THE OTAGO EXERCISE PROGRAMME:

DO STRENGTH AND BALANCE IMPROVE?

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ABSTRACT

Aim: The aim of this study was to evaluate the effect of participation in the Otago Exercise Programme (OEP) on strength and balance. The change in a number of balance and strength measures were compared between a group of community dwelling women over the age of 80 years participating in the OEP and a control group matched by gender and age.

Study design: A cohort study of two independent groups.

Participants: Nineteen women over the age of 80 years who were community dwelling and participating in the OEP and 18 age matched community dwelling women who continued with their normal activities of daily living.

Main outcome measures: Participants' strength and balance was measured using the timed up and go test, the step test, the 30 second chair stand test and gait velocity. Participants' fear of falling was measured with the Modified Falls Efficacy Scale and falls were monitored using a falls diary.

Results: There were no statistically significant improvements in strength and balance in the OEP group and no statistically significant differences between the OEP and control group, after participating in the OEP for 6 months. The only statistically significant change in the OEP group was a slowing of gait velocity, all other outcome measures remained unchanged for both the OEP group and the control group.

Conclusions: There were no statistically significant improvements in strength and balance after participating in the OEP. These results are consistent with those of the original Otago trial and the subsequent meta-analysis of all the Otago trials. The results from this study need to be interpreted with caution, as due to the small sample size the study was underpowered. The critical components of the OEP remain unknown.

ACKNOWLEDGEMENTS

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CERTIFICATE OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the qualification of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements.

1. INTRODUCTION

The consequences of a fall pose a major threat to the health and well being of older adults. Falls are the most common cause of injury and a major cause of hospitalisation in people over the age of 65 years (Accident Compensation Corporation, 2004). Each year approximately 30% of adults over the age of 65 years and 50% of adults over the age of 80 will experience a fall (A. J. Campbell, Borrie, & Spears, 1989). New Zealand is following the global trend toward an increasing proportion of older adults in the population, with currently 1 in 9 New Zealanders aged over 65 years. This proportion is predicted to increase over the next 50 years to 1 in 4 (Statistics New Zealand, 2004). Therefore the prevalence of falls is likely to increase resulting in a growing public health problem that is costly on public health resources and on individuals' functional independence and quality of life.

As falls are accidental, in New Zealand the Accident Compensation Corporation meets the hospital and medical costs. Of the $200 million dollars that the Accident Compensation Corporation bulk funds to hospitals per year it is estimated that $40 – 60 million is used to fund hospital care to older adults after a fall (K. Holt, personal communication, 2 March, 2005). Falls can result in physical and psychological consequences. The personal cost of a fall to an older adult can result in a loss of functional independence and quality of life. A person may lose confidence and consequently decrease their level of activity in order to prevent another fall occurring. In a worse case scenario the person may lose the ability to complete their activities of daily living independently and have to be placed in a residential care facility long term.

The causes of falls are multifactorial and more than 400 risk factors have been identified (Masud & Morris, 2001). Most falls occur as the result of an interaction of a number of risk factors and the more risk factors a person has the higher their risk of a fall (Nevitt, Cummings, Kidd, & Black, 1989). Risk factors may be categorised as intrinsic (within an individual) or extrinsic (environmental) and some risk factors can be ameliorated whilst others cannot. Tinetti et al.'s (1994) seminal study of a

multifactorial intervention, included a combination of adjustment to medications, education and exercise programmes and resulted in a significant reduction in the risk of falling in older adults. This study was one of the seven Frailty and Injuries: Co-operative Studies of Intervention Techniques (FICSIT) comparing the effect of different exercise based approaches that address the amenable factors of strength and balance. To deliver an exercise programme that is effective in preventing falls, the type, intensity, duration and frequency of exercise prescribed needs to be evaluated as not all exercise programmes have demonstrated a statistically significant reduction in falls in older adults (L. Gillespie, Gillespie, Robertson, Lamb, & Cumming, 2003; Lord, Ward, Williams, & Strudwick, 1995; Robertson, Devlin, Gardner, & Campbell, 2001; Robertson, Gardner, Devlin, McGee, & Campbell, 2001).

The Otago Exercise Programme (OEP) is an individually prescribed muscle strengthening and balance retraining programme that has been designed and refined from four clinical trials by the New Zealand Falls Prevention Research Group (A. J. Campbell, Robertson, Gardner, Norton, & Buchner, 1999a; A. J. Campbell et al., 1997; Robertson, Devlin et al., 2001; Robertson, Gardner et al., 2001). A meta-analysis of the trials demonstrated that the OEP was effective in reducing falls by approximately a third in community dwelling older adults and most effective in a subgroup of adults over the age of 80 years who had previously fallen (Robertson, Campbell, Gardner, & Devlin, 2002). What was lacking from the meta-analysis was strong evidence that the OEP significantly increases strength and balance. The aim of this study is to evaluate whether significant strength and balance changes occurred after 6 months of participation on the OEP when compared with gender and age matched controls.

1.1 Purpose of the study

The purpose of this study was to evaluate the effect of participation in the Otago Exercise Programme (OEP) on strength and balance. The change in balance and strength measures was compared between a group of community dwelling women over the age of 80 years participating in the OEP and a control group matched by gender and age. The women were tested at baseline and again after 6 months in order to detect whether the OEP had an effect on strength and balance.

1.2 Hypotheses

For this study the general hypotheses adopted were:

1.   Participation in the OEP for 6 months will result in a change in strength and balance in a group of community dwelling women over the age of 80 years.

2.   Participation in the OEP for 6 months will result in a change in confidence in completing daily activities without falling.

1.3 Delimitations

The following delimitations apply to this study:

1.   Only community dwelling women over the age of 80 years participated in this study.

2.   Extrapolation of these results is limited to community dwelling women over the age of 80 years of European ethnicity.

1.4 Limitations

The following limitations apply to this study:

1.   The medical history of participants was unknown.

2.   The falls history of participants prior to the study was unknown.

3.   The OEP is usually delivered as a year long programme although it would be expected that changes in strength and balance would be measurable over a 6 month period. Time limitations meant that data could only be collected for participants at the 6 month point in the programme.

4.   Follow-up data was not able to be collected as the participants were continuing with the OEP for 1 year.

1.5 Operational Definitions

Community dweller: This was defined as someone living independently in a private dwelling, apartment, or residential facility, not residing in a hospital or nursing home where they received nursing care.

Older adult: This was defined as a person aged 65 years or older, as this is the age at which an adult becomes eligible for government services for older adults in New Zealand (S. Jacobs, personal communication, 22 September, 2004).

Fall: This was defined as an event which resulted in a person coming to rest inadvertently on the ground and other than as a consequence of: sustaining a violent blow; loss of sudden consciousness; sudden onset of paralysis, as in a stroke; an epileptic seizure (Gibson, Andres, Isaacs, Radebaugh T., & Worm-Petersen, 1987).

Postural control: This was defined as the act of achieving, maintaining or restoring a state of balance during any posture or activity.

2. LITERATURE REVIEW

This chapter introduces and discusses the problem of falls in community dwelling older adults and the contributing risk factors for falls. The effects of age on strength and balance will be discussed and fall prevention studies investigating exercise based approaches to falls prevention in community dwelling adults will be reviewed. The rationale for the selection of assessment tools used in this study and their psychometric properties will be outlined. A justification for the current study will be presented.

2.1 Falls in older adults

The consequences of a fall pose major threats to the health and well being of older adults. Falls are the most common cause of injury and major cause of hospitalisation in people over the age of 65 years (Accident Compensation Corporation, 2004). Falls even if they do not result in a physical injury can have a psychological effect on older adults leading to a fear of falling, restriction of activity and a loss of confidence, mobility and independence (Nevitt, 1989). Each year approximately 30% of adults over the age of 65 years and 50% of adults over the age of 80 years will experience a fall (A. J. Campbell et al., 1989). New Zealand is following the global trend toward an increasing proportion of older adults in the population, currently 1 in 9 New Zealanders are aged over 65 years and this proportion is predicted to increase over the next 50 years to 1 in 4 (Statistics New Zealand, 2004). Therefore the prevalence of falls is likely to increase in the future, making falls prevention a population health priority due to the increasing need that will be placed on limited resources in the health sector (Ministry of Health, 2000).

2.1.1 Risk factors for falls in older adults

There are more than 400 identified risk factors for falling (Masud & Morris, 2001) the most common of which have been ranked as: muscle weakness, history of falls, gait deficits, balance deficit, use of assistive devices, visual deficit, arthritis, impaired activity of daily living, depression, cognitive impairment, and being older than 80 years (American Geriatrics Society, British Geriatrics Society, & American

Academy of Orthopaedic Surgeons Panel on Falls Prevention, 2001). There is a lack of agreement as to whether gender is an independent risk factor for falling or not. Tinetti, Doucette et al. (1995) highlighted female gender as a risk factor whilst Fletcher and Hirdes (2002) identified being male as a risk factor, whilst , others found no difference between genders (Cesari et al., 2002; Nevitt et al., 1989). However the circumstances of a fall have been related to gender, with men being twice as likely to fall outdoors as the result of a slip while women tend to fall indoors (Berg, Alessio, Mills, & Tong, 1997). The authors suggest this may be due to the division of labour around the home, with men being mainly responsible for outdoor tasks. Whether as time progresses gender roles continue to be split in such a way with future generations is yet to be seen as both men and women describe gardening as a favourite past time. However Campbell et al.'s (1989) study supports the view that risk factors for falling slightly differ between men and women.

Falls are often referred to as being multifactorial due to the multiple risk factors that contribute to an older adult falling (A. J. Campbell et al., 1989; Kulkarni, Hale, & Reilly, 1999; Tinetti, Speechley, & Ginter, 1988). Tinetti et al. (1988) investigated the risk factors associated with falls in community dwelling adults over the age of 75 years by assessing their mental status, physical status and home environment in a one-year prospective study. Over the course of a year 32% of the participants fell. The risk for falling increased linearly from 8% in participants with no risk factors to 78% in participants with four or more risk factors. Nevitt et al. (1989) conducted a similar study in a sample of adults over the age of 65 years who had fallen in the year prior to the start of the prospective year long study, in order to identify the risk factors for recurrent falls. A one off or accidental fall was found to be hard to predict whereas multiple falls could be predicted based on the number of risk factors present. The risk of falling in older people increased from 10% with no or one risk factor to 69% with four or more. These studies demonstrate an interaction between the number of risk factors and the risk of falling, with more risk factors being associated with an increased risk of falling. Unfortunately, Tinetti et al. did not report participants previous fall history however it is possible that the sample would have included participants who had fallen prior to the study as 35% of adults over the age of 65 years fall over the period of a year (A. J. Campbell et al., 1989). It is also possible that the sample used by Nevitt et al. included participants who had not fallen in the year prior to the study as poor recall of falls has been demonstrated in older adults (Cummings, Nevitt, & Kidd, 1988). The

finding of a linear relationship between the number of risk factors and the risk of falling suggests that a predisposition to falling may result from the accumulated effect of risk factors. The clinical implication of these findings is that if an older adult's fall risk increases with the number of risk factors then modification of even a few risk factors may result in a decreased falls risk.

A risk factor may or may not be modifiable so it is important for an older adult's risk factors to be correctly identified in order for an appropriate falls prevention intervention to be prescribed. Gender for example cannot be changed, while poor vision may be improved by prescription eyewear, and muscle weakness by appropriate strength training. Of the 11 most common risk factors (American Geriatrics Society et al., 2001) muscle weakness, gait deficits and balance deficits can be modified (Lord, Sherrington, & Menz, 2001) and may in turn modify the risk factors of using assistive devices and impaired activities of daily living. Risk factors may be described as extrinsic or intrinsic. An extrinsic risk factor is environmental and challenges an individual's balance beyond their capabilities resulting in a fall (Masud & Morris, 2001). While an extrinsic factor may not be able to be modified as it is unpredictable, an intrinsic risk factor relates to the individual's postural control and the effects that disease or ageing may have on this (Nevitt et al., 1989). While age can not be modified and disease may or may not be able to, the resultant impairments in balance and strength can be improved with rehabilitation (Buchner et al., 1997; Nelson et al., 2004).

2.1.2 Section Summary

A fall may be an accidental one off event, however more often in older adults there is an accumulation of risk factors that predispose an individual to an increased risk of falling. While risk factors may differ slightly between men and women, there are 11 major risk factors contributing to falls some of which can be modified in order to decrease an individuals overall fall risk.

2.2 Balance and the effects of age

Balance in mechanical terms, is the state of an object when the forces acting on it are zero (Newton's First Law) (Bell F. in Pollock, Durward, Rowe, & Paul, 2000). In an inanimate object when the line of gravity falls outside the base of support, it falls over. In a human being when the same situation occurs, muscle activity occurs to

counteract the effect of gravity to prevent falling. Human balance is a person's ability to maintain their centre of body mass within the limits of stability (Woollacott, 2000). This complex function is automatically controlled by the central integration of multisystem sensory inputs which result in context-specific motor outputs (Lord & Ward, 1994; Whipple, Wolfson, Derby, Singh, & Tobin, 1993). As such balance is an integral component of function as the demands of a task and the environmental context in which a person functions can challenge balance (Huxham, Goldie, & Patla, 2001). With the incidence of falls increasing in adults over the age of 75 years to one in three per year (Tinetti et al., 1988) it would seem reasonable to question whether age related changes occur in the systems which contribute to maintaining balance. The use of a systems approach to understanding balance enables the contribution of the physiologic systems to be evaluated and the effects of ageing considered. The systems are: 1) sensory, 2) central processing, 3) neural pathways for motor control, and 4) musculoskeletal (Woollacott, 2000). These systems contributions to balance will be described in the following sections.

2.2.1 Sensory systems

The contribution of the sensory systems to postural control has been evaluated in research using the Sensory Organisation Test. Described initially by Nashner (1982), the Sensory Organisation Test is a set of six sensory conditions that progressively alter visual, somatosensory and vestibular inputs, thus enabling the contribution of each sensory system to postural control to be evaluated. The Sensory Organisation Test was used by Wolfson et al. (1992) in conjunction with computerised dynamic posturography, to compare postural sway in healthy elderly and young adults while standing on an unstable surface. Postural sway is a measure of the timing and magnitude of an individual's response to balance threats. Postural sway in young (n= 34, mean age 34 years) and old (n = 234, mean age = 76) were similar until balance was stressed by occluding or distorting visual and somatosensory inputs. In these instances older adults exhibited increased postural sway or loss of balance. When the postural sway of adults over the age of 70 years was compared across five-year age bands there were no significant differences across the subgroups. As older adults with known medical factors affecting balance were excluded from this study, the authors proposed that the changes in balance in the older group may not be due to age itself but rather to age-related diseases that affect joint or sensorimotor function. This relationship between the presence of disease and decreased balance is supported by the findings of

Lawlor et al. (2003) who reports that an increased falls risk is associated with the number of medical problems an individual has. Wolfson et al. also observed significant increased muscle latencies in the older adult group by measuring the time it took for a participant to respond to a balance threat. The authors hypothesised that the increased latency observed in the older adults was due to a diminished capacity of central processing of sensorimotor inputs. The data from this study was analysed further to focus on the effect of changing visual input (Whipple et al., 1993). Not all the older adults lost balance during testing, those who maintained balance did not differ significantly from younger adults. However those who did lose balance were reliant on visual information and had difficulties maintaining balance when visual information was inaccurate. The authors proposed that older adults rely more on vision for compensatory balance control and that balance may not become significantly worse with age unless a pathology is present. These findings are congruent with those of an earlier study by Lord, Clark and Webster (1991), who found age-related changes in vision in a sample of 95 hostel residents aged between 59 to 97 years. The mean age of older adults diagnosed with a clinical eye disorder was 84.5 years while those without had a mean age of 81.6 years. The authors found no association between vision and postural control when participants stood on a stable surface but when proprioception was challenged by standing on foam there was an association with decreased postural control. Lord and Ward (1994) assessed the visual, vestibular and sensory systems individually for the effects of ageing as well as measuring body sway on stable and unstable surfaces while manipulating the senses. In a sample of 550 community dwelling women aged between 20 and 99 years old, all of the sensorimotor measures were significantly associated with age reflecting an age-related decline. The relative contribution of each sensory system to maintaining balance changed with age. There was an increased reliance on vision up until the age of 65 years which then decreased, the use of vestibular input declined with age whilst the use of somatosensory input increased. In contrast to Whipple et al. this study found that across all ages, peripheral sensation was the most important sensory system to maintain quiet stance balance. The authors excluded only non-community dwelling adults and those with little English in order to obtain a representative sample, rationalising that whether a medical condition was diagnosed or not it would be expressed in a decreased functional performance. Melzer, Benjuya and Kaplanski (2004) also identified the role of peripheral sensation in maintaining balance. In a sample of community dwelling older adults, 19 participants who reported at least 2 falls in the previous 6 months (mean age 78.4 years) and 124

participants who had not fallen (mean age 77.8 years) were compared on measures of strength, body sway and two-point discrimination. There was no significant difference between the two groups in strength. However postural sway significantly increased in the group of fallers when decreasing the base of support or standing on foam, and this group had significantly poorer two-point discrimination on the plantar surface of the great toe. The authors hypothesise that decreased plantar sensation would contribute to a delayed stepping response due to an impaired ability to detect movement underfoot. The authors do not consider whether the decreased sensation is due to age-related changes in the peripheral sensors or to the central processing of sensory information. This study was limited by the retrospective fall history used in the inclusion criteria into the fall group, as limited recall of falls in older adults is well documented (Cummings et al., 1988) as well as the small sample size of the fall group (n = 19).

The visual, vestibular and somatosensory systems all contribute to postural control. While there is evidence that the contribution of each system may change over the course of time due to the physiological process of ageing, age alone does not appear to be the cause for decreased postural control but rather a pathology or age-related disease.

2.2.2 Central processing

Quiet stance is not typically a challenging activity for an older person as they are well within their limits of stability. Falls typically occur during normal daily activity when increased cognitive demand or functional tasks further challenge balance (A. J. Campbell, 2002). Reacting to a balance threat or preparing the body for movement places a greater demand on the central processing of sensorimotor inputs as the body must select the correct postural response. The central processing of balance responses was studied by Duckrow, Abu-Hasaballah, Whipple and Wolfson (1999) using cortical evoked potentials to measure the activation of supraspinal centres. The cortical potentials evoked by stance perturbation were measured in a group of 8 young adults (mean age 30 years) and 33 older adults divided further by physical performance (n = 13 old-mobile adults, mean age 80 years; n = 20 old-frail adults, mean age 83 years). In response to a sudden balance perturbation all the older adults had smaller, slower and different shaped evoked potentials when compared to those of the young adults. The authors could not determine whether changes were centrally or peripherally mediated. However they reported that the group of frailer adults had pronounced evoked potentials

and decreased physical performance which led them to hypothesise that focal subcortical white matter changes may result in a gait disorder characterised by abnormal central processing. Hatzitaki, Amiridis and Arabatzi (2004) investigated the effects of ageing on the organisation of postural responses to self perturbation in young and older adults. Electromyography activity in tibialis anterior, medial gastrocnemius, rectus femoris and semitendinosus and the excursion of the centre of pressure, was compared in a group of 11 older adults (mean age 70.1 years) with 9 young adults (mean age 20.1 years) during repeated hip flexion/extension. Participants stood with their arms stabilised on their hips and were instructed to swing their leg through a full range of movement (in the sagittal plane) at maximum velocity. The authors found that older adults moved the lower limb at a slower velocity and smaller amplitude, had less ankle muscle activity and held the stance leg stiffer in order to maintain balance. The authors suggest three hypotheses for their findings; insufficient ankle muscle activity to properly control postural sway; central integration limitations at a higher level resulting in the selection of a posture that was less demanding centrally when multisegmental control was required; and increased anxiety associated with a postural threat.

A dual-task paradigm has been employed to study the relationship between attention and postural control. Attention can be defined as the capacity of an individual to process information (Woollacott & Shumway-Cook, 2002) so if an individual's attention is divided between two tasks and maximum capacity is reached, performance on one of the tasks will be affected, reflecting the degree of attention required to perform the task. Shumway-Cook, Brauer and Woollacott (2000) demonstrated the attentional demand of dual tasking on functional mobility by giving groups of older adults (fallers and non-fallers) and younger adults a secondary functional or manual task while completing the timed up and go test. Both groups of older adults took longer to complete the timed up and go test when a secondary task was added (regardless of task type) and the group with a history of falls took longer than the group of non-fallers. It was outside the scope of the study to determine why the increase in time was observed other than noting that increased attentional demand results in a detrimental effect on functional mobility. Teasdale and Simoneau (2001) used a dual task paradigm to assess the effect of reintegrating sensory information combined with cognitive demand on postural control. In a group of 8 older adults (mean age 68.0 years) and 8 young adults (mean age 24.8 years) during either quiet standing or sitting, proprioceptive input was removed by applying vibratory stimulation to the ankles, then reintroduced with or

without visual input. An auditory stimulus was also introduced within 3s of the sensory changes to increase attentional demand. The resultant excursion of the centre of pressure was measured using a forceplate and compared between the two groups. The authors found, similar to that of Whipple et al. (1993), that older adults relied more on visual than other sensory inputs to maintain balance. When a secondary task was introduced both young and older adults demonstrated that the postural task was attention demanding as both groups demonstrated decreased reaction times. The authors suggest from these findings that central processing factors play an important role in postural stability. Redfern, Muller, Jennings and Furman (2002) investigated whether there were age-related differences in the temporal dynamics of attention in postural recovery from a perturbation. An auditory or a visual stimulus was presented randomly during a task in which a force platform that the participant was standing on was perturbed. Reaction times were measured and compared between a group of 19 older adults (mean age 78.8 years) and a group of 19 young adults (mean age 23.5 years). The older adults were found to have longer reaction times to both stimuli when compared to young adults, and in the older adults the reaction time was longer for the visual stimulus than the auditory stimulus. Perturbations that occurred 250 milliseconds before the auditory or visual stimulus resulted in decreased reaction times for both young and older adults suggesting that there is initial attentional demand to interpret sensory inputs related to balance and then once the postural response has been selected and executed attention shifts back to the reaction time task. The authors also observed a faster postural response in the older adult when perturbed, this may reflect the stiffer posture with which older adults hold themselves when expecting a perturbation (Hatzitaki et al., 2004). All of the above studies used a sample of healthy older adults. Brauer, Woollacott and Shumway-Cook (2001) compared the cognitive demand and recovery of postural stability between a group of healthy older adults and a group of older adults who had fallen and had a Berg balance score of ≤ 50 out of 56. The authors found that reaction times as measured by verbal reaction time to auditory tones during balance recovery were longer in both groups for the dual task than the single task, indicating that balance recovery is attentionally demanding. Reaction times were longer in the sample of fallers when compared to the healthy adults, which the authors hypothesised may be due to an even greater attentional demand of maintaining balance in older adults with a history of falling. The ability of healthy older adults to recover balance was not affected by a concurrent secondary task. The authors suggest that a limitation of this study may be that the cognitive task was not demanding enough and

that a math task would be more challenging cognitively for healthy older adults. Lower velocity perturbations were used than in other studies due to the poorer balance abilities of those older adults with impaired balance, this lower velocity of perturbation may have decreased the challenge of this task.

It has been suggested that factors such as goal, instruction and nature of the cognitive task may contribute to the prioritisation a person places on concurrent tasks (Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997). Brown, Sleik, Polych and Gage (2002) explored the effect of increasing postural threat on prioritisation of postural control over a secondary task. Participants stood either in the middle or at the edge of a platform that was either at ground level or 1.4 m from the ground, creating four different levels of postural threat, whilst performing Brooks' Spatial Letter Task, a cognitively demanding task. The authors found that the young adults' postural stability and secondary task performance both improved with the arousal caused by the increased postural threat, they performed better when on an elevated platform. The authors hypothesise from this finding that the increased arousal caused by the postural threat improved performance and that the dual tasks did not exceed the attentional capacity of the young adults. In older adults in non-threatening conditions performance of the secondary task was maintained at the expense of postural control. However as the perceived postural threat increased, for example being on the edge of a raised platform and not being able to take a step forward to save oneself, postural stability in the older adults improved at the expense of performance of the secondary task. These findings are in agreement with those aforementioned studies that age related decline in cognitive capacity in older adults might reduce the ability to perform multiple tasks.

2.2.3 Neural pathways for motor control in balance

It is generally accepted that as part of the normal ageing process there are changes in the central nervous system (De Vito et al., 1998; DeCarli et al., 1995; Kirkpatrick & Hayman, 1987; Meier-Ruge, Ulrich, Bruhlmann, & Meier, 1992; Pendergast, Fisher, & Calkins, 1993; Roos, Rice, & Vandervoort, 1997; Sjobeck, Dahlen, & Englund, 1999). Some of the studies discussed in the previous section have alluded to decreased balance responses resulting from potential age-related changes occurring within the central nervous system (Duckrow et al., 1999; Hatzitaki et al., 2004; Redfern et al., 2002; Wolfson et al., 1992). Neurological signs and the effect on mobility and falls was studied in a population of older adults without a diagnosed

neurologic disease or cognitive impairment (Ferrucci et al., 2004). The prevalence of neurological signs increased with age and of the 71 adults over the age of 85 years only 2 had no abnormal neurological findings. The greater number of neurological findings a person had, the slower their gait velocity was likely to be, the more difficulty they had walking longer distances and the more likely they were to have fallen in the previous year. Ten neurological signs were identified that mutually correlated to either decreased walking speed or the ability to walk at least 1 km however it was beyond the scope of the study to elucidate where the changes took place in the central nervous system and what those changes were. Wolfson et al. (2005) examined the relationship between a neurophysiological measure, white matter signal abnormalities, and impaired mobility. A group of older adults with normal mobility (n = 7, mean age = 81 years) and a group of mobility impaired older adults (n = 7, mean age = 84 years) were compared on magnetic resonance imaging variables at baseline and at follow up at 20 months. The authors found that in the group of mobility impaired older adults, white matter signal abnormalities had increased five times faster than other magnetic resonance imaging variables. The authors propose that in a subset of older adults with impaired mobility that there is an accelerated accumulation of white matter signal abnormalities, which may explain the rapid decline in mobility without an apparent cause.

A decrease in brain weight has been demonstrated with an increase in age and may be due to shrinkage of the gray matter structures, the cortex, white matter or dehydration (Sjobeck et al., 1999). A loss of 16 – 20% of white matter between older adults and young adults was found and staining for myelin demonstrated that brains with a mean age of 78.7 years had 10 – 15% fewer myelinated fibres than brains of young adults (Meier-Ruge et al., 1992). Other white matter changes were demonstrated in a magnetic resonance imaging study of neurologically healthy older brains. In this study the authors found that 20 – 30% of the brains studied had white matter lesions (Kirkpatrick & Hayman, 1987). If white matter changes reflect nerve cell loss, the decrease in motor function observed in older adults appears to be a part of normal healthy ageing. This was demonstrated by Mackey and Robinovitch (2005) in a study of balance recovery from a static inclined standing position. The aim of the study was to compare strength and reaction time in the ankle strategies of young and elderly women. Older women took longer to initiate a muscle response suggesting a neural difference in sensing the stimuli and processing motor responses. The older women also had a smaller lean angle from which they could recover and produced a smaller

peak ankle torques than younger women did. These results should be interpreted with caution however as the testing protocol used to elicit an ankle strategy was predictable and did not reflect a real life situation. Brauer et al (2001) also noted a delayed onset of muscle activity in balance impaired older adults when compared to healthy older adults. The balance impaired group demonstrated delayed onset of gastrocnemius activation when recovering from a balance threat and a lower magnitude of gastrocnemius muscle activity. However, it was outside the aims of this study to identify why these responses were observed. Contradictory findings were demonstrated by Hall, Woollacott and Jensen (1999). Forward and backward force plate perturbations at differing speeds and amplitudes were used to examine the magnitude and rate of torque production during balance responses. The authors found no difference in the production of muscle torques between young and old and that the torque response elicited was task appropriate.

2.2.4 The musculoskeletal system

The age related changes in both the central processing and the neuromuscular response to a stimulus are compounded by changes in the muscle. The functional unit of a muscle is the motor unit, which is the axon and the muscle fibres it innervates. There are age-related changes that occur morphologically and neurologically. The morphological changes that occur are a reduction in muscle mass, a reduction in muscle fibre number, changes in muscle fibre size and the proportion of type I to type II muscle fibre types (De Vito et al., 1998; Grimby, 1995; Grimby & Saltin, 1983; Gunnar, 1995; Roos et al., 1997). The neurological changes that occur are a loss of motor units, motor units remodelling to denervate type II fibres and become reinnervated with collateral sprouting axons from slower type I fibres, a reduction in the velocity of motor nerve conduction and α-motoneuron degeneration. (De Vito et al., 1998; Roos et al., 1997). These factors all contribute to sarcopenia, a loss of muscle mass and strength (Janssen, Heymsfield, & Ross, 2002; Roubenoff & Hughes, 2000) that is accepted as being a part of the normal ageing process (Fiatarone & Evans, 1993; Hurley, Rees, & Newham, 1998; Madsen, Lauridsen, Hartkopp, & Sorensen, 1997; Skelton, Greig, Davies, & Young, 1994).

2.2.5 Section summary

The physiological process of ageing affects all the systems that contribute to balance. The relative contribution of the visual, somatosensory and vestibular systems to balance change with age and an individual has the capacity to compensate if one of

the systems is compromised. However if two sensory systems are compromised at the same time the increased attentional demand becomes too great and balance is affected. The demands of central processing are affected by age-related changes in the white matter and hence the attentional capacity required for an individual to multitask (for example walk and talk) becomes diminished, resulting in reduced postural responses.

2.3 Strength and the effects of age

The effect of the ageing process on muscle results in a loss of mass and strength that is defined as a condition called sarcopenia (Janssen et al., 2002; Roubenoff & Hughes, 2000). Sarcopenia can lead to functional impairment in the older adult, as a loss of muscle condition may result in an older adult falling beneath the critical threshold required to maintain independence (A. J. Campbell, 2002).

2.3.1 Muscle strength

Muscle strength is defined as the force of contraction that can be exerted by a muscle (Skelton et al., 1994), the diminishing of this force, that is muscle weakness, and ageing has been well documented. The most commonly tested muscle for strength in the lower limb is the quadriceps muscle due to its relevance to many tasks which are necessary for independence, such as standing up from a chair (Bassey, 1997; Hurley et al., 1998; Latham, Bennett, Stretton, & Anderson, 2004; Madsen et al., 1997). The reported declines in quadriceps strength ranges from 1-2% per annum (Skelton et al., 1994), to 7-8% per decade (Schiller, Casas, Tracy, de Souza, & Seals, 2000), to 35% between a group of women aged 18 – 40 years and 71 – 87 years (Madsen et al., 1997) have been documented.

The relationship between levels of physical activity and age-related decline in strength was investigated by Hunter et al. (2000). In a group of community dwelling women the authors found that there was a progressive decline in physical activity with age and that muscle strength declined with age however they were unable to establish a cause-effect relationship between levels of activity and strength. The strongest person within each age band was unable to produce the same level of force as the younger women. So although the most active older women were the strongest of their age band, high levels of activity were not able to prevent the effects of ageing, only delay them. This finding is similar to an observation of Fiatarone and Evans (1993) that muscle

mass and strength declined in both older adults that were sedentary and trained as endurance athletes.

Methodological differences in the testing protocols used in studies investigating the loss of muscle strength in older adults make it challenging to compare the research. Skelton et al. (1994) tested quadriceps strength isometrically in sitting with the knee flexed to 90°; Hunter, Thompson and Adams (2000) also tested quadriceps strength isometrically but tested with the knee flexed to 30°; while Madsen et al. (1997) used an isokinetic dynamometer to test quadriceps strength through a range of motion. However the consensus is that absolute strength exhibits an age-related decline (Grimby, 1995; Hurley et al., 1998; Madsen et al., 1997; Pendergast et al., 1993; Skelton et al., 1994).

The protocols used to test muscle strength in a laboratory setting are artificial when compared to how muscles are used functionally in daily activities. Commonly a muscle is strength tested in isolation (Pendergast et al., 1993; Thelen, Schultz, Alexander, & Ashton-Miller, 1996; Wolfson, Judge, Whipple, & King, 1995) when in an activity such as getting out of a chair, muscles work in synergy to produce the desired movement. Another factor of muscle function to be considered is muscle power, that is, how fast a muscle is able to contract. A person's ability to get out of a chair requires not only muscle strength but also the timing and the speed of a number of muscles contracting appropriately.

2.3.2 Muscle power

Muscle power is defined as the combined velocity and force of a muscle contraction (Skelton et al., 1994). It has been suggested that muscle power is the most functionally relevant measure of a weight bearing muscle as it is power rather than strength that is used in many functional tasks (Bassey et al., 1992; De Vito et al., 1998). Bassey et al. measured leg extensor power in a sample of very old men (n = 13, mean age 88.5 years) and women (n = 13, mean age 86.5 years). The authors found that on average women only had half the power of the men and both groups had only 20% of the power of young adults. Similarly De Vito et al. found muscle power declined steeply across a population of women aged 50 to 75 years of age. The authors proposed that it was the loss of the speed component of power that was the critical determinant in the age-related power decline. Further evidence of the decreased ability of older adults to contract a muscle at speed is provided by a study that examined the production of

ankle torque (Thelen et al., 1996). The authors found that older adults took longer than young adults did to develope moderate to large ankle torques and that older adults were not able to generate modest levels of ankle torque at high rotation speeds. The participants were tested in supine with all other joints restricted so the study findings should not be extrapolated to the generation of ankle torques in a weight bearing position. The finding that the speed component of power decreases is congruent with the reduction of type II fibres that occur with ageing and the slowing of motor nerve conduction (De Vito et al., 1998; Roos et al., 1997).

2.3.3 Section summary

The physiological process of ageing in the muscle of older adults results in a diminished capacity to produce strength and power. While maintaining high levels of activity may be able to slow down the loss of muscle strength and power, it appears to be an unavoidable result of ageing.

2.4 The relationship between strength and balance

Balance is the result of multisystem integration to produce an appropriate postural response to a balance threat. Postural responses require muscle strength that must be timed and of sufficient amplitude to be adequate to maintain balance.

The relationship between strength and balance was investigated by Wolfson et al. (1995). The authors found that older adults who fell during unstable platform tests on the Sensory Organisation test had 30% less lower extremity strength when compared to the older adults who did not fall during the same test. The findings of this study should be interpreted with caution due to voluntary strength tested in sitting being compared with an involuntary muscle response in standing, two dissimilar tasks. Whilst strength was associated with poorer performance a cause-effect relationship cannot be determined. Gu, Schultz, Shepard and Alexander (1996) resolved this methodological issue by measuring body segment motions and surface reactions during challenges to standing balance. They found that although there were age-related differences in the dynamics of maintaining standing balance, the joint torques used by both older adults and younger adults were less than 20 Nm, well below the available joint torque strengths of both groups. Similarly Hall, Woollacott and Jensen (1999) found no age-related differences in the magnitude or rate of ankle muscle torque produced in response

to balance perturbations. The authors found that torque production was not the primary determinant in the choice of balance response and hypothesised that fear of falling is an important factor and may bias balance response selection in older adults. Contradictory findings by Mackey and Robinovitch (2005) are based on a different methodology. Participants were placed in an inclined standing position and then asked to return to upright stance in order to test strength, or when support was suddenly removed, in order to test speed of response. The authors found that in the older adult the peak ankle torque was 7.7% smaller, reaction time was 27% slower and the rate of ankle torque generation was 16.5% slower when compare to that of the younger adults. While this methodology did enable the authors to determine the relative performance of strength and speed, by returning from an inclined position the calf muscle would be contracting concentrically when in response to a balance perturbation in the community the calf would be contracting eccentrically. An inherent difficulty in testing balance is reproducing real life situations in a laboratory setting.

The relationship between strength and balance could also be examined by investigating the effect of lower limb strengthening on balance or falls. In a systematic review of progressive strength training in older adults, no clear effect was shown on standing balance (Latham et al., 2004). This finding may be due to most progressive strength training studies using machines for strengthening programmes. Weight machines strengthen muscles in isolation, forming a closed kinetic chain which does not allow for postural adjustments or muscle synergies that are used in daily activity (Rutherford & Jones, 1986). However a study which used body weight alone for strengthening also resulted in strength gains in the older adult but no significant decreases in falls (Lord et al., 1995).

It is apparent that strength is a necessary component for balance however the strength required for balance does not have to be maximal, of more importance is that the musculoskeletal system can produce a response that is appropriately timed and of sufficient amplitude to be adequate to the task (Gu et al., 1996). The relationship between strength and falling is unclear.

2.5 Falls Prevention Interventions

The wealth of literature describing randomised controlled trials of interventions to prevent falls is steadily growing, evidenced by the number of trials identified in

systematic reviews. With so many interventions being researched and with growing evidence of the effectiveness of interventions or the lack thereof, Oliver (2004) offers a timely reminder that providing ineffective or harmful interventions is unethical in this day and age of evidence based practice. This section reviews studies that have evaluated different exercise interventions to prevent falls in community dwelling older adults.

2.5.1 Systematic reviews and meta-analysis of interventions

A systematic review uses explicit methods to perform a thorough search of literature to find evidence on a defined health question (Montori, Wilczynski, Morgan, & Haynes, 2003). Chang et al. (2004) conducted a systematic review of the literature from 1992 to 2002 and identified 40 trials published on interventions for preventing falls in elderly people (Chang et al., 2004). The Cochrane Musculoskeletal Injuries Group conducted a literature review on the same topic and initially identified 18 trials and 1 pre-planned meta-analysis (L.D. Gillespie, Gillespie, Cumming, Lamb, & Rowe, 2000), the same group made a substantive update to the review on 14 July 2003 to include 62 trials and 14 studies still awaiting assessment for inclusion (L. D. Gillespie et al., 2005).

A meta-analysis is a statistical process that is typically applied to data compiled through a literature review. It enables data from a number of trials to be pooled and analysed producing a result that is statistically more powerful (Paulson, 2003). Chang et al. (2004) and Gillespie et al. (2005) performed a meta-analysis on the identified trials to assess the effectiveness of interventions to prevent falls in older adults. Chang et al. categorised trials according to intervention and identified these as being: multifactorial assessment and management, exercise, environmental modification and education. The authors concluded that a multifactorial falls risk assessment and management programme was the most effective intervention (adjusted risk ratio 0.82, 95% CI = 0.72 – 0.94), and that exercise was shown to have a beneficial effect on the risk of falling (adjusted risk ratio 0.86, 95% confidence interval (CI) = 0.75 – 0.99). Environmental modification (adjusted risk ratio 0.90, 95% CI = 0.77 – 1.05) and education (adjusted risk ratio 1.28, 95% CI = 0.95 – 1.72) were not statistically significant in their effectiveness to reduce falls. Gillespie et al. did not categorise interventions as broadly as Chang et al. and therefore were able to conduct a more detailed meta-analysis. These authors found that interventions that were likely to be beneficial in preventing falls were:

- Multidisciplinary, multifactorial, health/environmental risk factor screening/intervention programmes in the community both for an untargeted population of older people (pooled relative risk (RR) 0.73, 95% CI = 0.63 – 0.85, and for older people with a falls history or selected because of known risk factors (pooled RR 0.86, 95%CI = 0.76 - 0.98)
- Muscle strengthening and balance retraining, individually prescribed at home by a trained health professional (pooled RR 0.80, 95% CI = 0.66 – 0.98)
- Home hazard modification professionally prescribed for older people with a falls history (pooled RR 0.66, 95% CI = 0.54 – 0.81)
- Withdrawal of psychotropic medication (relative hazard 0.34, 95% CI = 0.16 – 0.74)
- Cardiac pacing for fallers with cardioinhibitory carotid sinus hypersensitivity (Weighted Mean Difference –5.20, 95% CI = -9.40 to –1.00)
- 15 week tai chi exercise group (risk ratio 0.51, 95% = CI 0.36 – 0.73).

The authors also identified interventions that were of unknown effectiveness:

- Group-delivered home exercise

- Individual lower limb strength training

- Nutritional supplementation

- Vitamin D supplementation, with or without calcium

- Home hazard modification in association with advice on optimising medication, or in association with education on exercise and reducing fall risk

- Pharmacological therapy (raubasine-dihydroergocristine)

- Cognitive/behavioural approach alone

- Home hazard modification for older people without a falls history

- Hormone replacement therapy

- Correction of visual deficiency

Brisk walking was identified as an intervention that was unlikely to be beneficial in preventing falls. The Cochrane review (L. D. Gillespie et al., 2005) provides the most useful information as it is the most recent and extensive review. Both meta-analyses found multifactorial interventions were the most effective in preventing falls in the older

adult, followed by exercise interventions. What are not elucidated are the critical components of a multifactorial programme or the specific type and intensity of exercises that are effective.

The Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT) group evaluated the effect of short-term exercise on the prevention of falls and fall-related injuries in the older adult by conducting a pre-planned meta-analysis of different exercise interventions (Province et al., 1995). Spread over seven sites in America, all the FICSIT trials were designed to share certain descriptive (risk adjustment) measures and outcome measures to enable a common set of data on functional, physiological, psychosocial and environmental variables to be gathered (Buchner, Hornbrook et al., 1993). The trials differed in population, intervention type and length of intervention (see Table 1) but all included an exercise component. The FICSIT group categorised exercise components as endurance, flexibility, resistance or balance. The authors discuss the statistical difficulty of evaluating the effects of a single form of exercise as all were tested in combination with other interventions, however the main finding was that general exercise was significant in reducing falls with an incidence ratio of 0.90 (95% CI = 0.81 - 0.99) and that exercise interventions containing a component of balance training, had a significant effect with an incidence ratio of 0.83 (95% CI = 0.70 – 0.98).

There is strong evidence to suggest that exercise is a beneficial intervention to prevent falls in the older adult, however not all forms of exercise are beneficial (L. D. Gillespie et al., 2005) and it is unethical to provide ineffective interventions (Oliver, 2004). In order to deliver exercise that is effective in preventing falls, the type, intensity, duration and frequency of exercise prescribed needs to be evaluated.

Table 1.

Summary of the seven FICSIT studies included in the meta-analysis.

Location	Population	Trial type	Intervention	Groups (N)

Site 1 Portland, OR (Hornbrook, Stevens, & Wingfield, 1993)	1323 community-dwelling, ambulatory subjects & 1)>75 years old 2)>65 years old and a fall in the last month	Two-group RCT	Four months of group sessions of low-level endurance followed by flexibility exercises with education on home safety	C (662) E,F(661)
Site 2 New Haven, CT (Tinetti et al., 1993)	300 community-dwelling, ambulatory subjects at least 75 years old	Two-group RCT	Three months of usual health care + home visits versus usual care + individualised multidisciplinary programme	C (148) R,B,F(153)
Site 3 Seattle, WA (Buchner, Cress et al., 1993)	100 community-dwelling, ambulatory subjects aged 65 to 85 years old with balance deficits and thigh weakness	2x2 factorial RCT	Six months of flexibility training combined with resistance and/or endurance training	C (25) R,F (25) E,F (25) R,E,F (25)
Site 4 San Antonio, TX (Mulrow, Gerety, Kanten, DeNino, & Cornell, 1993)	194 nursing home residents at least 60 years old with some level of functional dependence and not severely impaired cognitively	Two-group RCT	Sixteen weeks of individualised physical therapy and functional activity training	C (97) R,B,F (98)
Site 5 Atlanta, GA (Wolf, Kutner, Green, & McNeely, 1993)	180 community-dwelling, ambulatory subjects at least 70 years old	Three-group RCT	Fifteen weeks of static balance training, Tai Chi or a control group of wellness discussion	C (64) B (64) B (72) Tai Chi
Site 6 Boston, MA (Fiatarone, O'Neill, & Doyle, 1993)	100 nursing home residents at least 70 years old, ambulatory, a high falls risk and no severe dementia	2x2 factorial RCT	Ten weeks of nutritional supplements and resistance training	C (26) R (25) R,N (25)
Site 8 Farmington, CT (Wolfson et al., 1993)	120 community-dwelling, ambulatory subjects at least 75 years old with no cognitive impairment	2x2 factorial RCT	Thirteen weeks of balance and resistance training	C (27) R (27) B (28) R,B (27)

Note. RCT = randomised controlled trial, C = control, E = endurance, F = flexibility, R = resistance, B = balance, N = nutrition.

2.5.2 Exercise interventions

That some form of exercise is recommended in most multifactorial trials, supports the clinical belief of the important role exercise has in preventing falls. To

deliver exercise that is effective in preventing falls, the type, intensity, duration and frequency of exercise prescribed needs to be evaluated. Therefore when discussing the studies evaluating different exercise interventions, the subtlety of the exercise prescribed, the dose and the population participating is of utmost importance.

2.5.2.1 Multidimensional exercise interventions

Multidimensional exercise programmes contain general exercises that would normally be considered to be good for health as well as for strength and balance. Lord, Ward, Williams and Strudwick (1995) assessed the effect of an existing community group multidimensional exercise programme on balance, reaction time, neuromuscular control, muscle strength and rate of falls in a group of women aged between 60 and 85 years. Women were identified from a previous study, during which they had been randomised to an intervention or control group, and then were invited to take part in the exercise trial. The exercise group participated in twice weekly 1 hour sessions for four 10 to 12 week terms, over the course of 12 months, the components of which and the allocated time are summarised in Table 2.

Table 2.

Components of community exercise group (Lord et al., 1995).

Exercise component	Time spent
Warm up (moderate walking with arm movements)	5 minutes
Conditioning period (Aerobic and strengthening exercises (using body weight), activities for balance (static and dynamic), flexibility, endurance, and hand-eye (throwing/catching) and foot-eye coordination)	35 minutes
Stretching (undertaken on a chair or the floor)	15 minutes
Relaxation (a variety of techniques were used)	5 – 10 minutes

At the conclusion of the trial, the exercise group had improved on all strength measures, reaction time, neuromuscular control, body sway on a firm surface and body sway on a compliant surface both with eyes open and closed. The control group showed no significant improvement on any of the measures. No significant difference was found in the proportion of fallers between the two groups. The authors noted a trend toward a dose effect as those who attended more than 75% of classes fell less than

those who exercised less or were control group participants but there was not sufficient data to test this assumption. The authors conclude that the exercise regime was of sufficient duration and intensity to effect change on sensorimotor function but that further studies are required to demonstrate that this exercise programme was an effective means of preventing falls.

Another community based multidimensional exercise programme (Barnett, Smith, Lord, Williams, & Baumand, 2003) assessed similar outcomes but used a population of older adults identified as being at risk of falls by their general practitioner. Participants were block randomised to an exercise or control group. The exercise group participated in a weekly 1 hour exercise session over four terms of a year and received information on falls avoidance strategies. The components of the exercise class are summarised in Table 3. The exercise group was also given a home exercise programme, based on the class content, and an exercise diary. The control group received the same information about falls avoidance but no sham activity. Both groups were similar at baseline with the exception of the sway measure of standing on foam with eyes open, on which the exercise group performed better.

Table 3.

Components of community exercise group (Barnett et al., 2003).

Exercise component	Time spent
Warm up (stretching)	5 – 10 minutes
Functional exercise (sit to stand practice, reaching and weight transference)	No time specified
Balance and coordination exercises (modified Tai Chi, Stepping, changing direction, dance, catching/throwing)	No time specified
Strength work (body weight and resistance bands)	No time specified
Aerobic activity (fast walking practice)	No time specified
Cool down (stretches followed by seated relaxation)	10 minutes

At the conclusion of the trial, the exercise group demonstrated significant improvement in some balance measures however there was no difference between the exercise and control groups in strength, reaction time, walking, Short-Form 36, Physical Activity Scale for the Elderly or fear of falling scales. The rate of falls was 40% lower for the exercise group when compared to the control group (IRR = 0.60, 95% CI = 0.36

– 0.99). In comparison to the intervention evaluated by Lord et al. (1995) trial, Barnett et al. (2003) had a greater focus on balance activities and participants were encouraged to practice in their home environment by being given a home programme, although it is not stated how often participants were asked to exercise at home. The participants may have learnt more about their own limits of stability as they practiced balance activities and therefore challenged those limits less during daily activities, resulting in fewer falls. Another possible explanation for the significant decrease in falls yet modest or no change in physical measures is that small changes may summate to result in functional improvements that may not be detected by clinical measures (A. J. Campbell, 2002; Nelson et al., 2004).

Hauer et al. (2001) targeted a frailer population to assess the effect of an outpatient strength, balance and functional performance programme on strength, functional ability, motor function, psychological parameters and fall rates. Participants who had fallen or had a history of recurrent fall were recruited for the trial on discharge from hospital. Participants were randomised into the exercise or control group. Due to orthopaedic problems that had resulted from previous falls, both groups received identical physiotherapy twice a week for 25 minutes but with any form of strength or balance training excluded. Both groups participated in their respective interventions three times a week for three months. The control group participated in 1 hour of seated placebo activities (flexibility exercises, calisthenics, ball games and memory tasks) and the exercise group participated in activities as summarised in Table 4.

Table 4.

Components outpatient exercise group (Hauer et al., 2001).

Exercise component	Time spent
Warm up (stationary cycling at a minimal workload)	10 minutes
Resistance training (load increased at each session – as tolerated)	1.5 hours
Progressive functional-balance training (static and dynamic including dance and basic forms of Tai Chi)	45 minutes

At the conclusion of the trial exercise participants demonstrated significant increases in strength, functional motor performance and balance as well as reduced fall-related behavior and emotional restrictions. The control group demonstrated no change in any of the outcome measures. There was no statistically significant reduction in the

incidence of falls between the exercise and control group of 25% (relative risk = 0.753, 95% CI = 0.455 – 1.245). Compared to the previous 2 studies (Barnett et al., 2003; Lord et al., 1995) this exercise group intervention was of a greater time duration, more times per week and loaded towards strength training. The population was also frailer. The finding of increased strength but no decrease in falls is congruent with the findings of Latham et al. (2004) that progressive resistance training may not be effective in decreasing falls.

Shumway-Cook, Gruber, Baldwin and Liao (1997) recruited subjects from an even frailer population to assess the effect of a multidimensional programme on balance, mobility and falls risk using a quasi-experimental, nonequivalent control group design. Subjects over the age of 65 years with a history of two or more falls in the previous 6 months and who were involved in a community exercise programme were invited to participate. Two exercise groups were identified on a post hoc analysis of adherence to the exercise programme. The fully adherent exercise group participated in outpatient physical therapy sessions twice per week for 8 to 12 weeks and exercised 5 to 7 days per week at home. The partially adherent exercise group participated in less than 75% of their therapy sessions and exercised at home fewer than 4 days per week. A nonequivalent control group of volunteers with a history of falls were included, this group received no intervention. Each participant in the exercise groups was individually assessed and then received an individualised multidimensional exercise programme. All exercises were designed to improve balance and mobility and were progressed as appropriate. Participants in both exercise groups demonstrated a significant improvement in balance ($p < .001$) and in mobility ($p < .001$) when compared to the control group. The differences between the two exercising groups in measures of balance and mobility were not statistically significant and therefore the amount of exercise required to improvement remains unclear. There was a significant difference in falls risk reduction between the three groups ($p < .001$) which suggests a dose effect similar to the finding of Lord et al. (1995). Falls risk decreased by 33% in the fully adherent exercise group, by 11% in the partially adherent exercise group and increased by 8% in the control group.

Multidimensional exercise interventions vary as much in their effectiveness in reducing falls, as they do in their exercise composition. A dose effect of more exercise participation resulting in less falls was demonstrated in two studies (Lord et al., 1995; Shumway-Cook, Gruber et al., 1997) and is consistent with the guidelines for strength

training in the older adult (American College of Sports Medicine, 1998). Although there is strong evidence that multidimensional exercise is beneficial in preventing falls it remains unclear as to what exercise type and intensity is most effective in preventing falls.

2.5.2.2 Single exercise interventions

Single exercise interventions evaluate the effectiveness of a specific exercise approach on falls prevention.

Balance exercise

Nitz and Low Choy (2004) used a work station format to evaluate the effect of balance exercises on preventing falls. Independent, community-dwellers who were 60 years or older with a history of a fall in the previous year were invited to participate in weekly 1 hour treatment sessions for 10 weeks. A physiotherapist and one or two final year physiotherapy students supervised exercise groups of no more than 6 participants. The work station format (see Table 5) was considered by the authors to be superior to a community balance group as the exercises were able to be more challenging and appropriately progressed due to the close supervision the participants received. The control group participated in a sham exercise class (see Table 6) in which activities were progressed by increasing the speed and the combinations of movements. Participants in both groups received a booklet on reducing the risk of falls at home and a falls diary.

Table 5.

Balance group activities (Nitz & Low Choy, 2004).

Exercise component	Response targeted
Sit-to-stand-to-sit	Lower limb strength; Functional ability; Multiple tasks
Stepping in all directions	Reaction time; Lower limb strength & coordination
Reaching to limits of stability	Challenging limits of stability; Vestibular stimulation and integration; Upper & lower limb strengthening
Step up and down	Lower limb strengthening and endurance; Reaction time
Ankle, hip, and upper limb balance strategy practice	Lower limb strengthening; Balance strategy training
Sideways reach task	Medio-lateral muscle strengthening in lower limbs; Vestibular stimulation and integration; Challenging limits of stability; Multiple tasks and confounded proprioceptive input
Ball games	Multiple tasks; Hand-eye coordination; Vestibular stimulation; Ballistic upper and lower limb activity
Card treasure hunt/sort into suits	Coping strategies with visual conflict; Vestibular stimulation and challenge of limits of stability

The authors found a main effect for falls reduction ($p < .001$) for both groups with no significant difference between the two groups. A possible reason for this finding may be that the exercises were not dissimilar enough, with respect to balance training, for a population with a history of falls. The control group exercises were all performed in standing, thereby challenging postural stability as the amplitude and speed of arm movements increased, and dynamic balance with the stepping exercises. Performing the control group exercises in sitting may have been a sufficient difference to result in significant difference between the groups. Both groups also received the same education booklet, a group that received just the education booklet would have enabled the authors to determine whether education alone had an effect on reducing the participants' falls.

Table 6.

Control group activities (Nitz & Low Choy, 2004).

Activity	Time spent
Warm up (walking on the spot, stretches for upper and lower limbs in sitting and standing)	5 minutes
Marching forwards, backwards and to the sides Standing still flexing and extending elbows Lifting arms alternately above the head then around the body Marching on the spot adding in upper limb movements Stepping forwards adding in upper arm movements	12 minutes
Rest and water stop	5 minutes
Hip extension and abduction whilst holding onto a chair Stepping sideways with arm swings to abduction or reaching above head Sitting alternate leg straightening with reciprocal arm bends Alternate hip flexion and reaching above head Marching forwards and backwards with arm circles	12 minutes
Warm-down, gentle stretching and walking on the spot	5 minutes

Tai Chi

Tai Chi is a form of traditional Chinese exercise that is centuries old. It emphasises slow, continuous movement and through the practice of forms incorporates dynamic balance, postural control and weight shift. It is classified as a moderate level of exercise with respect to intensity and is low impact (Verhagen, Immink, van der Meulen, & Bierma-Zeinstra, 2004). A recent systematic review on the efficacy of Tai Chi Chuan in older adults (Verhagen et al., 2004) identified 9 studies which met the inclusion criteria, 3 of which were concerned with the same study. The outcome measures used varied greatly between the studies and only Wolf et al. (1996) included reduction in falls as an outcome measure. Due to this variation of outcome measures the authors did not pool statistics and concluded that more randomised controlled trials are required in order to evaluate the effectiveness of Tai Chi falls prevention. The Atlanta FICSIT group found that participants in the Tai Chi group significantly reduced their falls risk by 47.5% (risk ratio = 0.525, p = .01). However if the Tai Chi group participants had fallen in the year prior to entering the study their fall risk actually elevated (risk ratio = 0.611, p = .0003). The authors conclude that Tai Chi may be beneficial in preventing falls in older adults but that more research is required to provide strong evidence.

Strength training

Buchner et al. (1997) compared the effect of 3 types of exercise on gait, balance, physical health status, falls risk and use of health services in older adults. One of the FICSIT trials, this study included a population of community dwelling 68 to 85 year olds that had been assessed as weak or having a mild balance deficit. Participants were randomised to a strengthening group, an endurance group, a combined strengthening and endurance group or a control group. All interventions (except the control group) were supervised group exercise (see Table 7) which lasted for 1-hour three times a week for between 24 to 26 weeks. All exercise sessions began with a 10 to 15 minute warm up period and ended with a 5 to 10 minute cool down period. The control group was advised to continue with their usual activities. After 6 months, the strengthening group demonstrated significant increases in isokinetic strength in all muscle groups except the ankle. The combined endurance and strength group increased in strength but only reached statistical significance at the knee. The endurance group strengthened only at the knee. There was no significant difference in any of the gait and balance measures or measures of physical health in any of the intervention groups. These results raise the question of the whether strength training programmes result in changes in functional performance.

Table 7.

Seattle FICSIT trial exercises (Buchner et al., 1997).

Exercise group	Exercise component	Time
Endurance training	Stationary cycle that is propelled by both arms and legs at 75% of heart rate reserve.	30 – 35 minutes
Strength training	Weight machines (leg press, leg extension, leg curl, hip adduction and abduction, rotary torso, incline press and rowing)	No time given but did 2 sets (10 repetitions) of each machine
Endurance and Strength training	Endurance training Strength training	20 minutes 1 set of each machine

In the Buchner et al study exercise was found to have a protective effect on the risk of falling (relative hazard = 0.53, 95% CI = 0.30 – 0.91) with 42% of exercise participants reporting a fall compared to 60% of control subjects in the year following randomisation. This finding should be interpreted with some caution as the fall rates for the exercise group in the 1 year prior to exercise was established by questioning the

participants. The exercise group had a fall rate of 22% which is considered low for this older adult population and may reflect the difficulty in recall of falls in the previous year. Similar to the strengthening studies reviewed by Latham et al. (2004) the apparatus used for strength training in this study were weight machines and so postural responses during the task would have been limited by the amount of support the machine was providing. Similarly the task used for endurance training was an exercycle not walking on a treadmill which may have incorporated more dynamic balance in the task.

Schlicht, Camaione and Owen (2001) investigated the effect of intense strength training on functional ability in relation to risk of falling. Participants aged 60 years or older were randomised to a control group or exercise group, which participated in an intense 3-days per week, 8-week strength training programme. Organised warm-up or stretching activities were excluded from the training programme so as not to introduce different forms of exercise into the study. After a 2 week period of acclimation, training levels were set at 75% of each participant's 1 repetition maximum for each exercise. The outcome measures used were muscle strength (1 repetition maximum for each exercise), maximal gait velocity, 5-repetiton sit-to-stand and 1-legged stand with eyes closed. Strength was significantly better in the strength training group for all the exercises when compared to the control group ($p < .017$) as was gait velocity [$F (1,19) = 5.03, p < .05$]. There were no significant differences between the training and control group for 1-legged stand [$F (1,19) = 0.82, p > .05$] or 5-repetiton sit-to-stand performance [$F (1,19) = 0.068, p > .05$]. The use of weight machines for strengthening exercises may be the reason why gains were not made in these two measures. Typically a weight machine supports and isolates the muscle being strengthened so no postural control is required during the strengthening task. A leg extension exercise is also dissimilar to the weight shift and movement of the centre of gravity that occurs when a person moves from sit to stand, more than pure strength is involved as muscles must work in synergy and as such task specific training is considered more beneficial (Rutherford & Jones, 1986). Schlicht et al. propose that older adults can safely perform high intensity weight training which is contradictory to the finding of Latham et al. (2004) that adverse events, predominantly musculoskeletal in nature, were evident in many trials of progressive resistance training in older adults. The review by Latham et al. of trials evaluating the effect of progressive resistance training in older adults, found no clear effect on measures of standing balance (standardized mean differences 0.11;

95% CI = -0.03 – 0.25) and insufficient data from trials to allow an adequate assessment for the effect on fall risk.

That an exercise regime using intense weight training did not affect balance is not surprising. To improve balance you have to practice it. Most these studies use weight machines that supported the patient and strengthened muscles in isolation, preventing the body's normal postural control from having to stabilise the core while moving the periphery, essentially a self perturbation. Current evidence points to progressive resistance training to be of questionable benefit in reducing falls in the older adult.

2.5.3 Section Summary

That exercise is effective in decreasing the risk of falls is increasingly supported in the literature. What remains unclear is the exercise type, frequency, intensity and duration which is most effective. Programmes that are multidimensional and include a balance exercise component appear to be the most effective in reducing the risk of falls. The population at which the intervention is targeted is also critical. Studies have used populations ranging from very frail (targeted) to independent community dwellers (untargeted) and it appears that those older adults who are at the greatest risk are those that are most likely to benefit from a falls prevention intervention rather than delivering a blanket intervention across a population. Such an approach would ensure that limited health care resources would be delivered to those most likely to benefit from the intervention.

2.6 The Otago Exercise Programme

A falls prevention programme designed to address the modifiable falls risk factors of decreased balance and weakness was developed by the New Zealand Falls Prevention Research Group (Gardner, 1997). The Otago Exercise Programme (OEP) is an individually prescribed, year long, home-based muscle strengthening and balance retraining exercise programme. The exercises increase in level of difficulty and are structured as level 1, 2, 3 or 4. The balance retraining exercises are progressed by decreasing the amount of hand support used and the number of repetitions completed, while strengthening exercises are progressed by the amount of weight used and the number of repetitions completed (Gardner, Buchner, Robertson, & Campbell, 2001).

The OEP was developed and refined from 4 clinical trials involving 1, 016 community dwelling men and women aged between 65 and 97.

The first Otago trial (A. J. Campbell et al., 1997) targeted community dwelling women over the age of 80 and recruited them through general practices. Women were randomised to an exercise group or a control group. The exercise group received four home visits from a physiotherapist over the first 2 months on the OEP to individually prescribe the exercise programme. The exercises are summarised in Table 8 and also included a walking plan. The exercises took 30 minutes to complete and the women were asked to do the exercises at least three times a week and to walk outside three times a week. After the initial visits, regular telephone contact was maintained for the rest of the year to motivate those in the exercise group. The control group received usual care and social visits to match the number of home visits the exercise group received.

Table 8.

Otago Exercise Programme exercises (A. J. Campbell et al., 1997).

Active range of movement exercises	Neck rotations, hip and knee extensions
Strengthening exercises – using an ankle cuff weight (0.5kg or 1 kg)	Target muscle groups: hip extensors and abductors, knee flexors and extensors, inner range quadriceps and ankle plantar and dorsiflexors
Balance exercises	Tandem stance; tandem walking; walking on toes and walking on heels; walking backwards, sideways and turning around; stepping over an obstacle; bending and picking up an object; climbing stairs at home; sit to stand; knee squat

The physical measures used to assess strength, balance, gait and endurance were the functional reach test, 4-test balance scale, knee extensor strength, 5 chair stand test, gait velocity, time taken to climb up and down a set of 4 steps. Health was assessed using the instrumental activities of daily living scale, physical self maintenance scale, fear of falling and the physical scale for the elderly. Falls, fall related injuries and exercise compliance were monitored by a postcard calendar that was returned to the researchers at the end of each month. The physical measures were reassessed after six months and showed an improvement in the exercise group's 4-test balance scale when compared to the control group (mean changes 0.42 +/- 0.86 and –0.01 +/- 0.80) respectively; difference 0.43; 95%CI = 0.21 – 0.65). The exercise group also had a greater proportion of improvement in the 5 chair stand test (relative risk = 1.4.1; 1.07 –

1.87). The authors state that no other physical assessments demonstrated differences between the two groups but did not publish the statistical data on which they based this statement. The mean rate of falls per year was lower in the exercise group than the control group (0.87 (1.29) and 1.34 (1.93) respectively; difference 0.47; 95% CI = 0.04 – 0.90) and the control group fell more over the year than the exercise group (152 falls versus 88 falls). After a year 42% of the exercise group were completing the exercises three or more times a week. The control group had become less active (mean –11.0 +/- 22.3 versus –4.6 +/- 22.9); difference 6.4; 0.2 – 12.6) and had increased their fear of falling (mean –6.1 +/- 12.2 versus –2.5 +/- 11.1; difference 3.6; 0.4 – 6.8). The authors state that there was no difference between the exercise group and control group for the instrumental activities of daily living or the physical self maintenance scale but did not publish the statistical data on which they based this statement. The authors may have made a Type I error by applying so many outcome measures, as there is a high possibility of at least one measure resulting in a statistical significant finding (M. J. Campbell & Machin, 1999) leading to the interpretation of the OEP being effective in increasing balance. As the authors have chosen not to publish the statistical analysis of the other measures it is not possible for a reader to make their own interpretation of the authors' results.

The second Otago trial (A. J. Campbell et al., 1999a) was an extension of the first to assess the effectiveness of the OEP over 2 years. From the original participants 69% of the exercise group and 74% of the control group agreed to continue in the study. The physiotherapist maintained telephone contact during the second year to motivate the exercise group. The outcome measures used in this trial solely assessed falls and compliance. Falls, fall related injuries and exercise compliance were monitored by a postcard calendar that was returned to the researchers at the end of each month. After the end of the second year 44% of the exercise group were still exercising. The exercise group reported fewer fall than the control group (138 falls versus 220 falls) over the 2 years and the rate of falls in the exercise group for 2 years was similar to that for 1 year. The difference between the two groups for rate of falls was a significant (exercise group 0.83 falls per person year versus control group 1.19 falls per person year). After two years the relative hazard for falls for the exercise group compared to the control group was 0.69 (95% CI = 0.49 – 0.97). The maintenance of a similar rate of falls over a 2 year period in the exercise group reflects the effectiveness of the programme in preventing falls. As no physical outcome measures were repeated in the second trial, it

is not possible to ascertain whether strength and balance improved over a 2 year period so the mechanisms by which the OEP prevents falls remain unclear.

The third and fourth trials were designed to assess the effectiveness of different models of OEP delivery and the cost effectiveness. District nurses delivered the OEP from community health service bases to men and women over 75 years in one trial (Robertson, Devlin et al., 2001) and practice nurses delivered the OEP to men and women over 80 years in the other (Robertson, Gardner et al., 2001). All the nurses were trained and supervised by a physiotherapist. The OEP exercises were the same as the first trial but the delivery had been altered slightly to include home visits on weeks 1, 2, 4, and 8 with a "booster" visit at six months. The 6 month visit was one of the recommendations from the second Otago trial (A. J. Campbell et al., 1999a) to not only maintain enthusiasm in the OEP but also to progress the exercises. Heavier leg weights were also used with some participants (1, 2 and 3kg, range 0 – 6kg). While the participants were still asked to do the prescribed exercises three times a week, they were only asked to walk twice a week. On the months that there was no home visit scheduled participants received a phone call. Falls, fall related injuries and exercise compliance was monitored using a postcard calendar that was returned to the researchers at the end of each month. The control group received usual care.

The district nurse delivered OEP resulted in a 46% reduction of falls in the exercise group compared to the control (IRR = 0.54, 95% CI = 0.32 – 0.90). The authors found no differences in falls in OEP group and control group participants aged 75 to 79 years but a reduced number of falls in OEP group participants over the age of 80 years compared to the control group participants (43 versus 81, p = 0.007). The practice nurse delivered OEP resulted in a 30% of falls in the exercise group compared to the control group (IRR = 0.70, 95% CI – 0.59 – 0.84) which was similar for both men and women. The cost of delivering the OEP using practice nurses was slightly cheaper (NZ$ 418 per person) than using district nurses (NZ $432 per person). The incremental cost per fall prevented was NZ$1803 for the district nurse delivered OEP and NZ $1519 for the practice nurse delivered OEP.

The results from these trials add to the evidence of the effectiveness of the OEP in decreasing falls. The OEP was just as effective whether delivered by a physiotherapist or a nurse trained and supervised by a physiotherapist. The implications of this finding are that a much larger workforce is available to deliver the OEP, for

example in New Zealand there are 1471 physiotherapists working in New Zealand (New Zealand Health Information Service, 2005) but 37,408 registered nurses (Nursing Council of New Zealand, 2005). In economic terms the OEP trials support prevention being cheaper than the results of a fall in health resource cost and use.

Robertson et al. (2002) performed a meta-analysis of all the Otago trials including data from a trial assessing the effect of psychotropic medication withdrawal and home based exercise in reducing falls (A. J. Campbell, Robertson, Gardner, Norton, & Buchner, 1999b). The authors found that the exercise programme was effective in reducing falls by 35 % (IRR = 0.62, 95% CI = 0.57 – 0.75) and serious or moderate falls injuries by 35% (IRR = 0.65, 95% CI = 0.53 – 0.81). The authors also found that the probability of falling was lower in the OEP participants (odds ratio = 0.67, 95% CI = 0.56 – 0.79). Women were over represented in the meta-analysis (75% of the exercise group and 79% in the control group), however men and women were found to benefit equally from the programme (IRR for falls in women compared with men = 0.99, 95% CI = 0.78 - 1.25). The authors' proposition that participants over the age of 80 with a history of a previous fall benefited significantly more than participants aged 65 to 79 should be interpreted with caution. Adults over the age of 80 were over represented in the meta-analysis (80%) due to three of the trials excluding adults under the age of 80 (A. J. Campbell et al., 1999a; A. J. Campbell et al., 1997; Robertson, Gardner et al., 2001). Based on the statistic of the number of falls prevented for each age group receiving the programme (falls prevented per 100 person years for participants over the age of 80 = 54.0 versus 5.4 for participants aged 65 – 79) there is a significant difference and for those aged over 80 with a history of falls (falls prevented per 100 person years for participants over the age of 80 with no previous falls = 54.0 versus 25.8 with a previous fall). However the ratio of the IRRs for falls between the age groups receiving the programme was not significant (ratio of IRRs for falls = 0.65, 95% CI = 0.38 – 1.12, p = .120).

The evidence from the Otago trials and meta-analysis helps to define a population in which exercise may be more effective but the question remains as to what is the critical component of an exercise programme in falls prevention. After the first trial, the authors reduced the physical assessments to two, the 5 chair stand test and the 4 test balance scale. Although the results of these two outcome measures were not reported in the individual trial publications (A. J. Campbell et al., 1999a, 1999b; A. J. Campbell et al., 1997; Robertson, Devlin et al., 2001; Robertson, Gardner et al., 2001)

the meta-analysis states that they were used in all the trials (Robertson et al., 2002). The measures were applied after 6 months in the first two trials and after 1 year in the second two trials. The meta-analysis reports that the exercise group improved on both tests and the control group stayed the same, but the authors do not report any statistical analysis other than the difference between the groups at follow up (4-test balance scale 95% CI = 0.2 (0.0 – 0.5; 5 chair stand test 95% CI = -1.8 (-2.8 to –0.8). The assumption from a lack of reported statistical significance is that there was none. The authors offer no explanation other than to say that although the strength and balance improvements were not large, small gains may be important in those near to losing independent function.

The current study aims to evaluate the effect of participation in the OEP on strength and balance by applying a different set of outcome measures to those used in the original Otago trials. The final version of the OEP (see Tables 9 and 10) was comprised of 5 warm up exercises, 5 strengthening exercises and 12 balance retraining exercises that were recommended to be completed three times a week and a walk twice a week (Accident Compensation Corporation, 2003). The exercise manuals were provided free of charge to registered health providers by the Accident Compensation Corporation (ACC) of New Zealand (a government funder of treatments secondary to accidents). Thus the OEP was rolled out as a national injury prevention in 2003 (K. Holt, personal communication, 3 March, 2005) based on the evidence that the OEP significantly decreased the rate of falls and fall injuries in older adults (Robertson et al., 2002). The current study will recruit participants from older adults who have been referred by their general practitioner to the OEP in West Auckland.

Table 9.

The OEP strengthening exercises (Accident Compensation Corporation, 2003)

Strengthening exercises

Knee extensor (front knee strength)	ALL 4 LEVELS Ankle cuff weights are used to provide resistance to the muscles and 10 repetitions of each exercise are carried out	
Knee flexor (back knee strength)		
Hip abductor (side hip strength)		
Ankle plantarflexors (calf raises)	LEVEL A 10 repetitions, hold support, repeat	LEVEL D 10 repetitions, no support, repeat
Ankle dorsiflexors (toe raises)	10 repetitions, hold support, repeat	10 repetitions, no support, repeat

Table 10.

The OEP balance retraining exercises (Accident Compensation Corporation, 2003)

Balance retraining exercises

	LEVEL A	LEVEL B	LEVEL C	LEVEL D
Knee bends	10 repetitions Hold support	i) 10 repetitions, no support or ii) 10 repetitions, hold support repeat	10 repetitions, no support, repeat	3 x 10 repetitions No support
Backwards walking		10 step, 4 times. Hold support		10 step, 4 times. No support
Walking and turning around		Walk and turn around (make figure of 8) twice. Use walking aid	Walk and turn around (make figure of 8) twice. No support	
Sideways walking		10 step, 4 times. Use walking aid	10 step, 4 times. No support	
Tandem stance (heel toe stand)	10 seconds Hold support	10 seconds No support		
Tandem walk (heel toe walk)			Walk 10 steps Hold support, repeat	Walk 10 steps No support, repeat
One leg stand		10 seconds, hold support	10 seconds, no hold	30 seconds, no hold
Heel walking			10 step, 4 times. Hold support	10 step, 4 times. No support
Toe walk			10 step, 4 times. Hold support	10 step, 4 times. No support
Heel toe walking backwards				Walk 10 steps No support, repeat
Sit to stand	5 stands, 2 hands for support	i) 5 stands, 1 hand or ii) 10 stands, 2 hands for support	i) 10 stands, no support or ii) 10 stands, 1 hand for support, repeat	10 stands, no support Repeat
Stair walking	As instructed	As instructed	As instructed	As instructed

2.7 Clinical measures

Testing a muscle in isolation to grade pure strength may not reflect an individual's ability to use a muscle functionally. During strength testing timing of contraction should be considered as well as the mode of muscle contraction used during a task (Chandler, Duncan, & Studenski, 1997). The strength thresholds below which functional tasks become impossible has not yet been identified (Skelton et al., 1994) but for an older person to maintain independence in their own home, the ability to mobilise and to transfer out of chair are basic tasks that are essential. Hence standardised tests of performance measures are widely used in research in the older adult as they reflect the interaction of performance ability with an individual's environment (Guralnik et al., 2000). Therefore the outcome measures chosen to assess change in strength and balance in this study are functional, task specific measures.

2.7.1 The step test

The step test (Hill, Bernhardt & McGann, 1996) is a measure of dynamic standing balance. The participant steps one foot up and down onto a 7.5cm step as many times as able in 15 seconds. This is completed with both the left foot and the right foot. This test was found to have high retest reliability in healthy older patients (ICC > 0.90) and to have concurrent validity with a significant correlation with scores on the Functional Reach test, gait velocity and stride length (Hill, Bernhardt, McGann et al., 1996). The step test appears to be sensitive to mild levels of balance dysfunction but have a floor effect on patients with severe dysfunction (Hill, Miller, Denisenko, Clements, & Batchelor, 2001). The greater the number of steps completed the better is the participant's dynamic standing balance. Differing normative scores for older adults have been published. Hill et al. (1996) established 17 steps in 15 seconds as a normative score for healthy older adults (men and women) over the age of 65 years (mean age 72.5 years, n = 41). Two studies refined the normative score by assessing only healthy, community dwelling older women (Hill, Schwarz, Flicker, & Carroll, 1999; Isles, Low Choy, Steer, & Nitz, 2004). Isles et al. (2004) used a higher step of 8.5 cm and had no women over 80 years in their study, they published a normative score of 13 steps in 15 seconds for women aged 70 – 79 (n = 91). Hill et al. (1999)

published a normative score of 13 steps for women over the age of 80 (n = 9). A significant age effect has been noted in the test (Isles et al., 2004) because of this the normative score used in this study will be 13 steps in 15 seconds as published by Hill et al. (1999) as although the sample was small, it was the only study that included women over the age of 80 .

2.7.2 The timed up and go test

The timed up and go test is a balance test designed to measure functional mobility in community dwelling, frail older adults (Podsiadlo & Richardson, 1991). The test requires the participant to stand from a chair with arms, walk 3 metres, turn around and return to sitting. The authors found this test to have high retest reliability in healthy older patients (ICC = 0.92) and high inter-rater and intra -rater reliability (ICC = 0.99 for both). The test also had concurrent validity correlating strongly with the Berg Balance scale (r = - 0.81), gait velocity (r = - 0.61), and Barthel Index (r = - 0.78) (Podsiadlo & Richardson, 1991). The timed up and go test has been found to be sensitive (87%) and specific (87%) for identifying community dwelling elderly individuals prone to falling (Shumway-Cook et al., 2000), however another study found specificity to 95% and sensitivity to be only 10% (Trueblood, Hodson-Chennault, McCubbin, & Youngclarke, 2001). The authors were able to improve the specificity to between 63% and 87% by lowering the cut off point from 20 seconds to 10 – 12 seconds. The original timed up and go test study established a normative score < 20 seconds for independent community dwelling older adults but included participants with neurological dysfunction (Podsiadlo & Richardson, 1991). A number of studies have attempted to establish a cut off point to indicate a high risk of falls in healthy community dwelling older adults (Bischoff et al., 2003; Hill et al., 1999; Isles et al., 2004; Shumway-Cook et al., 2000; Steffen, Hackner, & Mollinger, 2002; Trueblood et al., 2001) resulting in a cut off points ranging from 8 to 15 seconds. The cut off point used in this study is 12 seconds based on the findings from two studies (Bischoff et al., 2003; Trueblood et al., 2001) that used large samples (n= 413 and 160) of community dwelling women with ages that ranged up to 85 and 90 years respectively.

2.7.3 Gait velocity

Gait velocity is a performance measure of walking as well as reflecting lower limb strength (Bohannon, 1986; Menz, Lord, & Fitzpatrick, 2003; Schiller et al., 2000). Gait velocity has been found to be correlated to strength of the hip extensor (r = 0.595),

knee flexor (r = 0.466), ankle dorsiflexor (r = 0.559) and ankle plantar flexors (r = 0.468) (Bohannon, 1986). Further studies support a curvilinear relationship between gait velocity and lower limb strength (M. Brown, Sinacore, & Host, 1995; Buchner, Larson, Wagner, Koepsell, & de Lateur, 1996; Ferrucci et al., 1997). These studies suggest an association between gait velocity and lower strength.

Gait speed assessment has been found to be sensitive and specific (Fransen, Crosbie, & Edmonds, 1997) and to have test-retest reliability (ICC = 0.96) (Rome, Batey, Finn, & Hanchard, 2003). However the method used to measure gait speed has been found to influence these factors (Rigler, Studenski, & Wallace, 1997), with longer distances measuring endurance (Steffen et al., 2002) and cardiovascular fitness (Himann, Cunningham, Rechnitzer, & Paterson, 1988). An issue when testing gait velocity in people's homes is using a distance to measure participants over which is feasible (Guralnik et al., 2000). Worsfold and Simpson (2001) standardised a 3 metre gait velocity test for use in people's homes and suggested that even this distance may be too long to find in some homes. The method described by Worsfold and Simpson of timing a participant over the middle 3 metres of a 4 metre walkway to avoid the effects of acceleration and deceleration was found to have excellent repeatability (ICC = 0.97, 95% CI = 0.96 – 0.98) and was the method used in this study.

Gait velocity is important for community ambulation, as a person must be able to walk fast enough to cross the road while the pedestrian signal is on. In New Zealand the Land Transport Safety Authority calculates the pedestrian clearance signal from a pedestrian speed of 1.2 m/s (National Association of Australian State Road Authorities, 1987a). Established normative values for gait speed ranged from 0.58 m/s (Ferrucci et al., 1997) to 1.27 m/s (Bohannon, 1997). This study used the normative value for gait speed of 1.27 m/s for women in their 8th decade as it was the closest of the published gait velocities to that needed to cross the road. Simpson, Valentine and Worsfold (2002) suggested that an improvement of 36% in gait velocity was clinically meaningful. Although the sample consisted of adults with a mean age of 81.98 years and a mix of independently mobile adults (46%) and adults mobilising with a walking stick (33.3%) or walking frame (19.8%) an increase of 36% appears quite large. Especially in the light of a possible curvilinear relationship between gait velocity and lower limb strength as one would expect a weaker, slower adult to show a greater improvement than a stronger, faster adult.

2.7.4 The 30 second chair stand test

The 30 second chair stand test is designed to assess lower limb strength in older adults during a functional task (Jones, Rikli, & Beam, 1999) and has also been suggested that it may be an appropriate measure of lower limb endurance in older adults who are community dwelling (McCarthy, Horvat, Holtsberg, & Wisenbaker, 2004). The participant is asked to stand fully and sat down as many times as possible in 30 seconds from a chair (43.2 cm) without arms, with their arms crossed at the wrist and held against the chest. This test was developed from the 5 stand and 10 stand tests as both of these exhibited a floor effect (Guralnik et al., 1994). By timing the number of stands over 30 seconds, it is possible to assess wide variations in levels of ability. Jones, Rikli and Beam (1999) found this test to be reliable ($r = 0.84$) and valid ($r = 0.71$), with a moderate correlation to weight adjusted 1-repetition maximum leg-press strength. Normative values for this test were established from testing over 7,000 men and women aged 60 to 94. The resultant normative scores are reported separately for men and women in 5 year intervals (Rikli & Jones, 1999). While sit to stand tests are often used as proxy indicators of lower limb strength, it has been demonstrated that these tests are multidimensional due to performance variance not being completely accounted for by lower limb strength but also sensorimotor, balance and psychological parameters (Lord, Murray, Chapman, Munro, & Tiedemann, 2002; McCarthy et al., 2004). However as a precursor to walking the assessment of sit to stand is important in older adults and remains important however interpretation of results should consider these other parameters and not strength alone.

2.7.5 The Modified Falls Efficacy Scale

Fear of falling is a form of anxiety that a person may feel in relation to knowing the consequences that result from a fall. The person may not have actually fallen themselves but have heard or seen how a fall has effected someone else (Cumming, Salked, Thomas, & Szonyi, 2000; Delbaere, Crombez, Vanderstraeten, Willems, & Cambier, 2004; Tinetti, Mendes de Leon, Doucette, & Baker, 1994). If a person is fearful of falling, they are at a greater risk of falling and vice versa, as each is a predictor of the other and share the same predictors (Friedman, Munoz, West, Rubin, & Fried, 2002). Fear of falling can be established by simply asking a person if they are afraid of falling however due to judgment differences between individuals such dichotomy can be imprecise. Tinetti, Richman and Powell (1990) operationalised fear

of falling to be defined as low perceived self-efficacy in performing activities without falling and then developed a tool to measured fall-related self-efficacy. Recent work has identified fear of falling and fall–related self–efficacy as different concepts and caution that they should not be used interchangeably, however fall–related self–efficacy does play a mediational role in the effects of fear of falling on functional ability (Li et al., 2002).

The Falls Efficacy Scale (Tinetti et al., 1990) consisted of 10 questions related to activities of daily living, each of which were scored on a 10-point continuum (see Appendix B). The resultant score was the sum of each score of the 10 activities, with a possible range of 10–100. The Falls Efficacy Scale demonstrated good internal consistency ($\alpha = .91$), test-retest reliability ($r = .71$) and construct validity (Tinetti et al., 1990) however it did not include any outdoor activities making it less sensitive in more active older adults. Hill, Schwarz, Kalogeropoulos and Gibson (1996) created the Modified Falls Efficacy scale by adding four outdoor activities to Tinetti et al.'s original questionnaire, reversing the response scale and increasing it to an 11-point continuum, and presenting the continuum alongside a visual analogue scale. The authors found the new scale to have high internal consistency (Cronbach's alpha .95) and high retest reliability (ICC (3,1) = .95). A systematic review of the literature from 1966 to July 2003 for measures of the psychological outcomes of falls identified only two studies that had published evidence on the properties of the Modified Falls Efficacy Scale (Jørstad, Hauer, Becker, & Lamb, 2005). Jørstad et al. rated the scale as having evidence of reliability rating between good and adequate, and weak evidence of both validity and responsiveness. The authors suggest that research reporting the psychometric properties of the Modified Falls Efficacy Scale may not yet be available due to the recent development of the scale. However they propose that the self efficacy measures may be superior to fear of falling measures due to their grounding in social cognitive theory and the research base supporting this theory.

The Modified Falls Efficacy Scale is used in this study to measure the change in participants' confidence in completing daily activities without falling.

2.7.6 Fall diaries

A fall diary is a calendar on which a person records any falls that occur. Older adults demonstrate poor recall of falls over periods as short as 3 months and greater accuracy when recalling falls over a period of 12 months (Cummings et al., 1988; Hale,

Delaney, & Cable, 1993). Therefore by recording falls as they occur, if they remember to, a more precise fall history can be obtained. Although fall diaries are now commonly used in studies to monitor falls (A. J. Campbell et al., 1997; Clemson et al., 2004; Delbaere et al., 2004; Dhesi et al., 2004) there is a lack of literature published on the properties of such a research tool. Fall diaries are used in this study to recall falls.

2.8 General summary

There are over 400 risk factors that can contribute to an older adult suffering a fall. Decreased balance and muscle weakness are two risk factors that contribute to falls and are a normal of the physiologic process of ageing, however both these factors are modifiable. The optimum exercise type, intensity and duration necessary for falls prevention remains unknown however exercise programmes that contain balance exercises have been proven to be effective in decreasing an older adults' falls risk whilst the effects of strength training on falls risk is less clear.

3. METHOD

The purpose of this study was to evaluate the effect of participation in the Otago Exercise Programme (OEP) on strength and balance. The change in a number of balance and strength measures were compared between a group of community dwelling women over the age of 80 years participating in the OEP and a control group matched by gender and age. The women were tested on baseline measures of strength and balance and again after 6 months in order to detect whether the OEP had a positive effect on strength and balance.

3.1 Design

This study was designed as a cohort study of two independent groups, a group of community dwelling women over the age of 80 years who were participating in the OEP and an age matched control group of community dwelling women who did not participate in an exercise programme but continued with their normal activities of daily living. Potential participants were screened and if they met the inclusion criteria, were entered into the study. A blinded independent assessor, who was a New Zealand registered physiotherapist with 14 years experience of working with older adults, visited participants in their home to complete baseline and 6 month strength and balance assessments. At the first assessment the independent assessor gained written informed consent, explained the falls diary, administered the Mini Mental State Examination, and completed the strength and balance measures and the Modified Falls Efficacy Scale. The strength and balance measures were the timed up and go test, the step test, the 30 second chair stand test and gait velocity. Figure 1 illustrates the study design.

It was calculated that a sample size of 32, allowing for 80% power and 95% confidence for 2 sided tests, would give an expected effect size is 0.72. This means for a measurement tool that has a variance of 1.0 the maximum detectable difference between the two groups is 0.72, and similarly for a measurement tool with variance of 0.2 the maximum detectable difference is 0.144. For example in the step test a change in the order of 2 steps would be considered clinically significant, and assuming a variance of 1.0 this difference would be detectable.

3.2 Participants

The participants were women who had been approved by their general practitioner and referred onto the OEP and age matched community dwelling women.

3.2.1 Eligibility Criteria

The inclusion and exclusion criteria were the same for both the OEP group and control group participants. Volunteers were eligible to participate in the study if they were able to understand the requirements of the research (assessed by scoring no less than 27/30 on the Mini Mental State Examination), were female, 80 years or older, independently mobile, living in their own home and understood English (unless there was a family member or friend who was able to translate for them). Volunteers were excluded from participating in the study if they were currently receiving physiotherapy, participating in an exercise programme or living in a place of residential care (rest home or private hospital facility).

3.2.2 Recruitment of OEP participants

The OEP was offered by selected general practices within West Auckland as a pilot population health initiative for the period of a year. Due to funding restrictions the OEP was only available to a capped number of patients. General practitioners had guidelines from the funder as to which patients were likely to gain the most benefit from the OEP and were encouraged to refer the frailer of their patients onto the OEP. The process of general practitioner referral to the OEP was independent of the study. Women who were referred onto the OEP in West Auckland by their general practitioner were considered for inclusion into the study. The nurse delivering the OEP to individual women explained the study and asked if they were interested in participating. The nurse explained that whether they participated in the study or not, their current or future healthcare and participation in the OEP would not be affected. An information sheet (see Appendix C) inviting participation and explaining the study was left with potential participants to read in their own time. At the next scheduled OEP visit the participant informed the nurse whether they would volunteer for the study. If the participant volunteered to participate in the study, their contact details were forwarded by the nurse to the researcher. The researcher telephoned the participant to explain the study further, answer any questions, and screen for inclusion and exclusion criteria. If the participant fulfilled the inclusion criteria they were entered into the study. The

participant's contact details were forwarded to the independent assessor to make an appointment to visit the participant at their home to complete the baseline assessments. The pathway of entry into the study created a time lapse of a matter of weeks between participants beginning the OEP and the baseline measures being completed. However as changes in strength and balance occur over months and not weeks (Rutherford & Jones, 1986), this was not expected to have an effect on the outcomes.

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┌─────────────────────────────┐        ┌─────────────────────────────┐
│  Control group participants │        │    OEP group participants   │
└─────────────────────────────┘        └─────────────────────────────┘
              │                                       │
              ▼                                       ▼
┌─────────────────────────────┐        ┌─────────────────────────────┐
│ Responded to poster on      │        │ Approved by general         │
│ notice board in community   │        │ practitioner and referred   │
│ areas asking for volunteers │        │ onto the OEP                │
│ to participate in study     │        └─────────────────────────────┘
└─────────────────────────────┘                      │
                                                     ▼
                                        ┌─────────────────────────────┐
                                        │      Enrolled in OEP        │
                                        └─────────────────────────────┘
                                             │              │
                                             ▼              ▼
                              ┌──────────────────┐  ┌──────────────────┐
                              │ Agreed to        │  │ Did not agree to │
                              │ participate      │  │ participate in   │
                              │ in study         │  │ study            │
                              └──────────────────┘  └──────────────────┘
              │                      │          │          │
              ▼                      ▼          ▼          ▼
┌─────────────────────────────┐          ┌─────────────────────────┐
│ Screened by researcher over │          │   West Auckland OEP     │
│ phone for inclusion and     │          └─────────────────────────┘
│ exclusion criteria          │
└─────────────────────────────┘
        │              │
        ▼              ▼
┌──────────────┐  ┌──────────────┐
│ Excluded     │  │ Included     │
│ from study   │  │ into study   │
└──────────────┘  └──────────────┘
                        │
                        ▼
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Complete written informed consent and baseline assessments:
- Mini Mental State Examination
- Modified Falls Efficacy Scale
- Timed Up and Go Test
- 30 second chair stand test
- Step test
- Gait velocity

Given falls diary

Six month reassessments:
- Mini Mental State Examination
- Modified Falls Efficacy Scale
- Timed Up and Go Test
- 30 second chair stand test
- Step test
- Gait velocity

Figure 1. Research design

3.2.3 Recruitment of control participants

Posters inviting volunteers to participate in the study were placed on notice boards in the community areas at Selwyn Village and Ons Dorp (see Appendix D). Selwyn Village and Ons Dorp are residential facilities for older adults in west and central Auckland respectively. Both facilities provide levels of care ranging from licensed to occupy apartments (independent living) to private hospital. The community areas where the posters were placed served the independent living residents only. The Chief Executive Officer of the Selwyn Foundation and the Village Manager of Ons Dorp consented to residents being approached to participate in the study.

The Ons Dorp Village Manager suggested community meetings at which the researcher could talk to the residents about the study. After these meetings, a poster was left on the notice board for volunteers to write their name and contact number on. At Selwyn Village the Chief Care Officer addressed the residents at lunchtimes and at community meetings to explain the research further and point out the poster on the notice board.

All posters were checked weekly by the researcher to gather volunteers' names and phone numbers. The researcher then phoned the volunteers to explain the study further, answer any questions and screen for inclusion and exclusion criteria. The researcher also explained that a participant could withdraw from the study at any time and their current or future healthcare would not be affected. If the inclusion criteria were fulfilled the volunteer was then sent an information letter (see Appendix C). The participant's contact details were forwarded to the independent assessor to make an appointment to visit the participant at their home to complete the baseline assessments.

3.3 Ethical considerations

Ethical approval for this study was granted from the Auckland Ethics Committee X prior to the study commencing (Appendix A). All participants received an information sheet and had the opportunity to ask questions about the study before participating. All participants signed a written informed consent form (Appendix E) and were aware that they could withdraw from the study at any time without affecting their current or future healthcare.

3.4 Clinical Measures

The following measures were used at the baseline and 6 month assessments.

3.4.1 Mini Mental State Examination

The Mini Mental State Examination is a measure of cognitive ability (Folstein, Folstein, & McHigh, 1975). The participant was asked to complete the Mini Mental State Examination while seated. The examination is comprised of eleven questions concentrating on cognitive aspects of mental function, the first section tests orientation, memory and attention and the second section tests the ability to name objects, follow verbal and written commands, write a sentence and copy a complex polygon. The maximum total score is 30. The independent assessor was provided with a pad of Mini Mental State Examination questionnaires and the only equipment required was a watch, a pen and a piece of paper. The examination took approximately 5-10 minutes to administer the questionnaire.

3.4.2 The Modified Falls Self Efficacy Scale

The Modified Falls Efficacy Scale is a self report measure of the degree of confidence a person has in performing daily activities without falling (Appendix B) (Hill, Schwarz et al., 1996). The scale contains thirteen questions related to daily activities that require balance and are scored from 0 to 10, with 0 meaning "not confident at all" and 10 meaning "completely confident". A task is not scored if it is not a task the person would normally do. The result of this measure is expressed as a percentage of falls self-efficacy. Participants completed the Modified Falls Efficacy Scale while seated.

3.4.3 The 30 second chair stand test

The 30 second chair stand test is a measure of lower limb strength in older adults (Jones et al., 1999). The participant was asked to stand up straight and sit down as many times as possible in 30 seconds from their dining room chair, with their arms crossed at the wrist and held against their chest. The number of stands completed in 30s after the word "go" was counted. At the end of 30s if a participant was more than halfway up, the stand was counted. A score of 0 was awarded if any form of hand support was used. The test was stopped if any loss of balance occurred and the number of completed stands counted.

3.4.4 The step test

The step test is a measure of dynamic balance (Hill, Bernhardt et al., 1996). The participant was asked to step one foot up and down onto a 7.5cm step as many times as possible in 15 seconds. The number of steps completed was counted from the word "go". The equipment used for the step test was an upside down tote tray (Pay Less Plastics, Tote Tray 6L, 46581) with a depth of 7.5cm. This test was completed with both the left foot and right foot. A score of 0 was awarded if any form of hand support was used to provide balance. The test was stopped if any loss of balance occurred and the number of completed steps counted.

3.4.5 The timed up and go test

The timed up and go test is a performance measure of functional mobility as it includes sit to stand, walking and turning manoeuvres (Podsiadlo & Richardson, 1991). The participant was asked to stand from their dining room chair, walk at a comfortable speed to a mark on the floor 3 metres away, turn around and return to sit in the chair. The participant was timed from the word "go" until they returned to a sitting position.

3.4.6 Gait velocity

Gait velocity is a performance measure of walking as well as reflecting lower limb strength (Worsfold & Simpson, 2001). The participant was asked to walk a distance of 4 metres inside their home. They were timed over the middle 3 metres in an attempt to reduce the effects of acceleration and deceleration.

A tape was constructed with the marks needed for timing both the timed up and go test and gait velocity, so that one end could be fastened to a chair leg and then laid out making it easier for the independent assessor to mark out the distances without assistance. The independent assessor used the same stopwatch to time all the assessments. The participant's dining room chair was used for both the 30 second chair stand test and the timed up and go test, as this was more practicable than the independent assessor transporting two different chairs.

3.4.7 Fall diaries

All participants were given a diary to record any falls that occurred during the 6 month period of the study. A fall was defined as losing balance and coming to rest inadvertently on the ground or lower level.

3.5 Procedure

Once participants had been screened by the researcher and fulfilled the inclusion criteria, they were entered into the study. A blinded independent assessor visited participants at home on two occasions for data collection. The independent assessor was experienced in the assessment, treatment and rehabilitation of older adults and as such was familiar with the strength and balance tests used in the study. Further training was provided to the independent assessor by the researcher as well as documentation of how the assessments were to be performed (Appendix F). Data collection sheets were used to record the raw data (Appendix G).

On the first visit the independent assessor completed the written consent form, administered the Mini Mental State Examination and then completed the Modified Falls Efficacy Scale followed by the strength and balance measures in random order. The tests were performed wherever a clear space of 4 metres could be created. After a period of 6 months all participants were visited again and reassessed with the Modified Falls Efficacy Scale and the strength and balance measures (30 second chair stand test, timed up and go test, the step test and gait velocity). The independent assessor also collected the falls diaries. All participants were sent a letter informing them of their results. A results letter was also sent to the participant's general practitioner if this had been indicated by the participant on their consent form.

3.5.1 The exercise group participants

A nurse trained in delivering the OEP visited the participant and delivered the OEP as per the OEP manual (Accident Compensation Corporation, 2003). The participant was visited on weeks 1, 2, 4 and 8 and again at 6 months for the exercises to be prescribed and progressed (see Tables 9 and 10, Section 2.6). The participant was expected to complete the OEP 3 times a week and walk twice a week.

3.5.2 The control group participants

The control group received no sham exercises or equivalent social visits and received only usual healthcare from their general practitioner.

3.6 Data analysis

Data were analysed using the statistical analysis software programme, SPSS for Microsoft Windows (student version 11.0). The study sample size was small and on inspection the raw data was not normally distributed. Descriptive analysis of the data yielded information on the mean, standard deviation, median and interquartile range for the outcome measures. Non-parametric statistics were chosen to compare the results of the OEP group and the control group as the data was not normally distributed. An alpha level of .05 was used for determining the significance for all statistical analyses.

A Mann-Whitney U test was used to test for any differences between the OEP group and control group outcomes on the baseline measures of the Modified Falls Efficacy Scale, the step test, the timed up and go test, the 30 second chair stand test and gait velocity. The Mann-Whitney U test was used again to test for any differences between the outcomes of the OEP group and control group on the 6 month reassessment measures.   This test is the non-parametric version of the parametric t test for independent samples (Hicks, 2000). The Mann-Whitney U test tests the difference in ranks of data on two independent groups in order to calculate a statistic. The test statistic for the Mann-Whitney test is U. This value is compared to a table of critical values for U at the probability level of .05 based on the group sample size. If U is equal to or less than the critical value then the U value is significant.

A Wilcoxon signed-ranks test was used to compare changes within the OEP group and the control group on the Modified Falls Efficacy Scale, the step test, the timed up and go test, the 30 second chair stand test and gait velocity between baseline and 6 month assessment. This Wilcoxon signed-ranks test is a non-parametric test that compares the difference in ranks of scores of two related groups to calculate a statistic (Hicks, 2000). The test statistic for the Wilcoxon signed ranks test is T. This value is compared to a table of critical values for T at the probability level of .05 based on the group sample size. If T is equal to or less than the critical value than the T value is significant and there has been a statistically significant change within the group on the outcome measure.

4. RESULTS

The purpose of this study was to evaluate the effect of participation in the Otago Exercise Programme (OEP) on strength and balance. The change in a number of balance and strength measures were compared between a group of community dwelling women over the age of 80 years participating in the OEP and a control group matched by gender and age. The women were tested on baseline measures of strength and balance and again after 6 months in order to detect whether the OEP had a positive effect on strength and balance.

This chapter presents a descriptive analysis of participants in the study, their baseline and reassessment strength and balance measures and the findings of statistical analysis between the group of women participating in the OEP and the group of volunteer control participants. Due to the results being non-normally distributed the median score is used as a measure of central tendency, the interquartile range is used as a measure of spread and non-parametric statistics are used to statistically analyse the data.

4.1 Descriptive analysis of participants

The recruitment process resulted in 37 women over the age of 80 years volunteering to participate in the study. Of the 22 respondents to the posters at Ons Dorp and Selwyn Village 4 were excluded due to their male gender. Of the 25 older adults referred by their General Practitioner onto the OEP and then invited by the OEP nurse to participate in the study, six declined to participate in the study. There were 19 participants in the OEP group and 18 participants in the control group. The progress of the participants through the study is shown in Figure 2. At the completion of the study 8 (27%) of the participants did not complete a reassessment, which was similar to the 30% lost to follow up in the original Otago trials (Robertson et al., 2002). Of the 8 participants who were lost to follow up, 1 was a control group participant and 7 were OEP group participants.

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┌─────────────────────────┐          ┌─────────────────────────┐
│ Responded to            │          │ Referred by             │
│ posters (n = 22)        │          │ general                 │
│ Excluded for            │          │ practitioner to         │
│ being male              │          │ OEP (n = 25)            │
│ gender (n = 4)          │          │                         │
└─────────────────────────┘          └─────────────────────────┘
            │                                      │
            │                        ┌─────────────────────────┐
            │                        │ Invited to              │
            │                        │ participate in          │
            │                        │ study (n = 25)          │
            │                        │ Declined (n= 6)         │
            │                        └─────────────────────────┘
            │                                      │
┌─────────────────────────┐          ┌─────────────────────────┐
│ Control Group           │          │ OEP Group               │
│ (n = 18)                │          │ (n = 19)                │
└─────────────────────────┘          └─────────────────────────┘
            │                                      │
┌─────────────────────────┐          ┌─────────────────────────┐
│ Baseline strength and   │          │ Baseline strength and   │
│ balance measures        │          │ balance measures        │
│ (n = 18)                │          │ (n = 19)                │
└─────────────────────────┘          └─────────────────────────┘
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Lost to follow up:
Died (n= 1)

Lost to follow up:
Died (n= 1)
THJR operation (n = 1)
Awaiting THJR (n = 1)
Declined reassessment as no longer
doing OEP (no reason given) (n = 2)
Declined reassessment as no longer
doing OEP (medically unwell) (n = 2)

Reassessment at 6 months
(n = 17)
Falls monitored for 6 months
(n= 17)

Reassessment at 6 months
(n = 12)
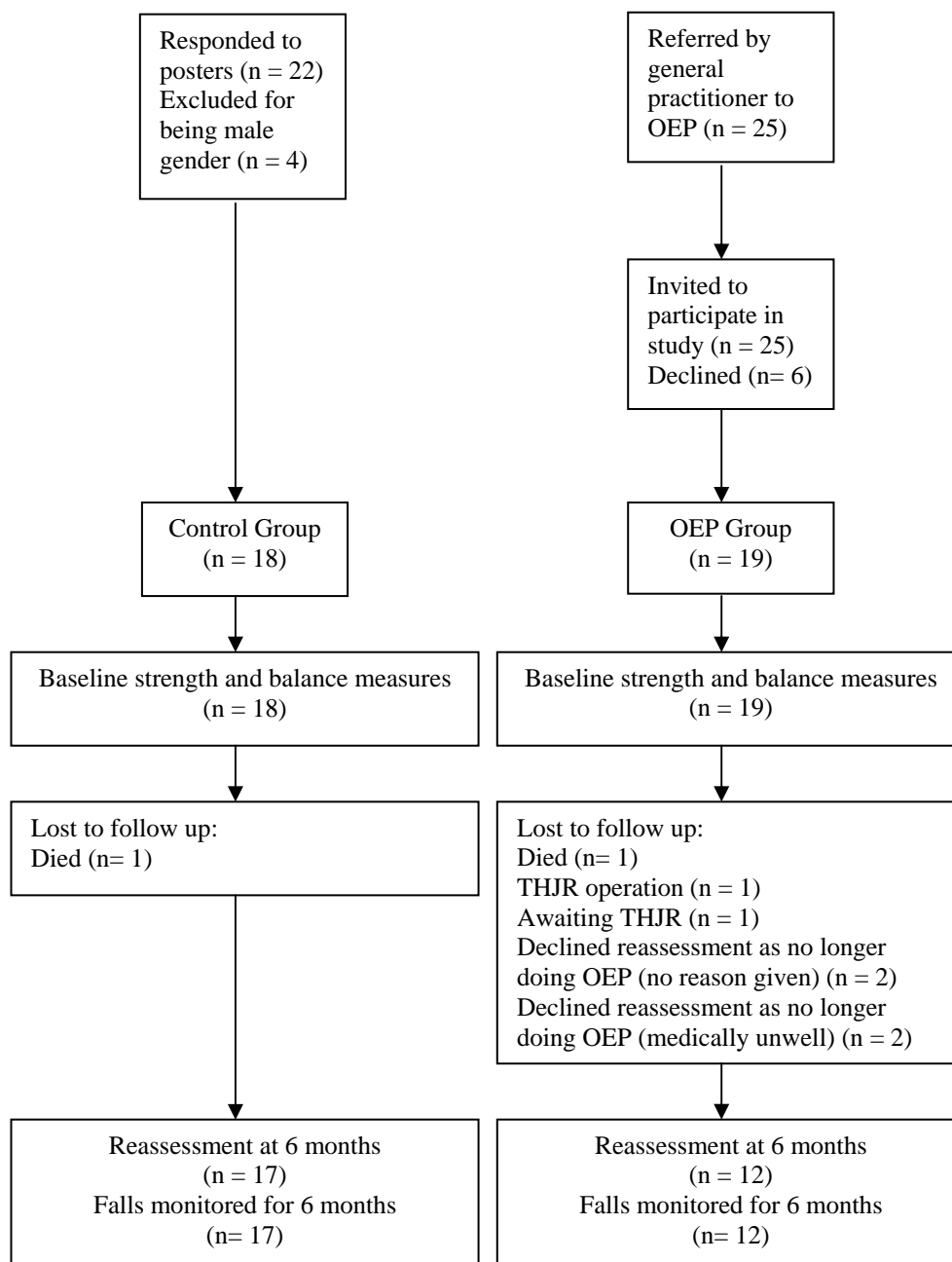Falls monitored for 6 months
(n= 12)

Figure 2. Summary of participant flow, numbers, reassessment and falls monitoring

Note. THJR = Total hip joint replacement

56

4.2 Comparison of the groups at baseline

Both groups were similar at baseline. The baseline assessments for both groups are summarised in Table 11. Raw scores of all the participants' baseline assessments are in Appendix H. Slightly more people in the OEP group used an assistive device for walking (68%, n = 13) compared to the control group (56%, n = 10).

Table 11.

Baseline assessments

Test	OEP Group Median (IQR) (n = 19)	Control Group Median (IQR) (n = 18)	U	p
Age	86.00 (5.00)	84.00 (6.25)	169.5	.96
MMSE score	29.00 (1.50)	30 (2.50)	140.5	.36
MFES (%)	85.00 (36.00)	95.50 (16.25)	109.0	.06
Gait Velocity (m/s)	0.80 (0.40)	0.80 (0.23)	170.5	.99
TUAG (s)	14.13 (11.13)	12.08 (6.78)	141.0	.37
30s Chair stand score	10.00 (7.00)	11.00 (6.25)	162.5	.80
Right step test score	10.00 (8.00)	10.00 (5.50)	137.5	.31
Left step test score	11.00 (7.00)	11.50 (4.75)	138.0	.33

Note. IQR = Interquartile Range. MMSE = Mini Mental State Examination: a score of < 27/30 indicates poor cognitive function. MFES = Modified Falls Efficacy Scale: a higher percentage indicates greater confidence in completing daily activities without falling. Gait velocity: normal = 1.27 m/s. TUAG = timed up and go test: >12 s indicates a high falls risk. 30 second Chair Stand: normal for 80 – 84 years old = 11, 85 – 89 years old = 10, 90 – 94 years old = 8. Step test: normal = 13 for either right or left leg.

The OEP participants were slightly more fearful of falling as measured by the Modified Falls Efficacy Scale however this was not a statistically significant difference. Gait velocity in both groups was slower than the age normative value of 1.27m/s for women over the age of 70 years (Bohannon, 1997). Median times on the timed up and go test for both groups were greater than the 12 s threshold that indicates a high risk of falls (Bischoff et al., 2003). The step test median score for the right and left legs in both groups was less than the normative score of 13 steps for women over the age of 80 years (Hill et al., 1999). The median score on the 30 second chair stand test for the OEP group corresponded to the normative score for women aged 85 – 89 years old (Rikli &

Jones, 1999), and the median age for the group was 86 years. The control group median score on the 30 second chair stand test corresponded to the normative score for women aged 80 – 84 years old (Rikli & Jones, 1999), and the median age for the group was 85. The baseline assessment results for both the OEP group and the control group indicated a degree of lower limb weakness and impaired balance.

The mean number of days between the OEP participants beginning the OEP exercises and completing the baseline assessment with the independent assessor was 15 (SD = 8.0) days and ranged from 8 – 32 days. This variability in time to assessment is unlikely to influence results as changes in strength and balance occur over a period of months not weeks (Sale, 1988).

4.3 Assessment after 6 months

A total of 29 participants (OEP group n = 12, control group n = 17) were reassessed after 6 months with the Modified Falls Efficacy Scale and the strength and balance assessments. The results for both groups are summarised in Table 12. Raw scores of all the participants' 6 month assessments are in Appendix H. The participants who did not complete a reassessment will be reported in Section 4.5.

The mean number of days between the baseline assessment and reassessment was 173.3 (SD = 12.8) days ranging from 148 –199 days for the OEP participants and a mean of 171 (SD = 3.5) days ranging from 165 – 177 days for the control participants.

Table 12.

Change in baseline measures after 6 months

Test	Baseline assessment	6 month assessment	Change over 6 months*
OEP group	*Median* (IQR) (n = 19)	*Median* (IQR) (n = 12)	*Median* (IQR) (n = 12)
MFES (%)	85.00 (36.00)	86.00 (31.75)	1.00 (5.75)
Gait Velocity (m/s)	0.80 (0.40)	0.70 (0.38)	-0.10 (0.18)
TUAG (s)	14.13 (11.13)	12.24 (5.16)	-0.18 (3.06)
30s Ch stand score	10.00 (7.00)	11.00 (16.50)	0.00 (2.75)
Right step test score	10.00 (8.00)	11.50 (7.25)	0.00 (3.75)
Left step test score	11.00 (7.00)	10.50 (7.25)	-0.50 (4.75)
Control group	(n = 18)	(n = 17)	(n = 17)
MFES (%)	95.50 (16.25)	94.00 (25.0)	0.00 (16.50)
Gait Velocity (m/s)	0.80 (0.23)	0.70 (0.3)	-0.10 (0.25)
TUAG (s)	12.08 (6.78)	14.41 (6.0)	0.09 (3.75)
30s Ch stand score	11.00 (6.25)	10.00 (5.0)	0.00 (2.50)
Right step test score	10.00 (5.50)	10.00 (3.5)	0.00 (3.50)
Left step test score	11.50 (4.75)	10.00 (4.0)	0.00 (3.50)

Note. IQR = Interquartile Range. MFES = Modified Falls Efficacy Scale: a higher percentage indicates greater confidence in completing daily activities without falling. Gait velocity: normal = 1.27 m/s. TUAG = timed up and go test: >12s indicates a high falls risk. 30 second chair stand test: normal for 80 – 84 years old = 11, 85 – 89 years old = 10, 90 – 94 years old = 8. Step test: normal = 13 for either right or left leg. For MFES, gait velocity, 30 second chair stand, right step test and left step test a positive value demonstrates an improvement in test performance.
For TUAG a negative value demonstrates an improvement in test performance.
* Change scores calculated for the individuals who completed both assessments.

4.4 Analysis of change

The results of the reassessment measures were not normally distributed therefore non-parametric statistical tests were used to analyse the data. The Mann-Whitney *U* test was used to determine whether there was a statistically significant difference between the two groups in the assessment measures. The Wilcoxon signed ranks test was used

to determine whether there was a statistically significant difference within the OEP group and the control group in the assessment measures.

4.4.1 Between group comparison at 6 months

The 6 month strength and balance assessments for the OEP group and control group are summarised in Table 13.

Table 13.

Six month assessment measures

Test	OEP Group *Median* (IQR) (n = 19)	Control Group *Median* (IQR) (n = 18)	*U*	*p*
MFES (%)	86.00 (31.75)	94.00 (25.0)	80.0	.35
Gait Velocity (m/s)	0.70 (0.38)	0.70 (0.3)	75.5	.25
TUAG (s)	12.24 (5.16)	14.41 (6.0)	76.0	.26
30s Chair stand score	11.00 (16.5)	10.00 (5.0)	95.0	.78
Right step test score	11.50 (7.25)	10.00 (3.5)	88.0	.56
Left step test score	10.50 (7.25)	10.00 (4.0)	97.5	.85

Note. IQR = Interquartile Range. MFES = Modified Falls Efficacy Scale: a higher percentage indicates greater confidence in completing daily activities without falling. Gait velocity: normal = 1.27 m/s. TUAG = timed up and go test: >12s indicates a high falls risk. 30 second chair stand test: normal for 80 – 84 years old = 11, 85 – 89 years old = 10, 90 – 94 years old = 8. Step test: normal = 13 for either right or left leg.

After 6 months there were no statistically significant differences between the reassessments of the OEP group and the control group in the Modified Falls Efficacy Scale or any of the strength and balance measures.

4.4.2 Within group comparisons

The OEP group and the control group were similar at baseline and after the 6 month reassessment, therefore it would not be expected to find any statistically significant differences within the OEP group or the control group. However due to the small sample size in each group, the change in individual participants was described in order to identify trends.

4.4.1.1 Control group

The baseline and 6 month measures for the control group and the change in those measures are summarised in Table 12.

At the 6 month assessment the Modified Falls Efficacy Scale had increased in 6 participants, decreased in 4 participants and remained the same in 2 participants. These changes were not statistically significant ($T = -1.33$, $p = .18$). Gait velocity was faster in 3 participants, remained the same in 3 participants and slowed in 11 participants. These changes were not statistically significant ($T = -1.80$, $p = .07$). The timed up and go test was faster in 8 participants and slower in 9 participants, with 5 of the 17 participants completing the test under the 12 s threshold that indicates a high falls risk. These changes were not statistically significant ($T = -0.64$, $p = .52$). On the 30 second chair stand test 7 participants attained a score better than the normative value for their age, 3 participants attained the normative score for their age and 7 scored lower. There was no statistically significant change within the group ($T = -0.36$, $p = .72$). On the right step test 8 participants attained a higher score, 2 stayed the same and 7 scored lower than previously. When testing the left leg, 5 participants attained a higher score, 4 stayed the same and 8 scored lower than previously. There was no statistically significant change within the group for either the right or left leg (Right step test $T = -0.92$, $p = .36$, left step test $T = -0.77$, $p = .44$).

4.4.1.2 OEP group

The baseline and 6 month measures for the OEP group and the change in those measures are summarised in Table 12.

At the 6 month assessment the Modified Falls Efficacy score had increased in 5 participants, decreased in 6 and remained the same in 6 participants. These changes were not statistically significant ($T = -0.56$, $p = .57$). Gait velocity was faster in 1 participant, remained the same in another participant and slower in 10 participants. The overall slowing in gait velocity was statistically significant ($T = -2.67$, $p = .01$). The timed up and go test was faster in 6 participants and slower in 6 participants, with 6 of the 12 participants completing the test under the 12 s threshold that indicates a high falls risk. These changes were not statistically significant ($T = -0.94$, $p = 0.35$). On the 30 second chair stand test 7 participants attained a score better than the normative value for their age and 5 participants scored lower. There was no statistical change within the

group ($T = -0.07$, $p = .94$). On the right step test 5 participants attained a higher score, 1 stayed the same and 6 scored lower than previously on the test. When testing the left leg 6 participants attained a higher score and 6 scored lower then previously. There was no statistically significant change within the group for either the right or left leg (right step test $T = -0.32$, $p = .75$, left step test $T = -0.27$, $p = .79$).

At the 6 month reassessment the only statistically significant change within the OEP group was a slower gait velocity. There were no statistically significant changes within the control group.

4.4.3 Descriptive analysis of the falls diaries

Not every participant who was reassessed returned a diary. Of the returned diaries 10 were from OEP group participants and 11 from the control group participants. Of those participants who did not return a diary, 5 told the independent assessor that they had lost it and 2 said that they had thrown it out. However, of the participants who did not return a diary 1 participant reported having fallen twice and 6 participants verbally reported no falls. Overall, in the OEP group 2 participants reported having fallen once, and in the control group 1 participant reported falling once and 1 participant reported falling twice.

4.5 Participants lost to follow-up

The baseline assessments for participants who did not complete reassessment are presented in Appendix H. Except for the two participants who passed away, all participants (n = 35) were contacted by the independent assessor for a reassessment. Six participants declined to be reassessed. The drop out rate in the OEP group was 37 % (n = 7) and in the control group it was 6 % (n = 1). The OEP baseline median and interquartile ranges have been split into subgroups of those OEP participants who completed reassessment and those who did not (see Table 14).

The subgroup of OEP participants who did not complete the 6 month assessments had scores below that of the OEP subgroup who completed the 6 month assessment, on the Modified Falls Efficacy Scale and all of the strength and balance measures.

Table 14.

Baseline assessments of OEP subgroups

Test	Total OEP Group Median (IQR) (n = 19)	Subgroup assessed at 6 months *Median* (IQR) (n = 12)	Subgroup not reassessed at 6 months *Median* (IQR) (n = 7)
Age	86.00 (5.00)	86.00 (5.50)	86.00 (6.00)
MMSE	29.00 (1.50)	29.00 (1.75)	28.5 (2.50)
MFES (%)	85.00 (36.00)	83.00 (37.00)	85.00 (37.00)
Gait Velocity (m/s)	0.80 (0.40)	0.85 (0.55)	0.60 (0.60)
TUAG (s)	14.13 (11.13)	12.91 (9.69)	15.31 (14.71)
30s Chair stand score	10.00 (7.00)	10.50 (6.50)	9.00 (5.00)
Right step test score	10.00 (8.00)	11.00 (5.25)	8.00 (12.00)
Left step test score	11.00 (7.00)	11.50 (5.25)	7.00 (12.0)

Note. IQR = Interquartile Range. MMSE = Mini Mental State Examination: a score of < 27/30 indicates poor cognitive function. MFES = Modified Falls Efficacy Scale: a higher percentage indicates greater confidence in completing daily activities without falling. Gait velocity: normal = 1.27 m/s. TUAG = timed up and go test: >12s indicates a high falls risk. 30 second chair stand test: normal for 80 – 84 years old = 11, 85 – 89 years old = 10, 90 – 94 years old = 8. Step test: normal = 13 for either right or left leg.

4.6 Summary of Results

The purpose of this study was to compare the strength and balance measures of a group of community dwelling women over the age of 80 years participating in the Otago Exercise Programme with a control group of community dwelling women over the age of 80 years. Results show that there were no statistically significant differences between the groups in measures of confidence, strength and balance and the only statistically significant difference within the groups was the slower gait velocity in the OEP group at 6 months compared to baseline.

5. DISCUSSION

The purpose of this study was to evaluate the effect of participation in the Otago Exercise Programme (OEP) on strength and balance. The change in a number of balance and strength measures were compared between a group of community dwelling women over the age of 80 years participating in the OEP and a control group matched by gender and age. The women were tested for baseline measures and again after 6 months in order to detect whether the OEP had an effect on strength and balance.

The hypotheses for this study were that muscle and strength measurements would improve after 6 months participation in the OEP when compared to an age-matched control group, as would confidence in performing daily tasks. The results of this study do not support these hypotheses. Participants who had completed 6 months of the OEP had no statistically significant improvement in strength and balance or confidence compared to a group of community dwelling women who had no form of intervention over the same period of time. The results from this study need to be interpreted with caution, as due to the small sample size the study is statistically underpowered.

5.1 Study sample

Five general practices in West Auckland committed to deliver the OEP to their patients using the practice nurse model of delivery trialled in the Otago Study B (Robertson, Gardner et al., 2001). The patients to whom these practice nurses delivered the OEP were the potential volunteers for the OEP group in this study. However recruitment and data collection was slower than anticipated for a number of reasons. Of the five OEP trained nurses, one fractured her scapula and was off work for the duration of the study and therefore did not recruit any study participants. All the nurses delivered the OEP on a part time basis, fitting the delivery around practice commitments. Most of the nurses were affected by having to increase their practice hours to cover for staff absence due to sickness or school holidays at some time during the study, contributing to less time being available to leave the practice to deliver the OEP to participants. A major national health promotion, the MeNZB immunisation programme, was launched in West Auckland halfway through the study. The objective

of the MeNZB immunisation programme was to immunise every child under the age of 19 years old against meningococcal B. Children not attending school or under the age of 5 years had the vaccination at their general practitioner's rooms creating an immense workload for practices. The MeNZB programme prevented the OEP nurses from leaving the practice to deliver the OEP hence there was no recruitment of new OEP participants onto the study over a 2 month period. Data collection was planned to take a year, but to recruit the number of participants needed for the study to be powerful enough another year would have been required. Time restrictions prevented this.

The inclusion criteria for participation in the study was based on the criteria used in the original Otago trial (A. J. Campbell et al., 1997) and the meta-analysis findings that the OEP was the more effective for adults over the age of 80 years (Robertson et al., 2002). At baseline there were no statistically significant differences between the OEP group and control group on any of the measures used, both groups demonstrated lower limb weakness and impaired balance (see Table 4.1). The OEP group was below age normative scores for gait velocity, the timed up and go test and the step test, while the control group was only below age normative scores for gait velocity and the step test. This slight difference is not unexpected, as the general practitioners had been encouraged by the OEP funder to refer their frailer patients to the OEP. The participants in both the OEP group and the control group met the criteria to receive the OEP however only the OEP group received the programme. The falls history of the participants prior to participation in the study was unknown.

5.2 Study findings

The study sample size was smaller than that which had been calculated for an effect size of 0.72, so the study findings should be interpreted with caution. However these findings add to those of the original Otago OEP trial to provide more evidence on the effects of the OEP on strength and balance. The original Otago OEP trial found an "improvement" on the 4-test balance scale however there were no statistically significant differences on any of the physical assessment measures (functional reach test, 4-test balance scale, isometric knee extensor strength, 5 chair stand test, gait velocity over 8 feet and 20 metres, timed stair climb, and the 6 minute walk test) (A. J. Campbell et al., 1997).

5.2.1 The Modified Falls Efficacy Scale

The Modified Falls Efficacy Scale is a measure of the degree of confidence a person has in performing daily activities without falling (Hill, Schwarz et al., 1996) and is predictive of an increased risk of falling and a decline in the ability to perform activities of daily living (Cumming et al., 2000). Delbaere, Crombez, Vanderstraeten, Willems and Cambier (2004) suggested that an individualised exercise programme which focuses on functionality could reverse the fearfulness of falling through decreasing physical frailty. This does not appear to be the case in this study as both groups remained almost unchanged on the Modified Falls Efficacy Scale, so the OEP had no measurable effect on this measure. A normative score on the Modified Falls Efficacy Scale is 96% for women over 80 years (Hill et al., 1999) and both the OEP group and the control group scored below this. Other studies have used categories to aid interpretation of the Modified Falls Efficacy Scale (Cumming et al., 2000; Mendes de Leon, Seeman, Baker, Richardson, & Tinetti, 1996), describing scores as low ($\leq$ 75%), moderate (76-99%) or high self-efficacy (100%). Using this categorisation both the OEP group and the control group would be classified as having moderate fall-related self-efficacy.

The independent assessor reported difficulty administering the Modified Falls Efficacy Scale to most participants, as they tended to answer the questions yes or no and struggled to refine their responses to a number on a 0 to 10 scale. This may have decreased the sensitivity of the scale in measuring the change in fall-related self-efficacy. The difficulty older adults have of scaling a response on the Modified Falls Efficacy Scale has been reported in one study (Cameron et al., 2000) although the authors offer no explanation other than there were multiple contributing factors and the scoring criteria are currently under review (L. Yardley, personal communication, 10 November, 2005).

5.2.2 Gait velocity

Gait velocity is a performance measure of walking and is significantly correlated to lower limb strength (Bohannon, 1986; Menz et al., 2003; Schiller et al., 2000). The OEP group and control group each had a median gait velocity of 0.8m/s which is slow when compared to the normative value of 1.27m/s for women in their eighth decade (Bohannon, 1997) or the 1.2m/s required for safe community ambulation (National Association of Australian State Road Authorities, 1987b). Both groups slowed by

0.1m/s over the 6 month period of the study however only the OEP group's decline was statistically significant. This finding suggests that lower limb strength in both the OEP group and control group had declined. As a functional outcome measure, comment is often made about how gait velocity relates to a person's ability to interact with their environment (Bohannon, 1997; Guralnik et al., 2000), which most commonly is interpreted as the ability to safely cross the road at a signalled pedestrian crossing. It is conceivable that participants in this study are completely safe and independent in their daily environments without having enough speed to cross a road.

The lack of improvement in the OEP group's gait velocity is similar to that observed in the first Otago trial (A. J. Campbell et al., 1997). Other fall prevention studies have used gait velocity as an outcome measure with mixed results. Buchner et al. (1997) and Barnett (2003) similarly found no improvement in gait velocity but a significant decrease in falls. While Hauer (2001) found a significant improvement in gait velocity after an intense progressive resistance and functional training and Schlicht et al. (2001) suggested intense strength training may improve maximal gait speed but neither of these studies demonstrated a significant decrease in falls. That the latter 2 studies did not decrease falls supports the theory that appropriate scaled and timed muscle contraction not maximal muscle contraction is required for balance tasks (Gu et al., 1996).

As discussed in Section 2.2.4 loss of fast twitch muscle fibre is part of the physiological ageing process therefore the slowing of both groups may reflect this aspect of the ageing process that cannot be ameliorated. An alternative explanation may be that the OEP was not designed to increase gait velocity. The OEP does prescribe a walking programme two days a week at the participant's own pace to increase physical capacity (Accident Compensation Corporation, 2003, p. 14). So after the OEP a participant may be able to walk further due to improved cardiovascular fitness but not necessarily faster. The latter explanation may be the more likely as training specificity is important in the older adult (Lord et al., 1995; Nitz & Low Choy, 2004) and the contribution of fast twitch muscle at such slow speeds would be questionable.

The independent assessor found that creating a walkway of 4 m was a challenge in a number of the participants' homes and had to move furniture to create an unobstructed space. Similar difficulties with finding a clear distance of 4 m in an individual's home has been reported in other studies (Ferrucci et al., 1997; Simonsick et

al., 1997). Ferrucci et al. (1997) dealt with this problem by using a 3 m distance when there was not adequate space for 4 m. This coping strategy was not employed in this study, as gait speed measures can be influenced by method (Rigler et al., 1997) and variation in testing method would lead to a lack of sensitivity in outcome results. Hence the testing protocol outlined by Worsfold and Simpson (2001) was adhered to in the present study to ensure reliability.

5.2.3 The 30 second chair stand test

The 30 second chair stand test is a measure of lower limb strength and is correlated to the one repetition maximum leg press, a criterion measure of lower limb strength (Jones et al., 1999). Maintaining lower limb strength is essential to independence in functional performance (Bassey et al., 1992; Ferrucci et al., 1997; McCarthy et al., 2004; Petrella, Miller, & Cress, 2004), from the 30s chair stand results it would appear that the OEP was effective in maintaining lower limb strength. However there was no statistically significant change for the OEP group or control group on this measure.

The OEP baseline group median score for the 30 second chair stand test was 10 sit to stands and after 6 months on the OEP the score had increased to 11. The OEP group with a median age of 86 years would be expected to complete 10 sit to stands in 30 s, which is the normative score for women in the age range of 85 – 89 years. The OEP group score of 11 after 6 months on the OEP was equivalent to the normative score for the younger age range of 80 – 84 years old, so the results reflect that the OEP group may have above normal leg strength for their age. The OEP group participants who dropped out are likely to have affected the group's median score on reassessment. The subgroup of OEP participants who completed the 6 month assessment had a baseline median score of 10.50 for the 30 second chair stand test, while the subgroup who did not complete reassessment had a baseline median score of 9.00. So it may be the effect of the frailer participants who dropped out rather than the OEP, which resulted in an improved 30 second chair stand test score for the OEP group.

The control group baseline median score for the 30 second chair stand test was 11 and after a 6 month period this had decreased to 10. The control group with a median age of 84 years, would be expected to complete 11 sit to stands, which is the normative score for women in the age rang of 80 - 85 years old. So the results for the

control group reflect that they may have weak lower limb strength for their age and a possible downward trend occurred over the 6 month period of the study.

Currently no other fall prevention studies have used the 30 second chair stand test as an outcome measure however the 5 chair stand test (A. J. Campbell et al., 1997; Robertson et al., 2002; Schlicht et al., 2001) and the 3 chair stand test (Hauer et al., 2001) have been used with mixed results. Schlicht et al., Campbell et al. and Robertson et al. found no improvement on this outcome measure while Hauer et al. found a significant improvement. The methodological differences between these three chair stand tests make it inappropriate to compare the results.

A possible explanation for the observed change in the 30 second chair stand test may be that the OEP contains a sit to stand exercise that is not too dissimilar to the 30 second chair stand test. This exercise (using two hands to push up from the chair) is a level A exercise that would have been prescribed to all OEP participants on day one of the OEP. Progressions of the sit to stand exercise is to one hand support and then to no hand support so it is possible that there was a practice effect when the 30 second chair stand test was reassessed.

5.2.4 The timed up and go test

The timed up and go test is a performance measure of functional mobility as it includes sit to stand, walking and turning manoeuvres (Podsiadlo & Richardson, 1991). Although the change measured by this test was not statistically significant for the OEP group or the control group, there were within group changes that were clinically meaningful.

If a person takes longer than 12 s to complete the timed up and go test they are considered to be a high falls risk (Bischoff et al., 2003). At baseline 12 OEP participants took longer than 12 s to complete timed up and go test, and after 6 months on the OEP this number had decreased to 6. Overall the OEP group median score improved to almost 12 s, which indicated that as a group they were moving towards no longer being categorised as being at a high falls risk. The OEP group participants who dropped out are likely to have affected the group's median score on reassessment. The subgroup of OEP participants who completed the 6 month assessment had a baseline median score of 12.91 s for the timed up and go test, while the subgroup who did not complete reassessment had a baseline median score of 15.31 s. So it may be the effect

of the frailer participants who dropped out rather than the OEP, which resulted in an improved timed up and go test result for the OEP group.

The reverse trend occurred in the control group. At baseline 9 control group participants took longer than 12 s to complete the timed up and go test, and after a 6 month period this number had increased to 11. Overall the control group median changed to be slower than 12 s, indicating that as a group there were moving towards being categorised as being at a high falls risk.

The timed up and go has been used in other falls prevention studies and shown significant improvements (Hauer et al., 2001; Nitz & Low Choy, 2004). As the timed up and go test includes the components of sit to stand and walking, it would be expected that the results on this test are congruent with those of the 30 second chair stand test and gait velocity. While the 30 second chair stand median score increased in the OEP group, gait velocity decreased. Therefore the finding of a trending upward of the OEP group on the timed up and go test is somewhat surprising and may support the idea that participation in the OEP maintains an older adult's current level of function rather than resulting in demonstrable increases in strength.

5.2.5 The step test

The step test is a measure of dynamic balance (Hill, Bernhardt et al., 1996). Neither the OEP group nor the control group's median scores changed over the 6 month period of the study, both groups remained unable to achieve the 13 steps in 15s which is normative for women over the age of 80 years (Hill et al., 1999).

The OEP was ineffective in improving dynamic balance in the OEP group as measured by the step test. The OEP exercises prescribed to improve balance are a mix of both static and dynamic exercises that progress from using hand support to using no hand support at all. Participants are progressed in the OEP exercises according to their individual capabilities so it is possible that participants may not have progressed to any exercises without hand support during the 6 months of the study if their balance was poor at the outset. Light touch with the hand has been found to result in modification of postural responses toward the side of support device as well as assisting in scaling of postural responses (Dickstein, Peterka, & Horak, 2003). So if a balance exercise is always practised with hand support it is possible that feedforward mechanisms are being developed in anticipation that the hand will be used for stabilisation. This would be

reflected by a poor result in the step test as hand support cannot be used in this test. Nitz and Choy (2004) demonstrated a significant improvement in the step test after a balance retraining programme however the balance exercises were all performed without hand support.

An alternative explanation for the observed lack of change in the step test is that the test measures the speed of lower limb movement as well as dynamic balance. As discussed in Section 2.2.4, loss of fast twitch muscle fibre is a part of the physiological ageing process. The step test measures how many times a person can place their foot up and down onto a step in 15 seconds so the effect of a decrease in fast twitch muscle fibres may result in a person not being able to move their lower limb at a high velocity and this may be a component contributing to the normative scores for the step test decreasing with increasing age.

5.2.6 Fall diaries

The OEP group returned more falls diaries than the control group. This may be due to the OEP nurse checking the diary on each of the OEP visits, so the OEP participants would have attached a greater importance to the falls diary then those in the control group. Of those who did not return a diary, 1 participant reported having fallen twice during the 6 month study period. Recall of falls has been shown to be more accurate over 12 months than a 3 or 6 month period in the elderly (Cummings et al., 1988; Hale et al., 1993), so it is possible that more participants may have fallen during the study period. Two OEP group participants and 2 control group participants fell so the OEP appeared to have no effect on falls in the OEP group. However the study was powered for strength and balance not falls and due to the small sample size resulting in an underpowered study this result should be interpreted with caution. The 14% of study participants who fell is less than the 43% of all participants who fell over a one year period in the first OEP trial (A. J. Campbell et al., 1997) , although a meta-analysis of the Otago studies found a 35% reduction rate in falls in the OEP participants when compared to the control group participants (Robertson et al., 2002). The difference in the time period of the 2 studies makes comparing the number of falls between the two inappropriate. It is likely that the rate of falls which occur over a 6 month period, as used in the present study, is too small to be statistically significant, which is why falls were not used as an outcome.

The OEP group also used the diaries to record when they had completed the OEP exercises or a walk. Of the 10 diaries returned, 3 had 6 months of exercises and walks fully documented, 1 had recorded a fall but no exercise, 2 had nothing documented, and the remaining 4 varied in the amount of recording. Therefore it is difficult to ascertain whether all the participants complied with the OEP as prescribed.

The independent assessor reported that a number of participants when contacted for the 6 month reassessment had no recollection of her having visited previously or of the tests that had been conducted. So although all participants had a Mini Mental Status Examination score of no less than 27/30, indicating intact cognitive status (Folstein et al., 1975), memory loss was anecdotally evident in some participants.

5.2.7 Lack of change

Overall, there was no change in strength and balance measures in the OEP group after 6 months participation on the OEP, which is similar to the findings in the Otago trials (A. J. Campbell et al., 1997; Robertson et al., 2002). Other studies have also significantly reduced falls in the intervention group without significantly improving strength and balance (Barnett et al., 2003; Tinetti, Baker et al., 1994; Wolf, Barnhart, Ellison, & Coogler, 1997). Considering the age group being studied this could be interpreted positively as maintaining their present functional level and preventing a decline in strength and balance. There are a number of possible reasons why a lack of change was observed. There may have been a lack of compliance with the exercises and due to the poor compliance with the exercise diaries this cannot be determined. The OEP exercises may not have been progressed substantially over the 6 month period of the study, for example from using hand support to no hand support, as the exercises are progressed due to the participant's level of ability. The prescribed ankle weights may not have been heavy enough. There were three strengthening exercises in the OEP that used ankle weights to provide resistance (knee extensions in sitting, hamstring curls in standing and hip abduction in standing). According to the OEP manual the amount of weight used for an exercise should "allow 8-10 repetitions before fatigue" (Accident Compensation Corporation, 2003) then once a participant was able to do 2 sets of 10 repetitions the weight was to be increased. Anecdotally the OEP nurses recalled erring on the side of caution and prescribing a weight of 1kg or less for participants. In the West Auckland and Southern New Zealand Otago trials, weights of up to 8kg were prescribed with no significant strength changes observed (Robertson et al., 2002).

Muscle strength is best developed by the progressive overload principle, which is defined as progressively increasing the resistance against which a muscle generates force over time or the frequency and duration of an activity (American College of Sports Medicine, 1998). It may be with the OEP that the loading used rarely attains the intensity required to lead to changes in strength. The outcome measures used were performance-based tests that identified functional limitations without necessarily identifying the cause (Boulgarides, McGinty, Willett, & Barnes, 2003) and were not direct measures for strength. Although gait velocity and the 30 second chair stand test are correlated to lower limb strength other factors are involved that may effect the outcomes of these tests (Lord et al., 2002).

It is of interest that the control group also maintained their functional level although they received no formal input. This may be due to 6 months not being a sufficient period of time in which to observe manifestation of physiological changes associated with the ageing process, or that they were a less frail group.

The outcome measure used to assess balance changes in the Otago trials was the 4-test balance scale, which measures static balance (Rossiter-Fornoff, Wolf, Wolfson, & Buchner, 1995). All the balance measures used in the present study measured dynamic balance. Static balance is the result of postural control that occurs to maintain a stationary body upright under the force of gravity (Huxham et al., 2001). Dynamic balance is the postural control required to counterbalance movement, whether it be raising an arm or taking a step, a person's centre of mass alters in relation to the centre of gravity (Huxham et al., 2001). Assessment of static balance therefore measures the most basic balance task, which is quiet stance. If balance is taken in the context of everyday life and the activities that occur, measures of dynamic balance for example the step test may be more relevant as not often in everyday life does a person remain absolutely still.

Training specificity is also an important concept. A muscle will strengthen in the range it is trained in (Higbie, Cureton, Warren III, & Prior, 1996; Kitai & Sale, 1989), for example seated knee extensions will strengthen the knee extensors through 0 - 90º of knee flexion and as the exercise is performed in sitting little postural stability is required. Latham, Bennett, Stretton and Anderson (2004) conducted a systematic review of progressive resistance training in older adults over the age of 60 years and most of the included studies had participants who were healthy, community dwellers.

The authors concluded that progressive resistance training does result in strength changes in older adults. They identified that most trials used machines for strength training and found no clear effect of strength training on standing balance. The results of the systematic review were not sufficient to be able to comment on the effectiveness on strength training in reducing falls risk. Considering the specificity of training, many weight machines tend to strengthen a muscle in a closed kinetic chain exercise and often do not require the co-contraction of other muscles or postural stability to maintain balance during an exercise. An improvement in balance could not expect to be observed, as balance has not been a part of the exercise. Similarly a recent systematic review and meta-analysis on muscle weakness and falls in adults over the age of 65 years living in institutions or community dwelling, identified that while strength is a risk factor for falls, more trials are needed to ascertain the effectiveness of strength training in falls prevention (Moreland, Richardson, Goldsmith, & Clase, 2004). Porter and Vandervoort (1997) demonstrated that strength gains from training ankle plantar and dorsiflexors in a standing position were not present when the same muscle was tested with the participant in a supine position. This suggests that strength gains may not be transferable to improvements in functional tasks. Lord, Ward, Williams and Strudwick (1995) found that strengthening exercises using body weight and general exercises were of sufficient intensity to improve strength in the lower limb and to decrease accidental falls in the exercising group compared to controls. When considering a strengthening programme in conjunction with a balance retraining programme, it would appear that the most beneficial strengthening exercises would be open kinetic chain using body weight, as this would be task-specific and relevant to the functional task to be maintained, that is moving ones body around in the environment.

Overall it is possible that improvements which occurred after participation in the OEP were too small to be detected by the clinical measures used. However in an aged population small improvements may summate to enable an individual to maintain functional independence and remain coping in their own home (Nelson et al., 2004; Robertson et al., 2002).

5.2.8 Participants lost to follow up

The participants who did not complete a reassessment were some of the frailest of the entire sample. Three of the participants who dropped out were unable to complete the step test with either leg and mobilised with a walking device. Of these 3

participants, all had very slow gait velocity, very slow timed up and go test scores and 2 had very low Modified Falls Efficacy Scale scores. One other participant was unable to stand without the use of their hands to perform the 30 second chair stand test, which is indicative of a high level of weakness in the lower limbs.

The effect of those participants who dropped out on the overall analysis was to improve the median test scores due to an incomplete data set being available. However a positive interpretation is that the general practitioners were identifying and recruiting their frailest patients onto the OEP. If the frailest of the frail were unable to complete the OEP, the next question to be asked is whether or not the OEP is the appropriate form of input for these patients. The next step may be to develop a screening tool that can be easily administered by a general practitioner to aid referral to the appropriate level of input for falls prevention programmes.

5.3 Study limitations

The following limitations of the current study have been identified.

1.   Sample size

There were 19 OEP participants and 17 community dwellers recruited onto the study. This small number of participants limits the statistical strength of the study. This has been discussed further in Section 5.1.

2.   Gender

In this study only women were eligible to participate. This was due a decision by the funders of the OEP in West Auckland (the Accident Compensation Corporation) to restrict the delivery of the OEP to this discreet population. This limits the generalisability of the study findings to women only however the meta-analysis of the Otago trials demonstrated that the OEP was equally effective for men as women (Robertson et al., 2002).

3.   Age

In this study only women over the age of 80 years were eligible to participate, for the reason that has been outlined above. This limits the generalisability of the study findings to only women over 80 years. The Otago trials (A. J. Campbell et al., 1999b;

Robertson, Devlin et al., 2001) that included participants younger than 80 years (65 years and older, and 75 years and over, respectively) found that the OEP was not effective in reducing falls in the younger older adult.

4.   Ethnicity

The study participants were all of European descent, which is not representative of the general population of New Zealand. Although all patients at the participating general practices had an equal opportunity to receive the OEP, the age criteria was a barrier to participation for Maori and those from Pacific nations as the life expectancy of people of these ethnicities is lower than that of New Zealand Europeans. As the OEP was designed to be a falls prevention programme it may be prudent for the funders to consider widening the delivery of the OEP to older adults over the age of 65 regardless of gender as this would increase access for all New Zealanders.

5.   Time period of study

The study was only 6 months long, as opposed to the full length of the OEP, which is 12 months. When strengthening the musculoskeletal system, the primary response is neural adaptation with muscular hypertrophy occurring secondarily over a longer period of time (American College of Sports Medicine, 1998; Deschenes & Kraemer, 2002). Strengthening is also dose responsive so with the OEP exercises being of a moderate intensity strength changes will occur slowly over a longer period of time (American College of Sports Medicine, 1998). It is possible that if the same outcome measures were applied to the OEP group and the control group after 12 months a difference between the two groups would may been observed. It was expected that if the OEP led to increased strength, that this would have been measurable at 6 months.

6.   Time lapse between starting OEP and baseline assessment.

The pathway of entry into the study created a time lapse of at least 2 weeks between participants beginning the OEP and the baseline measures being completed. Women who were receiving the OEP were invited, during the nurse's first visit to deliver the OEP, to participate in the study and left with a study information sheet to read in their own time. On the nurse's second visit, a week later, the potential participant was asked if they would like to volunteer. Recruitment was done this way in order to give potential participants time to consider participating in the study and to not feel pressured into giving an answer on the spot. However as changes in strength and

balance occur over months and not weeks (Rutherford & Jones, 1986), this was not expected to have an effect on the outcomes.

5.4 Clinical implications for physiotherapy

The results from this study did not demonstrate a significant change in measures of strength and balance in women over 80 years after participating in the OEP for 6 months. However the OEP is being widely used throughout New Zealand based on the previous evidence of its effectiveness in preventing falls.

For physiotherapists working in falls prevention in New Zealand, the OEP offers a well resourced, discrete intervention. However if the critical components of the OEP are not clearly understood one cannot be certain that the underlying cause of a fall is being treated. It may be possible that the OEP is effective because it is a general activation programme that encourages older adults who were not previously engaged in any form of regular exercise to become less sedentary. That the OEP group did not deteriorate in most of the outcome measures used would support this, as gait velocity, the step test, the 30s chair stand test and the timed up and go test all have age normative scores that decrease with age. However the control group did not deteriorate either, it could be that as a group they are sufficiently active to prevent physical decline or that 6 months is an insufficient period of time over which to observe age-related decline.

The multifactorial causes of falls are a challenge for physiotherapists to assess. Assessment tools vary from the level of impairment to activity to participation and do not always result in a clear direction for treatment options. The outcome measures used in this study were activity rather than impairment based reflecting the balance that is required in a home environment and also that balance does not require maximal strength but an appropriately scaled and timed task specific response (Gu et al., 1996; Hall et al., 1999). Of the participants who dropped out of the OEP group, three were unable to do the step test and one the 30 second chair stand test at baseline assessment. The inability of an older adult to perform a baseline measure may be useful in discriminating which older adults would benefit from the OEP and which are to frail to complete the OEP.

5.5 Further research

There have been suggestions made throughout the discussion regarding the future development of the OEP and its delivery. These will now be summarised and additional ideas proposed.

1.   The Accident Compensation Corporation is currently funding the OEP as a population health initiative, with the target population being dictated by current evidence of effectiveness. Such arbitrary criteria do not allow for individual need within the wider population and creates a bureaucratic barrier to those who may also benefit from the OEP. The criteria for access to the OEP should be widened to adults over the age of 65 years regardless of gender and a screening tool developed to ensure that the OEP is the appropriate level of input.

2.   The critical components of the OEP remain unclear. If these components were identified, then the relative contribution of individual exercises could be evaluated. Currently if a participant were prescribed all of the OEP, they would be completing a total of 22 exercises. This far exceeds the recommended number of 5 to 10 exercises to maintain adherence to an exercise programme (Rastall et al., 1999). Decreasing the number of exercises in the OEP may increase exercise adherence.

3.   The method of the ankle weight prescription could be improved, by adopting the testing and prescribing methods recommended by the American College of Sports Medicine. Conversely the exercises using ankle weights could be omitted from the OEP and a greater emphasis placed on exercises which use body weight for resistance. The effect of either of these changes would then need to be evaluated.

5.6 Conclusion

After 6 months on the OEP the only statistically significant change was a slowing of gait velocity in the OEP group, all other outcome measures remained unchanged. These findings are similar to the lack of change measured in the balance and strength tests in the Otago studies (Robertson et al., 2002). The four strength and balance measures that were used in the present study (gait velocity, the step test, the 30 second chair stand test and the timed up and go test) all have normative values that decrease with age, reflecting the physiological effect that ageing has on function. It is possible that expecting women over the age of 80 years to improve significantly in

strength and balance measures may be an unrealistic expectation, maintenance of strength and balance may be a more appropriate goal for this population. Overall the OEP group demonstrated an upward trend while the control group demonstrated the reverse, although these changes were too small to be statistically significant, a small change in functional capacity can have a large impact on a person's functional independence. This has been demonstrated in studies that have not made demonstrable changes in physical outcome measures but have significantly decreased the number of falls in participants (Tinetti, Baker et al., 1994; Wolf et al., 1996).

This study adds to previous research by the New Zealand Falls Prevention Group (the Otago trials) that was conducted in order to develop and evaluate the effectiveness of the OEP. The OEP is proven to be effective in decreasing falls and falls related injuries but the mechanisms by which this occurs are unclear.

The aim of this study was to evaluate whether strength and balance, and confidence in daily tasks changed after 6 months of participation on the OEP, as strong evidence of strength and balance changes was lacking from the original Otago trials. Different outcome measures were used in this study compared to the Otago trials, as assessments were completed in the participant's home rather than in a laboratory setting. The study was designed as a cohort study of two independent groups, a group of community dwelling women over the age of 80 years who were participating in the OEP and an age matched control group of community dwelling women who continued with their normal activities of daily living.

Participants were assessed at baseline and again after a period of 6 months. There were no statistically significant improvements in strength and balance, or confidence in the OEP group and no statistically significant differences between the OEP and control group. These results are consistent with those of the original Otago trial and the consequent meta-analysis of all the Otago trials. The results from this study need to be interpreted with caution, as due to the small sample size the study is underpowered.

The role of physiotherapy in falls prevention is based predominantly on treating the modifiable risk factors of muscle weakness and decreased balance. The results from this study could be interpreted in a number of ways that may be clinically meaningful. Firstly that a strengthening programme for adults over the age of 80 years may need to be longer than 6 months duration to produce a measurable change. Secondly, that in an

aged population the changes that occur to prevent falls may be too subtle to be detected by measures of strength and balance currently used in the community. And thirdly, the OEP may act on systems other than strength and balance in preventing falls.

As with other effective interventions of falls prevention programmes the critical components of the OEP remain unknown.

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APPENDICES

Appendix A

Ethical Approval

Appendix B

Modified Falls Efficacy Scale
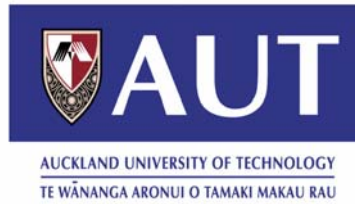
The Otago Exercise Programme (OEP):
Do strength and balance improve?
Modified Falls Efficacy Scale

Name:_____

Date: _____

On a scale of 0 to 10, how confident are you that you can do each of these activities without falling

0 means "not confident / not sure at all"
5 means "fairly confident / fairly sure"
10 means "completely confident / completely sure"

- If you have stopped doing an activity at least in part because of being afraid of falling, score 0.
- If you have stopped doing an activity purely because of a physical problem, leave a blank.
- If you do not currently do the activity for other reasons, please rate the item based on how you think you would rate if you had to do the activity today

Name:_____

Modified Falls Efficacy Scale

Get dressed and undressed
    0   1   2   3   4   5   6   7   8   9   10

Prepare a simple meal
    0   1   2   3   4   5   6   7   8   9   10

Take a bath or shower
    0   1   2   3   4   5   6   7   8   9   10

Get in / out of a chair
    0   1   2   3   4   5   6   7   8   9   10

Answer the door or telephone
    0   1   2   3   4   5   6   7   8   9   10

Walk around the inside of your house
    0   1   2   3   4   5   6   7   8   9   10

Reach into cabinets or closets
    0   1   2   3   4   5   6   7   8   9   10

Light housekeeping
    0   1   2   3   4   5   6   7   8   9   10

Simple shopping
    0   1   2   3   4   5   6   7   8   9   10

Using public transport
    0   1   2   3   4   5   6   7   8   9   10

Crossing roads
    0   1   2   3   4   5   6   7   8   9   10

Light gardening or hanging out the washing
    0   1   2   3   4   5   6   7   8   9   10

Using front or rear steps at home
    0   1   2   3   4   5   6   7   8   9   10

Appendix C

Information Sheet

AUT

AUCKLAND UNIVERSITY OF TECHNOLOGY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

**The Otago Exercise Programme (OEP):
Do strength and balance improve?**

Information Sheet

Principal Investigator   Elizabeth Binns
Contact phone number   839 0843

You are invited to take part in a study that is evaluating strength and balance. You may be either a member of a group participating in the Otago Exercise Programme or could be a member of the control group. Please take time to consider participating in this study, if you would like to, please contact the researcher within a week of receiving this letter. Should you not wish to be a part of this study, you will not be contacted further. Your participation is entirely voluntary (your choice). You do not have to take part in this study, and if you choose not to take part you will receive your usual health care.

ABOUT THE STUDY

This study will assess the strength and balance of people using simple clinical tests. If you participate, a physiotherapist will make two 1 hour home visits which will be 6 months apart.

The physiotherapist will take a history of your medical health, level of activity and history of falls, then conduct balance and strength assessments. You will also be given a falls and exercise diary, which is to record on what days you exercise and if you have any falls. This diary will be returned to the researcher on a monthly basis. If you did have a fall, the researcher will phone you to ask about the circumstances of the fall.

BENEFITS RISKS AND SAFETY

     The benefit of this study is to assess the effect muscle strength and balance have on the potential to decrease falls.

To be included in the study you must be:
     Able to understand the requirements of the study
     Able to understand English or have a friend or whanau interpret
     65 years old or older
     Living in your own home
     Independently mobile
You will be excluded from the study if:
     You are already receiving physiotherapy

PARTICIPATION

If you do agree to take part in the study you are free to withdraw at anytime, without having to give a reason and this will in no way affect your continuing health care. Participation in this study will be stopped should your doctor feel it is not in your best interests to continue.

GENERAL

"Will my GP be told I am in the study?"
It is your decision whether or not your GP will be informed of your participation.

"What will happen at the end of the study?"
The results of your assessments will be discussed with you at the completion of

the study and sent to you in letter form also. The results of the total study will be

published in a physiotherapy journal.

"Where can I get more information about the study?"
By telephoning the researcher, Elizabeth Binns on 839 0843, or her supervisors Denise Taylor on 917 9999 extension 7080 or Caroline Stretton on 917 9999 extension 7062

"If I need an interpreter, can one be provided?"
The study does not have the resource to pay for an interpreter but you may have a friend, family or whanau support to help you understand the risks and/or the benefits if this study and any other explanation that you require.

If you have any queries or concerns regarding your rights as a participant in this study you may wish to contact a Health and Disability Advocate, telephone 0800 555 050.

CONFIDENTIALITY

No material that could personally identify you will be used in any reports on this study. The results of assessments will be kept in a locked filing cabinet that only the researcher and her supervisor will have access to. After completion of the study all documents will be shredded.

STATEMENT OF APPROVAL

This study has received ethical approval from the Auckland Ethics Committee.

Please feel free to contact the researcher if you have any questions about this study.

Appendix D

Recruitment Poster

LOOKING FOR VOLUNTEERS

Would you like to participate in a research study?

Are you over 80 years of age?

Do you live in your own home?

Your strength and balance will be tested. The assessments will take approximately an hour and you will be informed of your results.

If you are interested please write your name and contact number at the bottom of the sheet.

If you would like further information you can contact Elizabeth Binns on 839 0843

Name & telephone	Name & telephone

Appendix E

Consent Form

The Otago Exercise Programme (OEP):
Do strength and balance improve?

Consent Form

I have read and I understand the information sheet dated _____ for people taking part in a study designed to assess muscle strength and balance. I have had the opportunity to discuss this study. I am satisfied with the answers I have been given.

I understand that taking part in this study is voluntary (my choice) and that I may withdraw from the study at any time and this will in no way affect my continuing health care.

I understand that participation in this study is confidential and that no material that could identify me will be used in any reports on this study.

I have had time to consider whether to take part in the study.

I know who to contact if I have any questions about the study or if anything occurs which I see as a reason to withdraw from the study.

I would like a copy of the results of the study.   **YES/NO**
I agree to my GP being informed of participation in this study   **YES/NO**

I _____ (full name) hereby consent to take part in this study.

Signed: _____   Date _____

Printed Name: _____

Address for results :   _____

Researchers names and contact phone numbers	Elizabeth Binns	839 0843
	Denise Taylor	917 9999 extension 7080
	Caroline Stretton	917 9999 extension 7062

Project explained by
Project role
Signature
Date

Appendix F

Assessor Instructions

INDEPENDENT ASSESSOR ASSESSMENTS

Timed Up & Go
A participant stands from a <u>chair with arms</u>, walks 3m to a line on the floor, turns around returns to the chair and sits down.
The chair should be 47cm high.
The participant should begin with their back against the back of the chair but if their height prevents this, start with their feet flat on the floor.
A line on the floor is used to mark 3m rather than a cone to try and reduce the variety of ways participants may turn.

30 second chair stand test
A participant is asked to fully stand up and sit down as many times as possible in 30 seconds from a <u>chair without arms</u>.
The chair should be 43.2cm high.
Participant's arms should be crossed at the wrist and held against the chest.

Gait velocity
A participant is asked to walk at a comfortable speed over a 4 metre walkway and is timed over the middle 3 metres (to avoid the effects of acceleration and deceleration).

Step Test
A participant is asked to step one foot up and down onto a 7.5cm step as many times as possible in 15 seconds. Both right and left legs are assessed. If possible this test is to be done in bare feet.

Appendix G

Data Collection Sheet

The Otago Exercise Programme (OEP):
Do strength and balance improve?

Assessment Form

Name:_____   DOB: _____

Date: _____   GP: _____

Mobility device	Y N
Step test	R L
TUAG	
Velocity (3m/?s)	
30s Chair stand test	
MMSE score	
Modified FES	

Appendix H

Raw Data

Baseline measures of control group participants

Participant ID	Age (years)	Date of first assessment	MMSE (%)	MFES (%)	Walking device	Gait velocity (m/s)	TUAG (s)	30s chair stand	Right step test	Left step test
001	83	31.05.04	28.0	100.0	no	0.8	8.85	12	14	13
002	82	04.06.04	30.0	100.0	no	1.0	11.22	11	10	12
003	87	01.06.04	30.0	76.0	yes	0.5	21.63	0	8	9
004	88	31.05.04	27.5	98.0	yes	0.7	19.44	6	10	10
005*	81	01.06.04	30.0	84.0	yes	0.8	9.06	15	15	16
006	83	04.06.04	30.0	87.5	yes	0.9	12.15	13	10	12
007	92	04.06.04	28.5	96.0	yes	0.3	33.91	0	6	6
008	82	31.05.04	30.0	87.0	yes	0.6	17.00	7	7	8
009	84	10.06.04	30.0	100.0	no	1.7	7.72	19	22	24
010	90	11.06.04	30.0	98.0	yes	0.9	10.09	12	14	12
011	89	10.06.04	30.0	100.0	no	0.7	12.00	0	13	12
012	86	15.06.04	27.0	83.0	no	0.8	15.22	6	7	6
013	86	18.06.04	30.0	100.0	no	0.9	9.78	14	15	15
014	84	18.06.04	30.0	80.0	yes	0.7	14.94	11	10	8
015	82	07.09.04	26.5	100.0	no	0.8	12.65	11	12	11
016	80	07.09.04	27.5	87.0	no	1.1	9.38	12	16	16
017	82	07.09.04	27.5	95.0	yes	0.8	11.43	9	9	9
018	90	15.10.04	27.5	81.0	yes	0.6	16.28	9	10	10

* dropped out before final assessment

Baseline measures of OEP group participants

Participant ID	Age (years)	Date of first assessment	OEP first visit	MMSE (%)	MFES (%)	Walking device	Gait velocity (m/s)	TUAG (s)	30s chair stand	Right step test	Left step test
101	86	05.05.04	05.05.04	29.0	62	yes	0.6	22.00	11	11	12
102	86	18.05.04	18.05.04	30.0	61	yes	0.7	17.20	9	10	9
103*	82	24.05.04	24.05.04	26.5	85	yes	0.6	14.53	0	10	8
104*	78	31.05.04	31.05.04	28.5	95	yes	1.0	10.07	12	12	12
105	83	08.06.04	08.06.04	30.0	94	no	0.8	14.13	14	11	11
106	88	22.06.04	22.06.04	29.0	100	no	1.2	7.56	20	17	19
107*	90	24.06.04	24.06.04	29.0	100	no	1.0	10.94	11	14	17
108	82	29.06.04	29.06.04	27.5	54	yes	0.4	19.94	0	4	5
109	91	30.06.04	30.06.04	30.0	64	yes	0.4	24.63	6	7	4
110*	87	30.06.04	30.06.04	22.5	82	yes	0.6	29.32	9	8	7
111*	87	01.07.04	01.07.04	28.0	58	yes	0.4	21.75	12	0	0
112*	81	29.06.04	29.06.04	30.0	55	yes	0.7	15.31	7	0	0
113*	86	06.07.04	06.07.04	29.0	87	yes	0.4	25.65	7	0	0
114	89	22.07.04	22.07.04	29.5	100	yes	0.8	12.94	14	9	9
115	82	02.08.04	02.08.04	28.5	85	no	0.9	11.53	8	11	11
116	87	13.08.04	13.08.04	29.0	81	yes	1.0	12.88	10	0	11
117	84	03.09.04	03.09.04	29.0	73	yes	1.2	10.62	9	12	12
118	86	14.09.04	14.09.04	26.0	10	no	1.1	9.22	17	15	15
119	80	30.11.04	30.11.04	28.0	98	no	1.4	7.50	15	16	16

* dropped out before final assessment

Reassessment measures of control group participants

Participant ID	Date of reassessment	Days between assessments	MFES (%)	Gait velocity (m/s)	TUAG (s)	30s chair stand	Right step test	Left step test	Falls
001	23.11.04	176	100.0	1.1	8.94	12	14	14	0
002	21.11.04	170	100.0	0.8	10.22	12	12	13	0
003	23.11.04	175	82.5	0.3	26.35	0	6	0	2
004	24.11.04	177	94.0	0.6	19.72	0	7	7	0
006	24.11.04	173	64.0	0.7	14.62	11	10	9	0
007	23.11.04	172	80.0	0.4	21.91	0	9	8	0
008	23.11.04	176	70.0	0.6	13.56	6	7	8	0
009	30.11.04	173	100.0	1.5	7.19	21	23	25	0
010	30.11.04	172	100.0	0.7	14.87	10	11	10	1
011	30.11.04	173	100.0	0.8	11.31	13	12	12	0
012	06.12.04	174	90.0	0.7	14.41	9	10	9	0
013	30.11.04	165	100.0	0.9	8.31	14	16	16	0
014	06.12.04	171	85.0	0.7	13.53	10	9	10	0
015	21.02.05	167	100.0	0.7	14.41	11	9	9	0
016	21.02.05	167	62.5	0.9	12.00	9	12	12	0
017	21.02.05	167	97.0	0.9	15.53	8	8	10	0
018	04.04.05	171	68.0	0.4	18.00	10	10	9	0

Reassessment measures of OEP group participants

Participant ID	Date of reassessment	Days between assessments	MFES (%)	Gait velocity (m/s)	TUAG (s)	30s chair stand	Right step test	Left step test	Falls
101	04.11.04	175	82.5	0.5	22.03	11	8	8	0
102	24.11.05	180	64.0	0.6	13.66	9	11	9	0
105	08.12.04	173	87.0	0.7	11.72	13	12	13	0
106	16.12.04	168	100.0	0.9	8.00	20	16	16	0
108	12.01.05	184	32.0	0.4	14.28	0	0	0	0
109	12.01.05	184	62.0	0.5	22.28	0	6	6	0
114	07.02.05	162	98.0	0.7	10.19	19	14	14	0
115	21.02.05	171	87.5	0.7	14.93	0	9	9	0
116	07.02.05	165	85.0	0.9	12.50	11	12	10	1
117	04.04.05	199	79.0	0.75	11.97	8	11	11	0
118	04.04.05	171	100.0	0.9	9.41	25	17	18	0
119	02.06.05	148	100.0	1.0	7.75	17	18	17	1