure 1.

Fear Avoidance Cycle



Note. Adapted from Hadjistavropoulos et al. (2011)

Using a modified version of Cohen and Wills (1985) theoretical model on general health, Bu et al. (2020), looked at two significant factors that could influence the risk of falling in older individuals such as loneliness and social isolation. Whilst loneliness and social isolation are two conceptually different measures, they both had equally adverse effects on individuals. In this context, both measures showed that living alone and having minimal social contact was associated with a higher risk of falling. Due to the loss of social contact with children, relatives and friends, simple everyday things such as hazards in the home environment are missed, and medicinal compliance was not upheld, adding to the already identified factors associated with an increased risk of falls for older community-dwelling adults. Scheffer et al. (2008) believed that knowing these risk factors in FOF could help develop multidimensional strategies to decrease FOF and improve quality of life. Whilst the only identified modifiable risk factor of FOF is a previous fall, the potential to educate elderly persons in preventing falls could significantly reduce the risk of fall and fall-related injuries. A study by Nicholson Jr (2005), looked at the relationship between injurious falls and social isolation, finding that the association between the two was so strong that the evidence linking the two is congruent with the epidemiological evidence linking smoking and health together. A few critical finds from the research showed that overall, socially isolated individuals have two-four times the risk of all-cause mortality compared with those who have more ties with friends, relatives and community. More evidence from the Nicholson Jr (2005) study, suggested that socially isolated individuals were two and a half times more likely to have mortality related to the heart (Relative Risk= 2.43). This study showed a significant correlation between the number of injurious falls and social isolation (Pearson's correlation coefficient was 0.40, $p<0.05$). Whilst fear of falls does increase social isolation and morbidity in individuals, coupled with reducing activity levels of individuals, the importance of implementing strength and balance programs that cater to the physiological, cognitive and social is of most importance in reducing the risk of falls in older adult's people.

2.3 Falls Intervention Programmes

In the late 1990s, the OEP, also known as the Otago Falls Prevention Programme, was developed and tested at the Otago Medical School. It is now the most widespread fall prevention programme globally and is implemented across New Zealand by the Accident Compensation Corporation (ACC) (Campbell, 2003). The OEP was explicitly designed to prevent falls in people over 65. It consists of leg muscle strengthening and balance retraining exercises specifically designed for fall prevention. It is individually prescribed and delivered at home by trained instructors. The initial studies which informed the creation of the OEP were described in four controlled OEP trials by (Campbell et al., 1999). Over 1000 men and women aged 65-97 were invited to participate in the OEP research study. In the first trial, the exercise program successfully reduced the risk of falling by 32% and the risk of a fall injury by 39% in one year. Combining the results from all four trials, Campbell et al. (1999), highlighted that the programme prevented most falls and injuries in those aged 80 years who had fallen in the previous year. This figure has not changed markedly since the inception of the OEP. In a recently updated Cochrane Systematic Review, Sherrington et al. (2020) stated that of exercise interventions to prevent falls in community-dwelling people aged 60 and over, 108 studies showed that exercise could reduce falls by up to 34%. In a recent meta-analysis study by Chiu et al. (2021), the effects of the OEP on actual perceived balance in older adults produced three points of interest. The first was the use of the OEP as a multimodal programme and the effects the multimodal programme had on static, dynamic and perceived balance. The analysis suggested that sessions of > 30 minutes were more effective in improving static ($p=0.003$) and dynamic ($p=0.001$) and perceived balance ($p=0.008$). Furthermore, evidence suggested that a multi-component/ modal exercise programme focusing on static, dynamic, proactive and perceived balance can effectively improve balance, mobility and physical endurance. The second point of interest in the Chiu et al. (2021) study identified that the more an exercise caters to a specific motor task, the greater the carryover from that exercise to performing ADL. Finally, the meta-analysis by Chiu et al. (2021) also showed that the improvement in cognition was related to the improvements in balance networks using the OEP due to the belief that they may share a common neuronal pathway.

Research from Moreland et al. (2004), found that averting muscle mass reduction and improving balance control could reduce the risk of falling; thus, leg strength training is crucial to prevent falls. Though including static and dynamic training as part of the OEP could reduce the decline in leg strength by 2.5-4% per year after the age of 75 years of age. An additional meta-analysis by Papalia et al. (2020) showed that in patients who performed static and dynamic balance training, there was a statistically significant decrease in both the number of falls and fallers (respectively $p=0.008$ and $p = 0.02$). The OEP has proved to be an effective fall prevention strategy that benefits balance function and lessens the FOF, however, its prescription has not kept pace with research findings. A strong recommendation from the meta-analysis of Papalia et al. (2020) was the promotion of new innovative strategies to prevent falls in older people. An earlier systematic review by Sherrington et al. (2016) also strongly recommended that exercises must provide a moderate or high-challenge to balance to be effective in falls prevention. High-challenge balance exercises can be achieved through the movement of the centre of gravity. The ability to transfer the body's position whilst standing, reaching and transferring body weight from one leg was considered crucial in building confidence and reducing FOF.

In an additional systematic review, this time by Martins et al. (2018), a range of studies examined whether a modified OEP improved balance in older people. Two studies of note looked at modified formats of the OEP, including an augmented reality by Yoo et al. (2013) and the use of a DVD in a rural community by Davis et al. (2016). Yoo et al. (2013) analysed the effect of augmented reality-based OEP on balance, gait and falls efficacy in older adults compared with the original OEP. After the intervention, an augmented reality-based OEP revealed significant improvements in balance ($p<0.001$) and falls efficacy ($p<0.05$). In the study by Davis et al. (2016) an alternative method of delivering the OEP using an interactive OEP DVD was investigated. The participants were rural community-dwelling older adults who received regular phone calls and one visit from a physiotherapist. After six months of the intervention of this study, the results had significantly reduced the risk of falls compared to a control group (no intervention) ($p=0.007$). Using evidence from these two studies, Martins et al. (2018) suggested a need to investigate modified OEP exercise programmes instead of investigating the different exercise programmes to prevent falls.

2.4 Strategies & Training

One modified version of a fall prevention programme was conducted by Oliveira et al. (2020) looking at the effects of a yoga-based exercise falls prevention programme using Successful AGEing (SAGE) to support the fall prevention movement. The SAGE yoga exercise programme emphasises standing yoga postures that challenge balance to improve leg strength and stability. The participants were invited to partake in 80 one-hour classes weekly over 12 months. The control and intervention groups were randomly selected for SAGE Yoga and relaxation yoga. The participants were instructed to complete 20 minutes of unsupervised yoga based on the class content twice a week. This duration and frequency are in accordance with recommendations from Sherrington et al. (2016) and the OEP falls prevention guidelines, which state that exercise should be ongoing and of a high dose to prevent falls. The growing availability of yoga studios worldwide and access to online classes provide a broader delivery and implementation of balance exercises. This research also aligns with a systematic review by Martins et al. (2018) that looks at whether a modified OEP would improve balance in older people. The findings discussed the increased need for tailored exercise programmes that resulted in the development of other exercise approaches such as group exercise and modified formats of the OEP. In a study by Granacher et al. (2012), it is suggested that implementing balance training as an intervention slows the physiological decline of balance in the elderly. It is also suggested by Dunsky (2019) that balance training can aid the performance of the neuromuscular control system to reduce the further physiological decline in older individuals.

Furthermore, Zech et al. (2010) suggested that when performing static and dynamic training, programmes should use stability training devices to reduce the base of support and visual information (eyes open, eyes close), attempting to stimulate natural life perturbations. Wobble boards, wobble cushions and foam were among a few suggested training aids to stimulate real-life changes in balance. In a study by Nalcakan and Yeliz (2020), it was suggested that the stability training devices could be effective in not only dynamic balance but in developing static postural sway, which is one of the critical movements when using a stability training device, thus increasing strength within the lower leg limbs. It was also suggested that balance training promotes proprioception and neuromuscular control changes. The mechanism which may improve static, dynamic, proactive and reactive balance likely lie in the coordination of the afferent and efferent systems. Since ageing declines the afferent systems, training the efferent systems in order to maintain functionality and prevent a fall is a worthwhile pursuit (Horlings et al., 2008).
Zech et al. (2010) suggested that proprioception is an essential component of joint function because it provides extensive afferent information on the joints' internal environment, such as tension in ligaments, intra-articular pressure, mechanical stress, and joint velocity. Thus, training on stable and unstable surfaces with different equipment can develop dynamic balance ability, potentially reducing the risk of a fall. Using a stability training device requires rapid reaction in both proprioception and neuromuscular control, requiring individuals to make rapid, controlled changes in posture. Whilst the mechanisms around falls prevention in an ageing population remain unclear, the opportunity to reduce fear of falling and first falls seem valuable, and support from the literature can be found for implementing innovative adaptations of the OEP.

This concludes the review of the literature. The next chapter will describe the methods used to implement the stability training used in this study.

Chapter Three: Method

3.1 Experimental Design

The Eastern Institute of Technology Research Ethics & Approvals Committee approved this research in April 2021 (Appendix A). The study was a parallel-group design trial with an experimental and control group. The experimental group completed a series of measurement tests pre and post a four-week training intervention. The control group completed the same pre and post-tests but performed no training during the intervening test period.

All experimental pre and post-tests were performed under laboratory conditions (and adjoining facilities where appropriate) at the Eastern Institute of Technology, Pettigrew Green Arena. On the participant's initial visit, they completed a Falls Efficacy Scale, a demographic data collection, including height, weight, and blood pressure. Participants used the Tanita BC-541 Inner Scan Body Composition Scales (Tokyo, Japan) for weight measurement, a Wedderburn (Southampton, UK) stadiometer for height measurement and a SunTech Tango M2 (Morrisville, NC, USA) to measure blood pressure.

3.1.1 Participants

Initially, 24 participants volunteered for this research; however, due to issues with the New Zealand nationwide Covid-19 lockdown, only 14 completed the study and were included in the data analyses. Fourteen healthy participants (males n= 2), females n=12) were included in this study. Participants were informed of the study requirements, provided their written informed consent (Appendix B), and completed a Pre-Exercise Screening forms (Appendix C) to ensure they were injury-free before commencing testing and training. Participants were asked to complete a Falls Efficacy Questionnaire for qualitative purposes but also to assess any potential fears of falling. Participants who had notable medical conditions were asked to seek doctors' clearance before commencing the study. The participants were randomly divided into control (n=7) and experimental (n=7) groups. The experimental group participants (n=7) who completed all testing and training mean (± SD) physical characteristics of age, weight, and height were males (n=2) 75.5 ± 3.5 years, 78.9 ± 7.9kg, 167.8 ± 0.4 cm, and female 77 ± 3.4 years, 70.9 ± 9.7 kg and 160.2 ± 4.6 cm. The control group participants females (n=7) 64.3 ± 4.7 years, 68.0 ± 6.2 kg and 161.86 ± 4.4 cm. The demographics of each group are shown in Table 1.

Participants were all non-sedentary people who lived semi-active lives. Hours of weekly exercise ranged from 2-7 hours. The participants were asked to maintain their habitual exercise routines but refrain from further organised training. All training sessions were held at the same time.

Table 1.

Participant Demographics (mean ± SD) for control and intervention groups

Characteristic	Control Group		Experimental Group	
	Mean	SD	Mean	SD
Age (yrs.)	64.3	4.7	77.0	3
Weight (kgs)	68.0	6.2	73.2	8.7
Height (cm)	161.9	4.4	162.4	4.9

3.1.2 Training

Training for the experimental group involved a warm-up and then seven dynamic balance exercises based on movements from the OEP adapted to be used with a RIB stability training device.
The board's dimensions are as follows, length 89 cm, width 32 cm, height 15 cm and weight 3.5 kgs. The RIB is made out of layered ply and finished with a cork underside to assist stability and grip. The RIB also had fabricated grove cut-outs whereby the option of a resistance band could be added if necessary.

Figure 2.

RIB used in the stability training exercises

Group exercise sessions were organised and conducted twice a week for 50 minutes per session for four weeks. See section 3.3.1 for a detailed explanation of the exercises chosen. An unforeseen extension to the training program was initiated due to a nationwide Covid-19 lockdown during the training intervention, which involved a further two weeks of remote exercise sessions facilitated by video conferencing technology. The exercises remained similar; however, they were conducted by participants isolated in their own homes. At this time, a training sheet was provided to guide participants through each exercise to assist with technological complications (a copy of the sheet is provided in Appendix D).

3.2 Data Collection

The data collected was gathered through methods of exercise testing in accordance with the OEP (Campbell, 2003) and the Falls Efficacy Scale (Tinetti et al., 1990). Test data was collected at the Pettigrew Green Arena Sport Science Laboratory following research protocols and institutional Covid-19 Guidelines.
Pre and Post-intervention data collection followed a similar order. Each assessment measure is described as follows.

3.2.1 Exercise Tests

The Romberg Test

The participant stands with feet together on a flat surface with arms down by their side. The tester stands close by and reassures participants should they fall. Participants then closed their eyes as the tester started the stopwatch. The tester looks for significant postural sway, and when this occurs, the stopwatch stops timing. The participant then opens their eyes, and the results are recorded. The test is repeated three times, and the best time is recorded.

The Functional Reach Test

Participants started behind a measured tape line beside a whiteboard, where a one-metre ruler was attached to the wall. Participants were then instructed to lean as far forward as possible. The participants were instructed to make a fist with their hand and stretch their arm out as far as possible without their heels lifting off the ground and arm contacting the whiteboard. A measurement length was taken from the middle knuckle and recorded. Participants made three attempts at the test, with 30 seconds recovery between each trial.

The Sit to Stand and Timed Up and Go Test

The Sit to Stand and Timed Up and Go Tests were amalgamated and completed as one test.
Participants began the test in a seated position. On a countdown given by the tester, the participant stood and walked to a cone placed 3 metres away, then returned to their seat and sat back down. The test was measured using a stopwatch. The first part of the test, which was the Sit to Stand, was measured in the first split, where the participant went from being seated to fully erect. The second part of the test was the Timed Up and Go, where the second split was measured when the participant took their first step after becoming fully erect from the Sit to Stand test. The Timed Up and Go was terminated when they returned to a seated position.

The Force Frame Knee Extension L & R Test

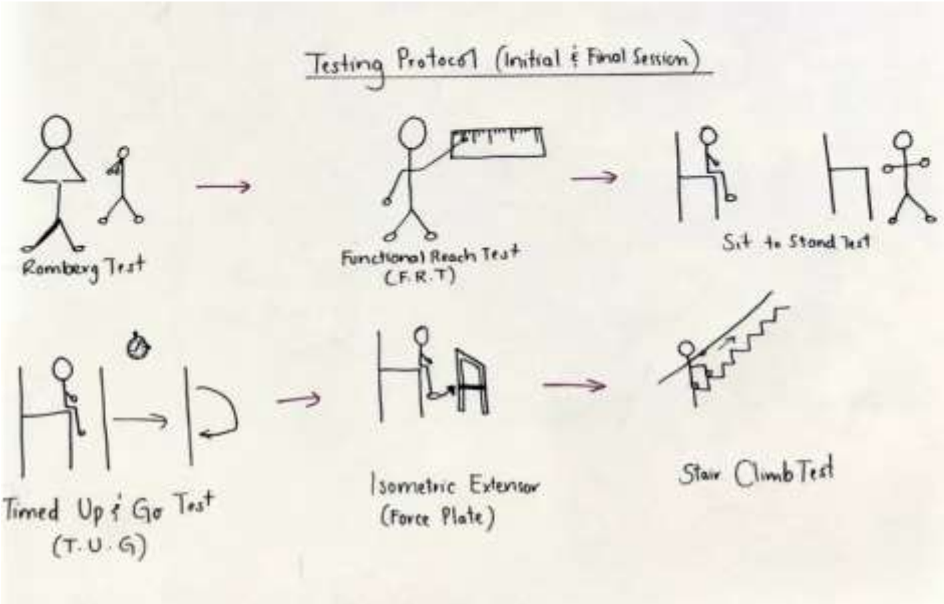
Knee extension strength was measured using a Vald Performance Force Frame (Albion, Australia). Participants were required to sit on a chair with their feet flat on the floor. Each leg was measured separately by participants exerting maximum force against a shin pad attached to the force frame. Participants exerted maximal force for a period of 3 seconds. Participants were required to repeat this test 3 times with 1-minute passive rest between trials. The highest measures were used for data analysis. Data was recorded via blue tooth to the Vald Performance App via a smartphone (iPhone 8; California, USA).

The Timed Stair Climb Test

Participants were required to climb a set of 24 stairs as fast as possible, each step measured 0.4m in height and 0.4m in depth. Participants were required to start 0.3m from the base of the first stair. Participants were timed as they walked up to one flight of stairs, around a cone at the top and back down. Participants were allowed to use the handrail if required. Participants were only required to do this trial once. Therefore, the total climb was 9.6m, followed by 9.6m of descent and a total horizontal distance travelled of 19.8m.

Figure 3.

Pre & Post Testing Protocols



3.3 Training Programme

The RIB stability training for the experimental group involved a warm-up of two to three minutes consisting of general rocking side to side on the board, performing stretches (e.g., rocking side bend stretches) and breathing techniques (e.g. breathing in and out into a rocking tempo). Once the training group was reacquainted with the board and its unstable nature, the dynamic warm-up stretches began, e.g. chin tucks. Following the warm-up that was adapted to mimic the exercises in the OEP, the dynamic balance training began. Seven dynamic balance exercises from the OEP were adapted to be used in conjunction with the RIB stability training device (e.g. seated knee extensions and side leg raise). All participants were offered the use of a resistance band as an additional exercise extension. Bands were included for all participants after a total of three RIB sessions were completed to ensure increased intensity. Once all exercises were complete, a cool-down period of 2-3 mins took place, with a final exercise at the end of balancing on boards with eyes closed.

The group training took place at Riversdale Lifestyle Village in Taradale, Napier, in the village's Community Centre Hall. The Hall was a fully carpeted hexagon shaped room where the participants performed group exercises in a semi-circle. All participants had full access to a RIB, resistance band and a chair (if required). During each session, technique and form were regularly checked, and feedback was given to participants. Group exercise sessions were conducted twice a week for 50 minutes per session for four weeks.
After all sessions, a general discussion was had with participants.

Figure 4.

Community Hall at Riversdale

An unforeseen two-week (four-session) extension to the training programme was initiated due to a nationwide Covid lockdown. This involved remote exercise sessions facilitated by video conferencing technology. The exercises remained similar; however, they were conducted by participants isolated in their own homes. To assist with technological complications, a training sheet was provided guiding participants through each exercise. A copy of the exercise sheet that corresponds to the training exercises below is provided in the appendices (Appendix D)

3.3.1 Training Exercises

Warm-Up

The strength and balance session began with a warm-up lasting 5 minutes consisting of continual rocking and upper body stretches.

1. Head Rotations- Rock on RIB horizontally with hands-on-hips.
   Rotating the head from left to right, changing direction every two rocks.

2. Head & Trunk Rotations- Rock on RIB horizontally with hands-on-hips.
   Rotating the head and trunk from left to right, changing direction every two rocks.

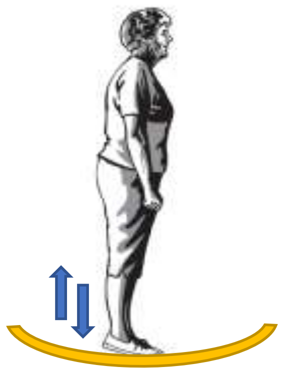
3. Chin Tucks- Rock on RIB horizontally with two fingers on the chin.
   Compressing neck every two rocks with two rocks rest in between.

4. Back Extensions- Rock on RIB horizontally with hands on the lower back.
   Back extended and held for four rocks. Participants resume normal rocking positions for a rest period of four rocks.

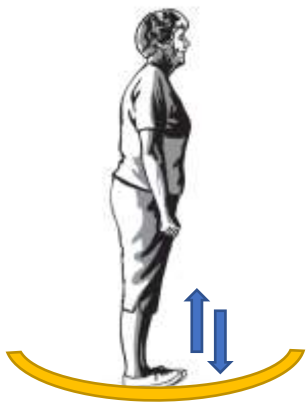
Intervention Exercises

1. Plantar & Dorsi Flexion Roll- Participants seated with RIB flipped upside down. Participant places feet shoulder-width apart on top of the RIB. With shoulders back and abdominals engaged, participants rock the board back and forth. Efforts lasted five minutes with intermittent rests of 30 seconds in between each 1-minute effort.

2. Calf Raises- Participants stand on board vertically with a chair placed directly in front if needed. Participants placed hands on hips and rise onto toes and back down for ten repetitions for five minutes with 30 seconds rest in between.



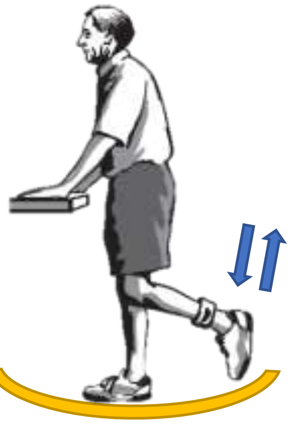
3. Heel Raises- Participants stand on board vertically with a chair placed directly in front if needed. Participants placed hands on hips and lifted toes up and back down for ten repetitions for five minutes with 30 seconds rest in between.



4. An extension of both the Calf Raise and Heel Raise exercises is to turn the board to a vertical position and stand at the rear of the board. This adds another dimension of difficulty to keep the board balanced whilst performing the above exercises.

5. Knee Extension- Participants stand on board vertically with a chair placed to the near side if needed. Participants placed hands on hips from a standing position with their feet off the ground. The is knee is extended out in front for ten repetitions for five minutes with 30 seconds of rest in between.

6. Reverse Knee Extension- Participants stand on board horizontally with a chair placed to the near side if needed. Participants placed hands on hips and, from a standing position with foot off the ground, bring the heel up to touch glutes for ten repetitions for five minutes with 30 seconds rest in between.



7. Hip Adduction- Participants standing on board horizontally with a chair placed to the near side if needed. Participants placed hands on hips and lifted straight leg up and down for ten repetitions for five minutes with 30 seconds rest in between.

NB. An extension of exercises 5,6 & 7 was required for higher capability participants. This involved tying a resistance band around the board as required.

In the remote session's exercises, 1-7 were used via a video sharing platform. Each user was provided with their board, a resistance band, individual notes (see Appendix D) and connected into synchronous sessions twice a week in a similar time frame to that established in the original intervention.

3.4 Data Analysis

The mean effects of the training intervention and their 95% confidence limits were estimated with a custom spreadsheet (Hopkins, 2003) via the unequal-variances t-statistic computed for change scores between pre-tests and post-tests in the two groups. Each subject's change score was expressed as a percentage of the baseline score via analysis of log-transformed values to reduce bias arising from any non-uniformity of error. Meaningful differences were interpreted and reported using Cohens D with effect size thresholds (D) of 0, 0.2, 0.5, and 0.8 for trivial, small, medium and large, respectively, in line with the recommendations and guidelines of Cohen (1988). The spreadsheet also provided the between-group change as a p-value computed from the t-statistic. Significance was set at $p \leq 0.05$ for all measures.

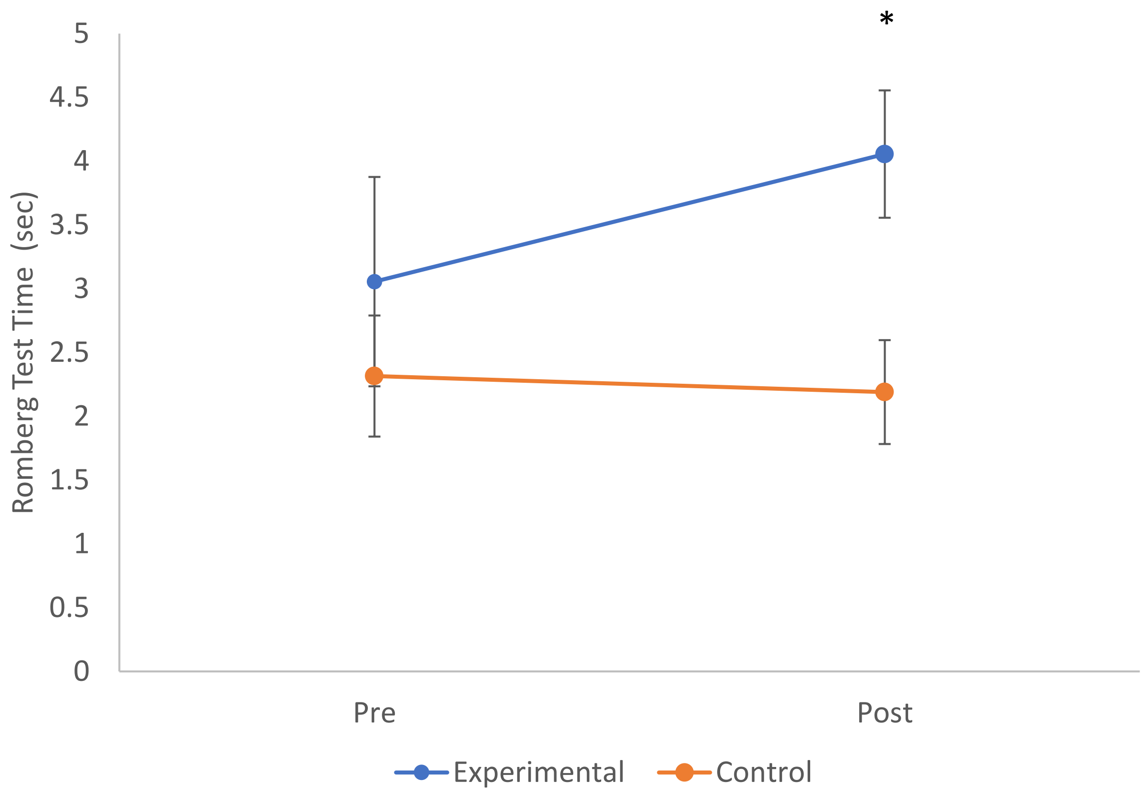
Chapter Four: Results

Between-group comparisons showed a significant difference ($p \leq 0.05$) between the experimental and control group for age but no significant difference for age and height ($p > 0.05$).

As shown in Figure 5, the mean (SD) time for the Romberg Test. There was a significant improvement ($p = 0.023$) in balance time for the experimental group from pre to post-tests and no significant change in the control group. The magnitude of improvement in the experimental group was 36.7% (36.9%), with a large effect size (d) of 1.05.

Figure 5.

Romberg Test comparisons for time (mean ± SD) for the control and experimental groups.



Note. * indicates significant difference at $p < 0.05$ for pre to post-tests.

As shown in Figure 6, the mean ± (SD) time for the Sit to Stand Test. The experimental group improved their sit to stand time by 2.6%, while the control group increased their time to stand by 20.0%. Results showed no significant between-group difference (p=0.18) but a small effect size (d) of 0.45.

Figure 6.

Sit to Stand Test comparisons for time (mean ± SD) for the control and experimental groups.

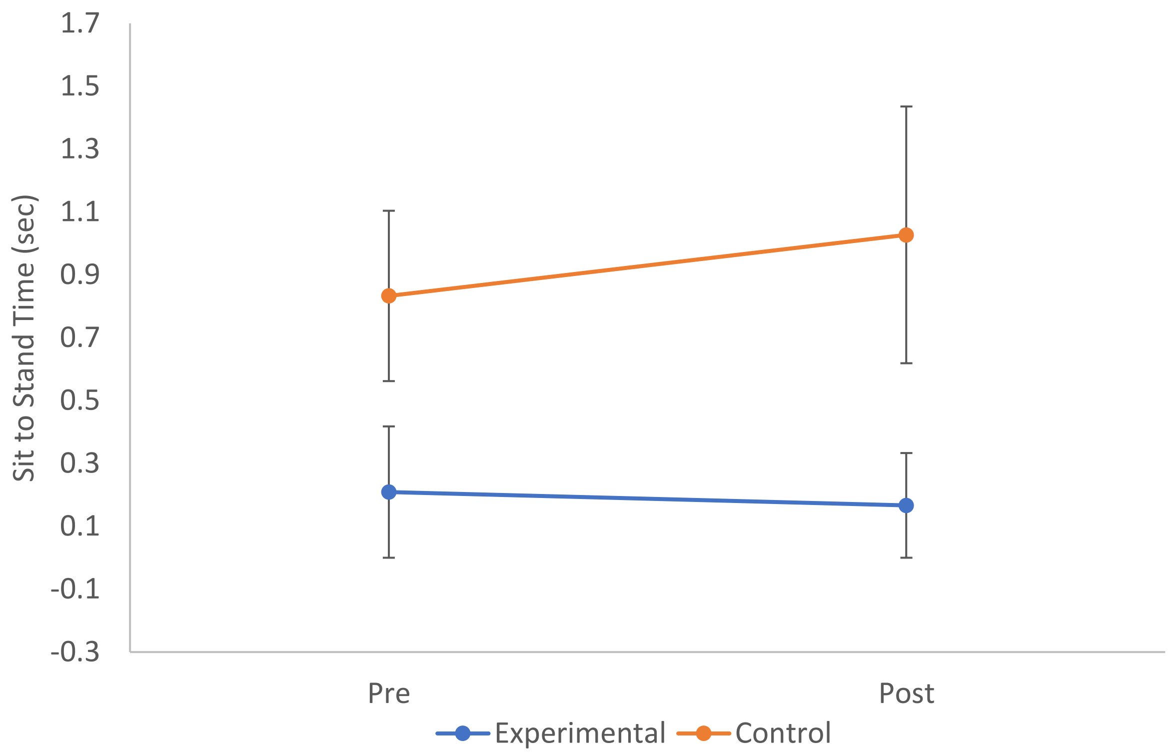
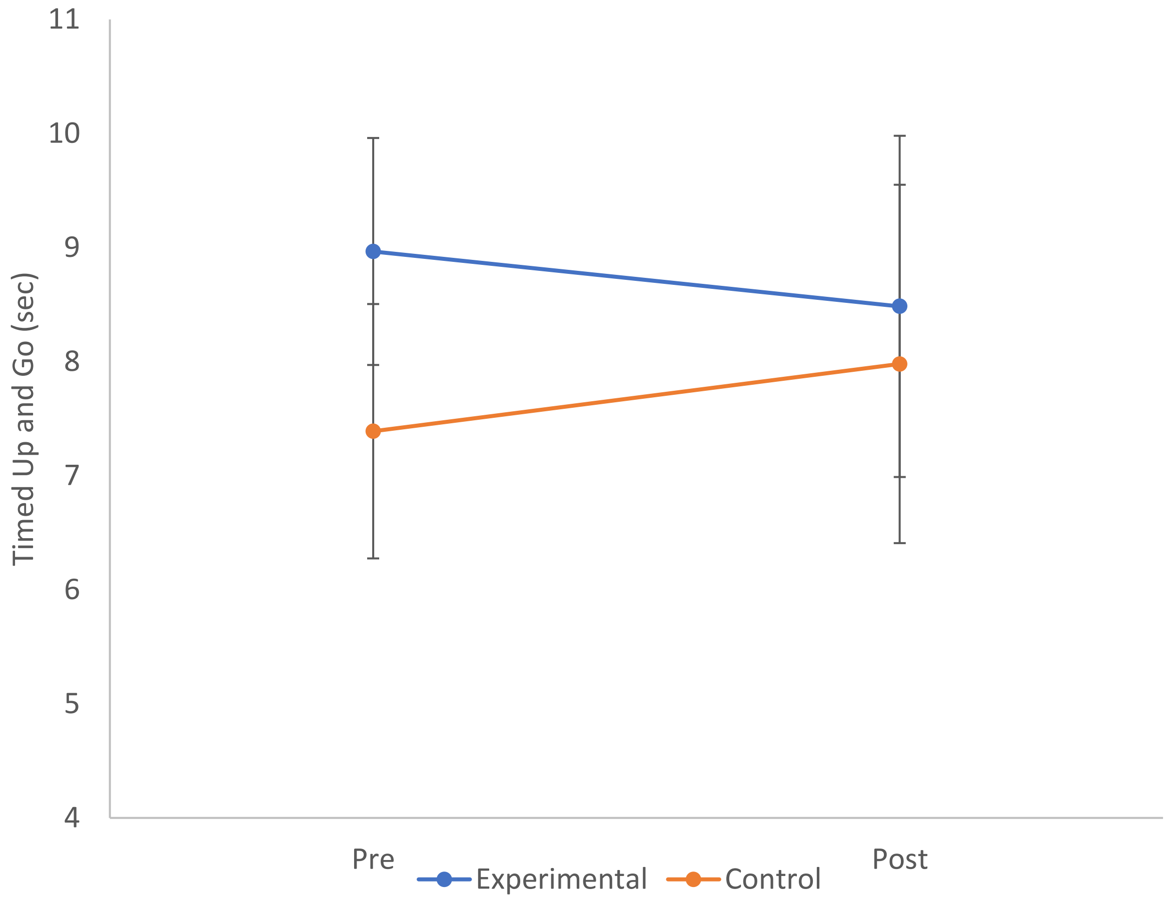


Figure 7 shows the mean (SD) time for the Timed Up and Go Test. There was a significant improvement ($p=0.03$) in time for the experimental group from pre to post-tests from 8.96 secs to 8.48 secs, while the control group performed worse in the post-test, increasing their Timed Up and Go by 7.1 %. A drop in time in this test relates to an increase in speed for the participant getting up and going. The magnitude of improvement in the experimental group was -6.3 (11.6) %, with a moderate effect size (d) of 0.68.

Figure 7.

Timed Up and Go Test comparisons for time (mean ± SD) for the control and experimental groups.



Note. * indicates significant difference at $p<0.05$ for pre to post-tests.

Figure 8 shows the left leg's mean (SD) force using the Force Frame. There was no significant improvement (p=0.58) in Newtons for the experimental group from pre to post-tests. The magnitude of improvement in the experimental group was 3.5 (67.1) % with a small effect size (d) of 0.2. While the mean scores for the left leg force increased in the experimental group, the standard deviations were such that no significant difference was observed.

Figure 8.

Force Frame (L) Test comparisons for time (mean ± SD) for the control and experimental groups.

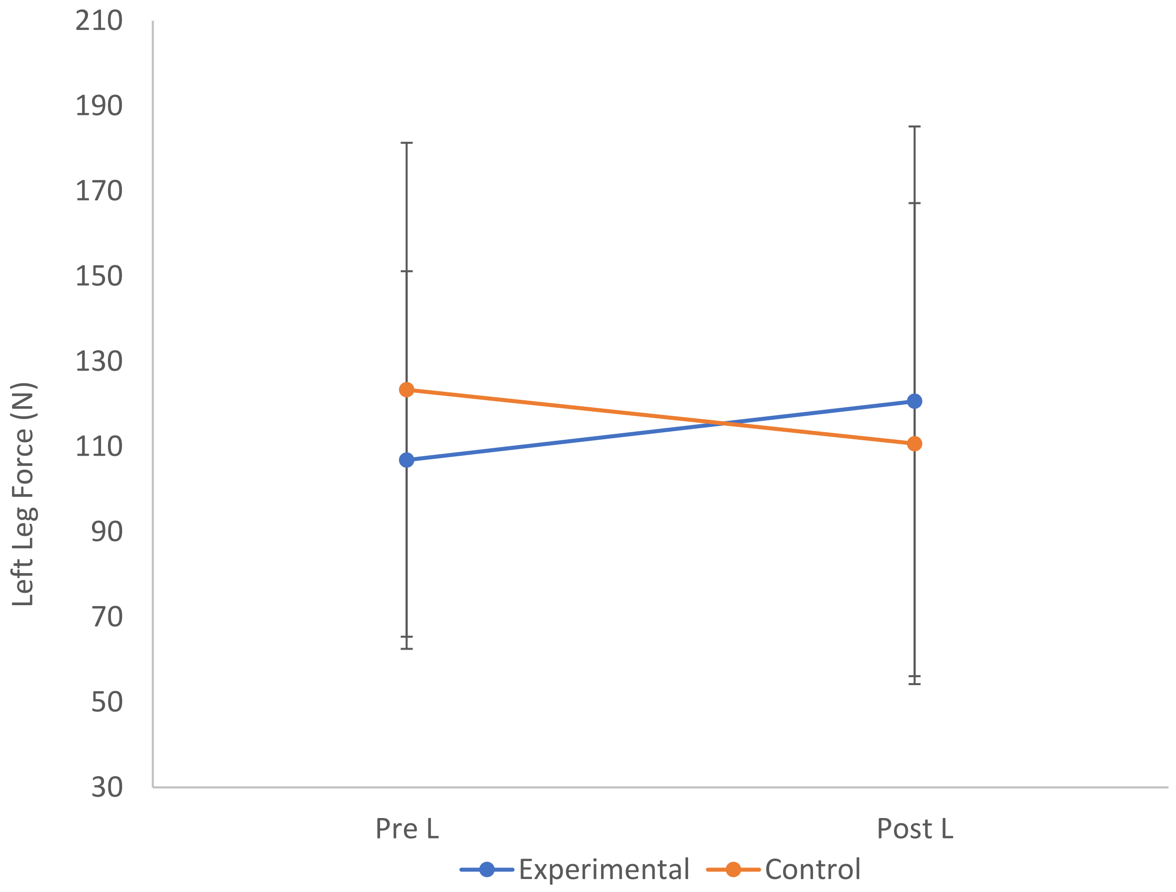


Figure 9 shows the mean (SD) force for the right leg in the Force Frame Test. There was no significant improvement (p= 0.38) in newtons for the experimental group from pre to post-tests. The magnitude of improvement in the experimental group was 6.1 (45.7) %, with a small effect size (d) of 0.42. The control group decreased their overall performance in the pre to post-testing of their right by 11.2%.

Figure 9.

Force Frame (R) Test comparisons for time (mean ± SD) for the control and experimental groups.

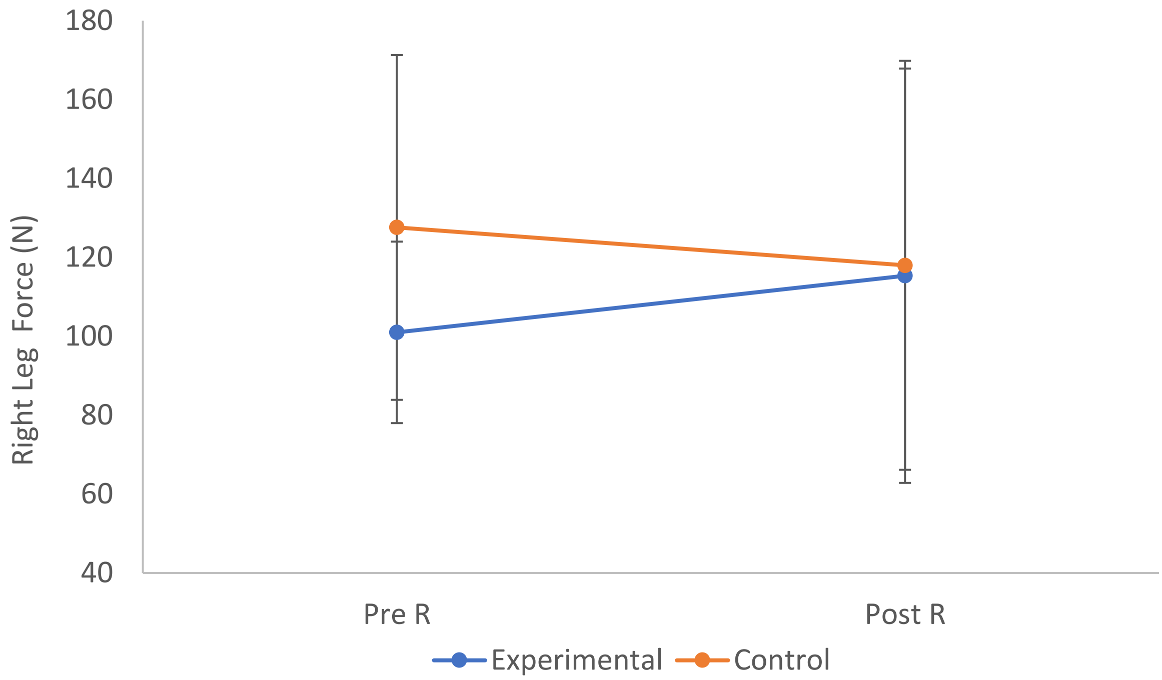


Figure 10 shows the Functional Reach Test's mean (SD) score. There was no significant change (p=0.09) in the distance reached for the experimental group from pre to post-tests and significant change in the control group. The magnitude of improvement in the experimental group was 4.6 (6.4) %, with a moderate effect size (d) of 0.66. The control group pre to post-test of the Functional Reach Test results decreased by 0.6%.

Figure 10.

Functional Reach Test comparisons (mean ± SD) for the control and experimental groups.

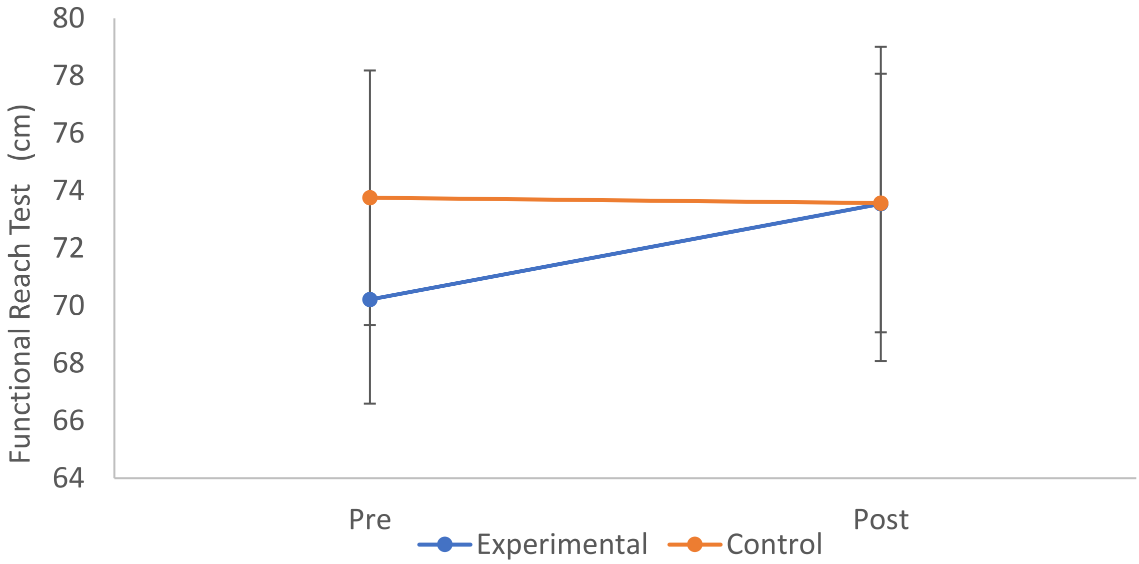
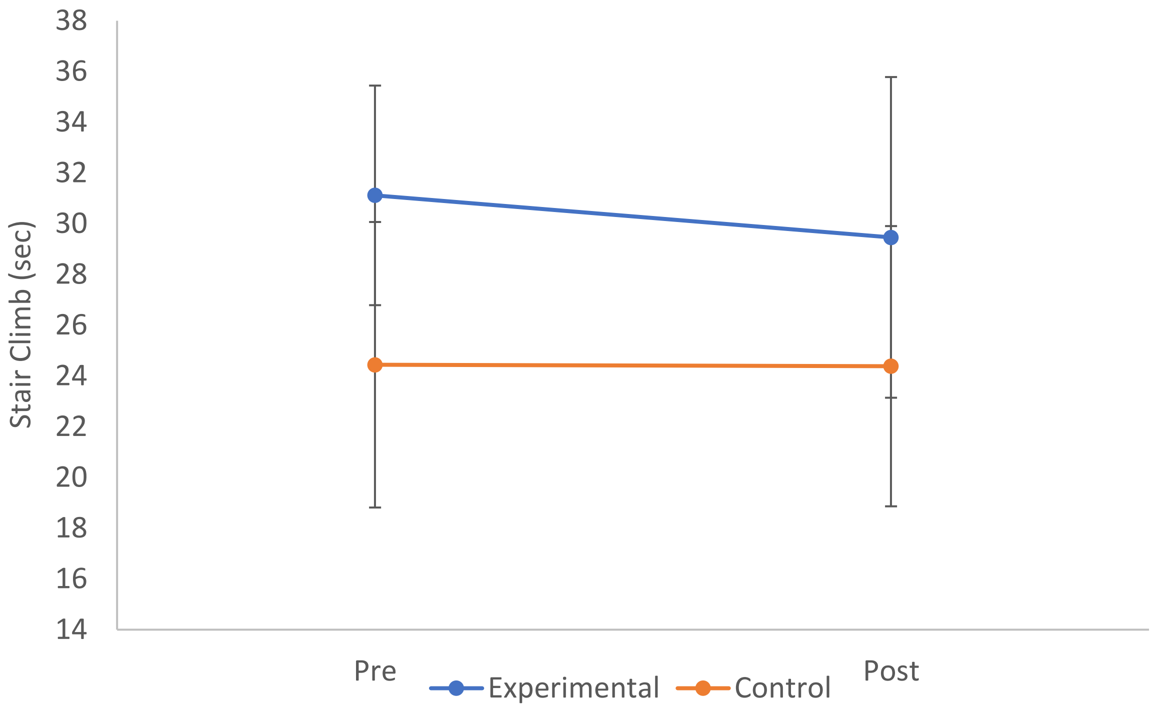


Figure 11 shows the Stair Climb Test's mean (SD) time. There was no significant improvement (p=0.29) in speed for both groups from pre to post-tests. The magnitude of improvement in the experimental group was -6.9 (16.4) %, with a small effect size (d) of 0.26. The experimental group showed a 16.4 % improvement in performance by reducing their start to finish time in the Stair Climb Test.

Figure 11

Stair Climb Test comparisons for time (mean ± SD) for the control and experimental groups.



This concludes the results of this experiment. The next chapter will discuss the findings of this investigation.

Chapter Five: Discussion

This research aimed to evaluate whether the use of a RIB stability training device could improve strength and balance in older people, which could potentially reduce the risk of a fall. This was achieved by assessing the effects of a six-week RIB training intervention to determine whether there would be improvements in both dynamic, static and proactive strength and balance. The findings of this study show that there were substantial improvements across a range of stability and strength tests. The results of these tests and the implications for future falls prevention programmes will now be discussed.

The first significant finding from this study was that the Romberg Test ($p=0.023$) demonstrated a significant improvement in static balance following the training intervention. The magnitude of improvement in the Romberg Test was deemed a large effect ($d=1.05$) in the experimental group relative to the change in the control group. There have been limited findings where the standard Romberg is used in isolation. Cho and Kamen (1998) suggested that using the Romberg is inadequate when assessing subtle balance disorders. However, the results in this study aligned with those of Jalali et al. (2015) who found the Romberg Test to be an important predictor of falls in older adults. The Romberg static balance test was used to identify any improvement in postural sway within the groups. Our research suggests that the training intervention had a beneficial effect on the efficiency in which the body responds to proprioceptive feedback through the nervous system, thus reducing sway. As a result of our findings, we can hypothesise that there is a likely improved function in the dorsal columns of the spinal cord, which enables the body to hold its position in space. Improvements in test times show participants were better able to hold a static balance pose and may indicate improvements in the efferent motor system. A previous study by Horlings et al. (2008) suggested that improvements in the efferent motor system allow for increased proprioception, reducing sway and the risk of falling. With improved efferent sensory input, we can speculate that the nerve fibres could operate more efficiently in processing signals from the brain. Improved involuntary responses allow the peripheral nervous system to initiate voluntary skeletal muscle movements faster thus preventing the risk of a potential fall. Faster initial responses of muscle movements in day-to-day activities may also increase the confidence factor in individuals, where they are more intuitive of their surroundings.

An improvement in the Romberg Test may also demonstrate that the use of the RIB dynamic training exercises improves neuromuscular feedback and improves muscle strength, i.e., reduce limb weakness. The dynamic strength and balance exercises used in our study primarily focused on improving the activity of the lower limb (legs) muscle groups. As stated previously in the literature review, Aartolahti et al. (2020) suggested that the relationship between lower limb muscle weakness and the risk of injurious fall were directly related to a reduction in muscle strength and power. A proposed improvement in muscular strength in the experimental group is supported by the results from the Force Frame left and right leg strength assessments. The Force Frame results for the experimental group showed small improvements in muscular leg strength for a seated leg extension in both left and right legs; a small magnitude of effect 0.2 (d) left leg and moderate magnitude of change in the right leg or 0.42 (d). We can speculate from these results that the dynamic lower limb exercises utilised in the study, such as the seated knee extension and continuous rocking back and forth with downwards and upwards pressure, have potentially improved muscular leg strength and that the greater change in the right leg is associated with preferred leg dominance. Similar results were reported in a systematic review by Muehlbauer et al. (2015), where they found an overall trend that decreased lower limb muscle strength was a falls risk factor in older adults who had significant postural sway. The review found that the chances of implementing a dynamic balance programme demonstrated changes between dynamic and steady-state maximal strength was small ($r \leq 0.69$) and the results from our study support that prediction of small changes in strength. These study results show that whilst the different training components of balance and strength were still largely dependent on each other for improvement, the improvements may not be of a similar magnitude. The results from our Romberg Test showed that an improvement in static balance can be achieved following the dynamic exercises on the RIB. Whilst many would consider improvements in strength and balance to be synonymous, the evidence from our Force Frame data suggests that these two components may need to be individually targeted to achieve gains of a similar magnitude.

The second finding from this study was that the Timed Up and Go Test demonstrated a significant ($p=0.03$) reduction in time for completion following the experimental intervention. There was a moderate magnitude effect of 0.66 (d), and the difference between the experimental and control group mean was ≈12%. The nature of the TUG test suggests that improvements may have occurred in gait, speed, stride length and balance in locomotion as a result of the dynamic nature of the training program. The improvement also suggests that there may have been improvements in cognitive function, lower limb strength and balance. Previous research by (Beauchet et al., 2016) suggests that an improvement in cognitive function may be strongly associated with cognitive and balance networks sharing common neuronal pathways. In a study by Coelho-Junior et al. (2018), the physical capabilities of community-dwelling women were measured in a Timed Up and Go Test. Pearson's correlation results indicated that TUG performance was significantly associated with lower limb strength (i.e. sit to stand), balance (i.e. one leg stand), power (i.e. countermovement jump) and mobility (i.e. usual and or maximal walking speeds). In the Coelho-Junior study, the strongest correlation between the variables was between Sit to Stand Test and TUG ($r=0.53$), suggesting that the greatest improvements in TUG are associated with strength rather than locomotion. The improvement in lower limb strength in our study has been previously described, thus, whilst inconclusive regarding the importance of strength alone in falls prevention. This study highlights the need for a battery of tests when assessing the efficacy of falls prevention programmes. Our results indicate that a 6-week training programme comprising of static and dynamic exercises of 50 minutes may improve static balance and lower limb strength. These results were supported in a meta-analysis by Chiu et al. (2021), looking at the effects of the OEP on perceived balance in older adults. The results from five studies showed that the Timed Up and Go measuring dynamic balance reached a significance of $p=0.04$.

Another finding which trended toward achieving significance was that of improvements in the Functional Reach Test ($p=0.09$). In this measure, we observed a moderate magnitude of improvement ($d=0.66$) in the experimental group relative to the control group. The results from the Functional Reach Test indicates there was a moderate improvement d= 0.66 in the distance reached by individuals following the 6-week stability training programme. Weiner et al. (1993) suggested that improvement in the Functional Reach Test would indicate enhanced anteroposterior stability within individuals. It is speculated that the dynamic exercises we used improved anteroposterior stability and proprioception and may enable enhancements in both the afferent and efferent systems. According to Behrman et al. (2002) changes in anteroposterior stability through dynamic exercises training may also improve vestibular inputs and better central processing of the somatosensory resulting in better dynamic stability. Ultimately, improvements in functional reach can be seen as improvements in the ability to maintain balance prior to an overbalancing, i.e., the ability to self-correct and prevent a fall. It was suggested by Duncan et al. (1990), that the ability to integrate anticipatory postural adjustments when self-correcting may prevent a fall. In a study by Bourrelier et al. (2021) using virtual reality to improve cognitive and motor deficits, the FRT was used to show that proactive balance training consisting of virtual reality games that used maximal reach, such as bowling, could be significantly improved by an experimental intervention. It was postulated that improvements in maximal reach allow for optimum coordination between posture and movement. In our study, the RIB dynamic training exercises also used maximal reach of the arm when rocking back and forth on the board. These exercises may have contributed to the improvements in the FRT for the experimental group.

The Stair Climb Test in our research study produced a small magnitude of effect ($d=0.26$) however no significant results ($p= 0.29$) in the experimental group. However, it is worth noting the relationship between cognitive decline and physical performance in climbing stairs. The ascending and descending of stairs pose functional limitations in older people regardless of whether they have difficulty or not. In a study by Oh-Park et al. (2011), they found that older people have a slower performance rate in stair climbing due to their negotiation time when it came to both climbing and ascending. The ascending and descending of stairs is another multifaceted daily activity that older people find difficult due to lack of balance, muscle function, cognitive ability and environment. The kinematics of stair climbing is a far more complex task when compared with easier acts of daily living such as walking because of the combined factors that an individual has to process before taking the first step. Whilst our study mimicked a stair climb action of lifting the leading leg and rocking with forward pressure on a RIB, it showed some small improvement but not enough to reach significance. It can, however, be recommended that an extended training programme with a more kinematic approach to exercises may increase the result in a Stair Climb Test.

The results of the Force Frame Left and Right Leg Test showed a small change ($d=0.2$ and 0.42), however, failed to reach significance ($p=0.58$ and 0.38). The Force Frame left and right legs still improved from pre to post-testing, however, two out of the seven participants provided unreliable data. The remaining five participants all showed improvements in lower limb power, however, two decreased their times drastically resulting in skewed data. Upon reflection, it is important when using equipment with participants that requires very specific processes that participants are familiar with the equipment, using greater familiarisation of this test may have been beneficial. Whist this measure was a useful indicator, a recommendation for future research might be to adopt a test measure such as the seated squat using a Force Plate when investigating limb strength. By focusing investigation towards a dynamic double leg seated squat assessment, we may be better able to obtain more information about muscle strength and reactive power in older people. This would be a positive step in potentially moving test measures towards a more dynamic nature, given that basic standing up and down from a chair is very much a universal act of daily living (ADL).

The FES proved to be a valuable qualitative assessment that we collected both pre and post-testing. Our FES was a self-administered questionnaire (see Appendix C) that was designed to assess the fear of falling in both our experimental and control group. It provided our research with an insight as to how our participants perceived their own ability to perform daily tasks and how some perceptions changed over the course of the intervention. It was clear from our research that 12 out of 14 participants were exceptionally confident in their own day-to-day tasks. We saw a positive improvement in two of our experimental participants who felt that they had improved in regards to their own physical capability of performing ADL but also in their approach to living. It was said that they felt more aware and confident in making environmental decisions. The most common piece of anecdotal feedback in our questionnaire was that their confidence had improved when performing ADL and that they had found more enjoyment in being a part of their extracurricular activities. The FES has provided our research with some important feedback. In line with the research from Tinetti et al. (1990), a recommendation would be to implement a FES or similar questionnaire when programming. This will be able to give the health practitioner who is administering the training program more information to help guide decision making and ultimately assist in reducing the risk of falling.

Conventional modes of exercise such as aerobic, tai-chi and yoga training are effective ways in preventing falls among elderly people. However, Yang et al. (2020) suggests that poor exercise compliance and the inability to effectively maintain training outcomes influence the success of interventions. The recommendation from Yang et al. (2020) is for researchers and practitioners to redirect their attention to other alternatives. Stability training using a RIB could potentially alter how older people wish to exercise and could entice the frequency of use. The RIB is a quirky innovation that potentially may increase the want for older people to exercise. The ease-of-use nature that the RIB has, makes it an easy device for older people to maintain physical activity in the comforts of their own home. It is lightweight and able to be transported with ease in the backseat of the car to group fitness sessions for a more socially interactive training session. The RIB is a practical stability training device that has produced many positive results in our experimental group, from a small magnitude of change to reaching significance.

This training study was not intended to develop a new intervention but simply take a method that we know works and modify it. Our training intervention moves in a fresh direction of dynamic training and testing measures to potentially reduce the risk of falling in older people.

This approach has been recently supported in the literature by Nalcakan and Yeliz (2020), who suggested that stability training devices can be effective in dynamic balance, increasing strength within the lower leg limbs and promoting changes in proprioception and neuromuscular control. Our research strongly promotes the use of the RIB to be used as a strength and balance training device in conjunction with those selected exercises from the OEP.

Given that we function in more of a dynamic environment, the nature of falling is a dynamic movement. Current research focuses on falls prevention programmes from a static standpoint instead of a dynamic one. Seldom do falls occur in a static position. Tinetti et al. (1988) and Berg et al. (1997) have stated that many older people fall during dynamic movements of habitual daily activities, like walking or rising from a chair or a bed. Our training and testing measures need to reflect this to mimic real-life scenarios, which may reduce the potential risk of a fall in older people.

Chapter Six: Conclusion

The purpose of this study was to evaluate the use of a RIB stability training device to improve strength and balance, which could potentially reduce the risk of a fall in older people. The main result of this study was that following a six-week training intervention, the Romberg and Timed Up and Go resulted in significant improvements in older adults. All other test measures showed a magnitude of improvement from small to large.
The data suggests that RIB dynamic strength and balance exercise training is likely to have beneficial improvements for older people, thus decreasing the potential risk of falling. The results from our experiment indicate that there may have been an overall increase in the efferent neurological pathways, lower limb strength and the ability to self-correct in the event of a fall.

Our research strongly supported the ideas of previous researchers such as Cattaneo et al. (2014) and Benavent-Caballer et al. (2016), that innovative programs and or multimodal group exercise using a modified OEP may be more successful than the use of the OEP as a stand-alone program. The idea of adapting the OEP to be used in conjunction with our RIB stability training intervention produced positive results that may reduce the risk of falling in older adults. Whilst the evidence was inconclusive on some improvements in strength, the study can conclude that a 6-week programme on the RIB using modified exercises from the OEP does significantly improve balance and the time it takes older adults to get up and go.

Any research into the area of falls prevention is increasingly important, due to the booming age demographic within our society. With increased age comes an increased risk of a potential fall. Falls can be serious and potentially life-threatening, especially in our older populations. In all cases that are health and wellbeing related, whether it be falls prevention or health and safety in the workplace, prevention will always be better than cure.

6.1 Future Research

While there is consistent evidence that the OEP is a versatile falls prevention training programme, little research looks at the OEP being used in conjunction within stability device training. Further research looking at the OEP being used with other types of stability training is an area that needs to be explored. The OEP is a valuable tool that needs to be expanded to optimise strength and balance training in older people. In exploring more options to enhance strength and balance performance, it is not adhering to a one size fits all approach. People fall in all kinds of different scenarios and for different reasons. The one thing we can be assured of from our study is that a fall occurs more dynamically than statically. Therefore, tailoring programmes to an individual's needs is a positive step in reducing the risk of falls in older people.

Another recommendation for future research is to look at further training with a larger participant group over an extended training period. This may produce some different results and show a larger magnitude of effect to determine the effectiveness of stability training devices.

Falls prevention is an area that has been explored thoroughly, however, the relationship between strength, balance and brain exercise is yet another area that is to be explored. The importance of strength and balance in older populations is a key factor in ultimately keeping them vertical, but we believe that another key area of research is finding optimum brain exercises that work in conjunction with strength and balance training. By adding the element of brain exercise, it is hoped that the neurological decline will slow in older people, thus reducing the risk of a potential fall in older people.

6.2 Limitations

A limitation of this study was the nationwide Covid-19 lockdown which occurred during the week of post-testing. The training invention was extended using remote sessions to maintain gains until post-testing could be conducted. This resulted in a further two weeks of remote sessions based on adaptations of the initial programme.

A further limitation was the size of the cohort recruited. Whilst every effort was made to recruit more widely, due to time constraints and the impact of the pandemic, the results of this study may have been limited by the size of the initial recruitment pool.

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Appendices

Appendix A: Approval from the EIT Research Ethics and Approval Committee

EIT

EASTERN INSTITUTE OF TECHNOLOGY
TE AHO A MĀUI

Our Ref: EA02310321

Primary researchers: Elizabeth McKay

28 April 2021

Dear Elizabeth,

Thank you for your application for your research project, *The use of a Rock-it Board device to improve strength and balance in older adults*, received by the Research Ethics Approvals Committee.

I am pleased to inform you that your human research ethics application has been approved.

As you continue with your research, please refer to the EIT Code of Research Ethics. As a reminder, if your proposal changes in any significant way, you must inform the Committee. Please quote the above reference number on all correspondence to the Committee. Please send all correspondence to REACapprovals@eit.ac.nz.

The Committee wishes you well for the project.

Yours sincerely

Megan Allardice
Research Operations Manager
p.p. REAC

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Appendix B: Informed Consent Documentation

EASTERN INSTITUTE OF TECHNOLOGY
TE AHO A MĀUI

Information for Research Participants

Project Title:	The use of a Rock-it Board device to improve strength and balance in older adults.

To:	Participants

Researcher(s):	Ms Elizabeth McKay, Dr Carl Paton, and Dr Patrick Lander

Affiliation:	The Eastern Institute of Technology

Description of the research:

This research aims to assess the effectiveness of a strength and balance exercise programme performed on a stability training device (Rock-it Board) in older people.

What will participating in the research involve?

All volunteers will initially perform a health screening, body composition and strength and balance (S&B) assessment. Measurements taken from the participants will include weight, height, blood pressure, and a 3D Body Scan. Following that, participants will be asked to complete six movements recognised internationally as relevant to improving strength and balance in older adults.

All tests are pictured below.

Following baseline testing participants will be assigned to either a control or intervention group.

The intervention group will meet twice per week over eight sessions to participate in an exercise programme using a Rock-it Board (RIB) stability training device.

The S&B programme will consist of lower leg limb and core stability exercises aimed at potentially increasing confidence and reactive coordination in the event of a fall. These exercises will mimic the daily movements one's body naturally undergoes, such as walking, stepping and sitting.

The session will run for approximately 50 minutes, where the participants will perform a rhythmic warm-up consisting of five exercises. Following this, the participants will perform a set of strength and balance exercises on the RIB for approximately 20 minutes.

Following this, a cool-down of rhythmic movement for 10 minutes. Lastly, 5 minutes will be allocated for questions.

After the eight sessions the baseline measures will be repeated to observe any changes.

There will be no requirement to audio or video record the participants.

What are the benefits and possible risks to you in participating in this research?

The benefits of participating in this research project would be the opportunity to participate in weekly exercise sessions focussed on the prevention of falls, the strength and knowledge from which may be helpful now or in the future. Furthermore, participants will receive two 3D Body Scans (priced at $80 each) along with the opportunity further to understand the use of sports science in the community. The physical activity involved in this study is a low form of risk since the exercises mimic natural daily movements. In the event that a participant may suffer a fall or medical emergency, the relevant safety procedures would be invoked e.g. calling 111. The location of an AED and staff with first aid training will also be identified at the start of each session.

Your rights:

- You do not have to participate in this research if you do not wish to.
- If you are a student at EIT and decide to take part, you can withdraw from the research at any time and this will not affect treatment or assessment in any courses at EIT.
- If you are a patient or under the care of students or staff from EIT, you can withdraw from the research at any time and this will not affect your treatment or assessment in any way.
- Once you have completed the research you have a one month period within which you can withdraw any information collected from you.
- You are welcome to have a support person present (this may be a member of your family/whanau or other person of your choice)
- You may request a summary of the completed research

Confidentiality:

The results of the pre and post- assessment will be confidential. Identifiable information will not be made available to any other people without the participant's written consent. This research project's data will be securely stored for up to five years with the primary researcher and the Eastern Institute of Technology.

If you wish to participate in this research, or if you wish to know more about it, please contact

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Mobile phone #	0211566459			

Supervisor Name(s):	Patrick Lander & Carl Paton			
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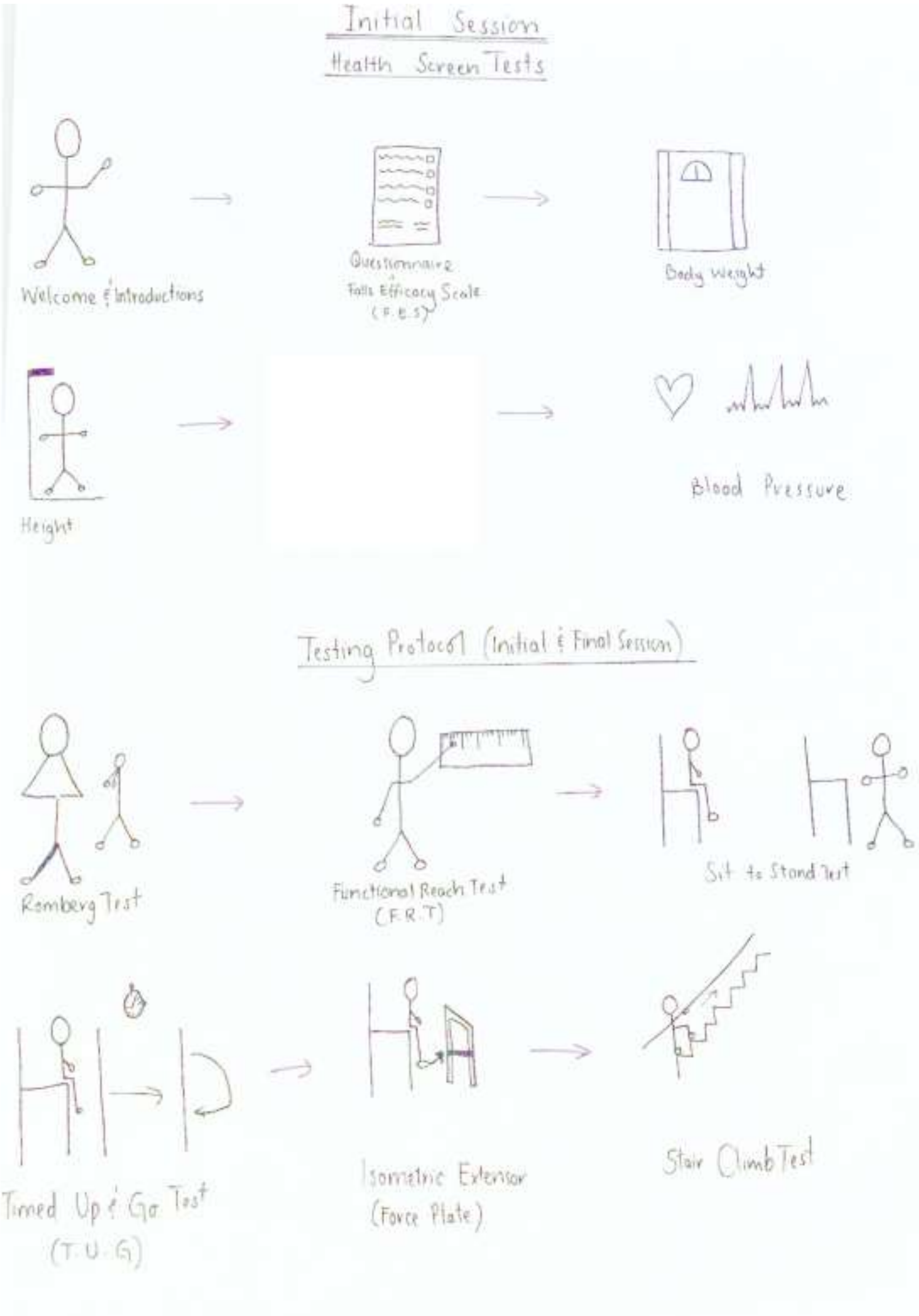
Head of School/Manager	Ondene van Dulm			
Work phone #	06 830 1502		Email address	ovandulm@eit.ac.nz

For any queries regarding ethical concerns,
please contact: Chair, Research Approvals Committee, EIT. Ph. (06) 974 8000


Initial Session
Health Screen Tests
Welcome & Introductions
Questionnaire
Falls Efficacy Scale
(F.E.S)
Body Weight
Height
Blood Pressure
Testing Protocol (Initial & Final Session)
Romberg Test
Functional Reach Test
(F.R.T)
Sit to Stand Test
Timed Up & Go Test
(T.U.G)
Isometric Extensor
(Force Plate)
Stair Climb Test

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Informed declarations of consent

(To be filled in by each participant before participating in any screening or fitness test)

These tests will be administered by………………………………………… on behalf of EIT. EIT supports the Sport Science New Zealand code of ethics, and supports the interests, confidentiality, comfort and safety of its clients. This form and the accompanying information (verbal and/or printed) are given to you for your own protection. Your signature below recognizes that you have understood eight (8) things:

1. You have been informed of the requirements of the test(s).
2. You have understood the requirements of the test(s).
3. You have been given the opportunity to discuss the test(s) requirements with assessor(s) prior to commencing the assessment.
4. You clearly understand the procedures and possible risks.
5. You voluntarily agree to participate in the assessment(s).
6. You have informed the assessor(s) of any injury, illness or physical defect and you have and which may contribute to the level of risk.
7. You release the provider from any liability for any injury or illness that you may suffer while undertaking the assessments, or subsequently occurring in connection with the assessments or that is to any extent contributed to by it.
8. You are free to withdraw consent and discontinue participation without prejudice or jeopardising your involvement/relationship with EIT or its representatives.

All my questions regarding the tests to be administered have been answered to my full satisfaction. I have freely given my consent to participate and I know that I am free to withdraw from the assessment(s) at any time without prejudice. I understand the nature of the testing procedure(s), and the consequences and risks involved in my participation. I understand that the data collected will remain confidential to me and the assessor(s) unless written permission is given from me.

Participant Name	
You will perform the following exercise test/s:	
The equipment used for your test/s will include:	
Freedom of Consent • **Your permission to perform this exercise test is voluntary. You are free to stop the test at any point, if you so desire.** • **I have read this form and I understand the test procedures that I will perform and the attendant risks and discomforts.** • **Knowing these risks and discomforts, and having had the opportunity to ask questions that have been answered to my satisfaction, I willingly consent to participate in this test.** • **If you have any concerns or questions, please ask us for further explanations**	
Date:	**Participant Signature:**
Researcher Name:	**Researcher Signature:**

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Pre-screening questionnaire (EIT)

Name		Occupation	
Address		Day Phone	
		Evening Phone	
Contact Person (1) Phone		Contact Person (2) Phone	
Today's Date		Doctor	
DOB	Height	Weight	
Gender	Age	H/R	B/P

Please answer the following questions by placing a tick √ in the appropriate box.

	Health Status	**Yes**	**No**
1	Have you ever had a stroke or heart condition?		
2	Have you ever had high blood pressure?		
3	Have any family members had heart problems before age 60?		
4	Have you experienced chest pain when engaged in physical activity?		
5	Have you experienced chest pain when not engaged in physical activity?		
6	Have you ever had, or do you currently have, high blood cholesterol?		
7	Have you ever suffered from asthma or breathing difficulties?		
8	Have you ever smoked – cigarettes, pipes or cigars?		
9	Are you pregnant or have you been pregnant within the last three months?		
10	Have you been hospitalised within the last six months?		
11	Are you currently taking any medication(s)?		
12	Have you ever had, or do you currently have, diabetes, epilepsy, hernia, dizziness or loss of consciousness?		
13	Have you ever had any disease or injury of the back, joints, bones or muscles that may be aggravated by exercise?		
14	Are you aware of any other health-related issues that may affect your participation in physical exercise?		

Details of "Yes" answers, medications, possible contraindications to exercise, etc.

PTO

Please answer the following questions by placing a tick √ in the appropriate box.						
Exercise Participation					**Yes**	**No**
1 Have you been participating in regular physical activity? If yes, what type?						
If yes, what type?						
2 How would you describe your current physical condition? (Tick √ one or more boxes).						
unwell	**overweight**	**unfit**	**healthy**	**Fit**		
3 What are your exercise goals? (Tick √ one or more boxes).						
fat reduction	**improve fitness**	**maintain fitness**	**health / wellness**	**stress reduction**		
muscle tone	**increased mass**	**sport training**	**falls injury prevention**	**social contact**		

- **I have understood all the questions and have answered them to the best of my knowledge.**
- **I certify that I have disclosed fully any conditions that may affect my participation in physical exercise.**

Date	**Participant Signature**
Researcher Name	**Researcher Signature**

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Name	Date
Group	Location

Participant Baseline Measures

Height	Weight
RHR	BP

Participant Pre-Test Measures

Romberg Test		**Functional Reach Test (F.R.T)**		**Sit to Stand Test**	
Pre	Post	Pre	Post	Pre	Post
Timed Up & Go Test		**Isometric Extensor**		**Stair Climb Test**	
Pre	Post	Pre	Post	Pre	Post

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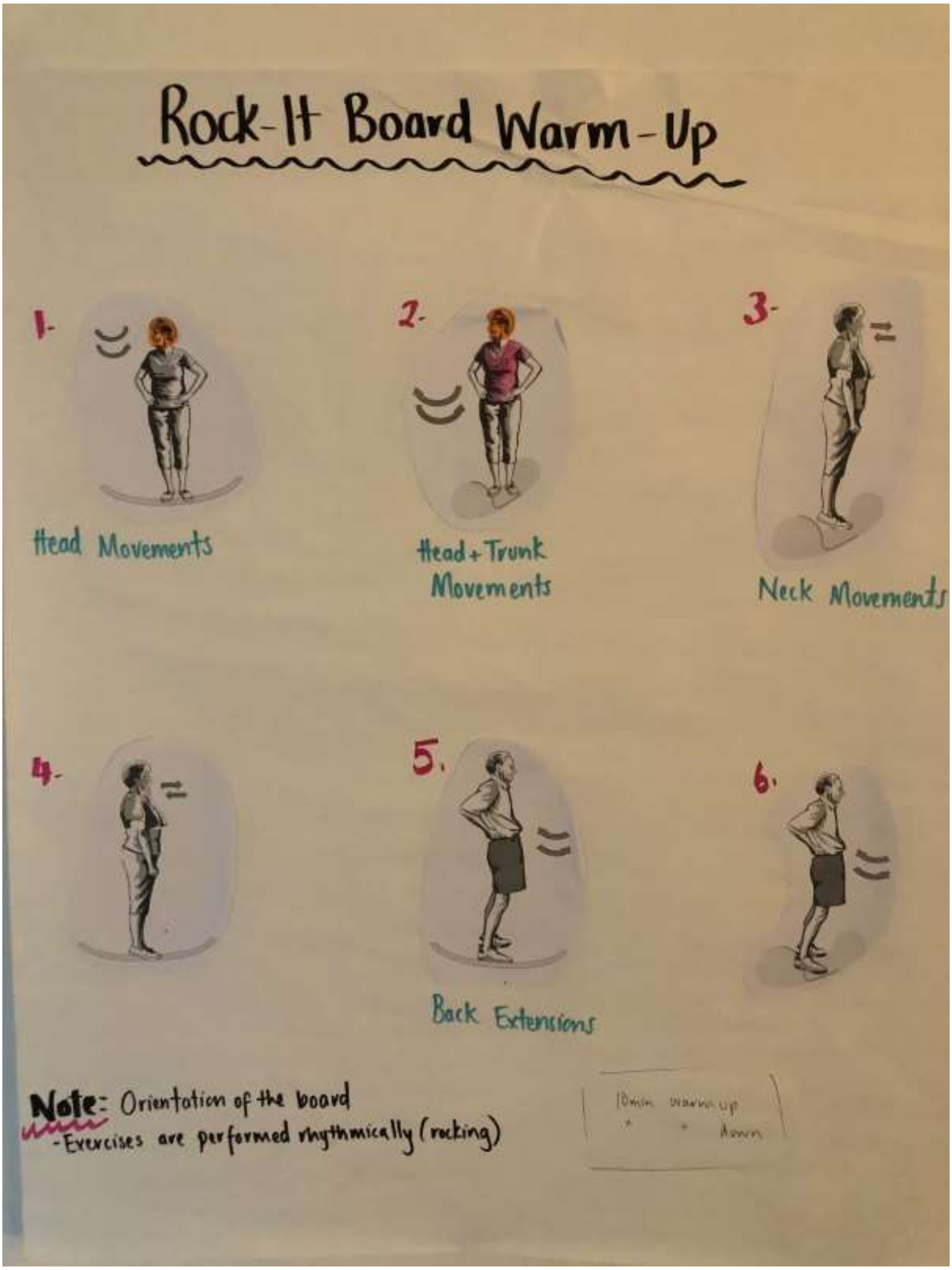
Fear of Falling (Falls Efficacy) Questionnaire

Please circle one answer for each question

Have you fallen in the last year?	Yes	No
Do you worry about falling over?	Yes	No
Do you feel unsteady when walking around the home?	Yes	No
Do you need assistance when walking i.e. walking stick, walking frame?	Yes	No
Do you steady yourself by holding onto furniture when doing daily activities around the home?	Yes	No
Do you have trouble climbing stairs or stepping up?	Yes	No
Do you exercise?	Yes	No
How often do you exercise in a weekly period?	Less than 1 hour	1-2 hours
	2-3 hours	3-4 hours
	4-5 hours	5-6 hours
	6-7 hours	7+ hours

Researcher notes

Appendix D: Rock-It Board Exercises



Rock-it Board Exercises
1.
Plantar + Dorsi Flexion Roll
2.
Calf Raises
3.
Heel Raises
4.
Knee Extension w/ Resistance Band
5.
Hip Adduction
6.