School of Physiotherapy

Functional Adaptation to Exercise in Elderly Subjects

Annette Isobel Brown

This thesis is presented as part of the requirements for the award of the
Degree of Doctor of Philosophy
of the
Curtin University of Technology

March 2002

Abstract

Maintenance of physical function with advancing age is vital to continued independent living, which is highly valued by older people. Although commonly associated with the ageing process, loss of functional ability may well be accelerated by inactivity and subsequent decreasing physical capacities, such as muscle performance or balance abilities. The impact of increased levels of activity on physical performance and functional ability was investigated by a single blind randomised controlled study.

Two intervention programs, one based on increased levels of physical activity and the second on increased levels of social activity, were provided to a group of community-living participants aged 75 years and over. Another group, receiving no intervention was also included. The exercise intervention offered twice weekly sessions of exercise over a 16-week period. This was designed and supervised by physiotherapists. The social intervention offered a weekly, two-hour session over 13 weeks. Baseline, post-intervention and follow-up assessments measured aspects of physical performance (muscle, balance, gait and step height performance) and functional ability (tiredness of limbs, mobility tiredness and the need for assistance with mobility and activities of daily living). In addition, all participants completed a monthly health and falls report. One hundred and forty-nine subjects were admitted into the study with 108 completing the intervention phase and all four assessments

Analysis of data indicated that the exercise intervention was effective in improving muscle performance (shoulder abduction mean difference 13.00, 95%CI 11.63-14.37; hip abduction mean difference 5.97, 95%CI 4.73-7.20; knee flexion mean difference 4.10, 95%CI 3.32-4.88; dorsiflexion mean difference 4.72, 95%CI 3.74-5.71), dynamic balance ability(Functional Reach mean difference 11.45, 95%CI 9.41-13.48), maximal gait speed (mean difference 0.62, 95%CI 0.50-0.74) and step height performance (mean difference 0.19, 95%CI 0.01-0.29). Improvements in dynamic balance and maximal walk performance were maintained for a period of four months following cessation of the intervention. The social program did not affect aspects of physical performance.

Functional improvements were evident for both exercise and social subjects. Immediate improvements in limb tiredness (upper mean difference 0.37, 95%CI –0.11-0.84; lower mean difference 0.63, 95%CI 0.37-0.89) and mobility tiredness (mean difference 1.43, 95%CI 1.16-1.70) and activities of daily living dependence (mean difference 0.25, 95%CI –0.23-0.75) were demonstrated. Four and eight months later, exercise subjects had maintained the improvement in mobility tiredness and activities of daily living dependence. Mobility dependence showed a delayed improvement in both the exercise and social intervention participants. This improvement was not evident immediately following intervention, but emerged at both the four and eight month follow-up assessments.

An intention to treat analysis (involving both completing and non-completing subjects) confirmed the usefulness of the exercise intervention as a strategy to improve and maintain functional ability in older subjects, specifically with regard to tiredness of the lower limbs, tiredness during mobility tasks and activities of daily living dependence. In addition, following the cessation of the exercise intervention, participants reported less mobility tiredness and dependence in activities of daily living tasks over the following eight-month period.

The relationship between physical performance and functional ability indicated that muscle performance and limb tiredness were significantly associated. Decreased muscle performance of the upper limb was associated with reports of increased tiredness during functional activities involving the upper limb, such as combing hair and dressing the upper body. Similarly, decreased muscle performance of the lower limb, especially proximally, was associated with increasing tiredness of the lower limb during functional activities. Further, decreased proximal muscle performance of both the upper and lower limb was significantly associated with decreasing independence in the performance of physical activities of daily living. These results indicate the significant influence of muscle performance on functional ability, especially on tiredness of the limbs and activities of daily living dependence.

The ability to predict future functional limitation, based on decreasing physical performance, was examined and shown to be of limited value. Hip muscle performance and changes in usual gait speed were poorly associated with increased lower limb tiredness and dependence in physical activities of daily living respectively. The lack of a robust relationship between variables of physical performance and functional ability measures indicates that loss of physical performance is not strongly associated with the development of functional limitations.

Self-reported falls were monitored throughout the study. A significant increase in the number of participants reporting falls was evident in both the social intervention group and the control group throughout the study. In contrast, there was no change in the number of exercise participants reporting falls. These results suggest that the exercise intervention was effective at minimising the usual increase in the number of older people experiencing falls over time.

The results of this study suggest that the exercise intervention program was effective in improving physical performance in elderly subjects. This also resulted in improved functional ability. Positive effects continued following completion of the program as improvements in mobility and activities of daily living tasks were demonstrated for a further eight months. By contrast, the social intervention program appeared to influence only the need for help with mobility tasks in the longer term.

Increased physical activity, in the form of an exercise intervention program, specifically designed for community-living elderly people, can improve and maintain functional ability, both immediately and for up to eight months following the completion of the program. As such, involvement in exercise, even in the short-term, should be encouraged as a means of maintaining physical independence in later life. Therapists devising exercise programs specifically for older people should ensure that the associated outcome measures incorporate assessments of functional ability and not simply measures of impairment. This study has demonstrated that a real benefit of increased physical activity in older people may well be the increased physical independence associated with participation.

Acknowledgements

I wish to sincerely thank my supervisor Professor Joan Cole for her encouragement and faith in my ability to complete this work. Her enthusiasm, guidance and patience throughout the years have culminated in this thesis.

I also wish to thank those who have assisted in the position of Associate Supervisor, Drs Kathy Briffa and Garry Allison, for their advice and assistance, both specifically to this study but also to the process of doctoral research.

My appreciation is extended to members of staff of the School of Physiotherapy, particularly Associate Professor Rosemary Coates for her compassion and wise counsel and Dr Marie Blackmore for statistical advice and assistance.

I am grateful to the subjects who generously participated in this study, some for as long as two years, and whose commitment and enthusiasm encourages me still.

Physiotherapists Sue Morris, Karen Morley and Dean Newman assisted in physical data collection at each assessment and Tony Petta supervised and led the exercise intervention program. I thank them for their commitment and professionalism during their involvement with this study.

Financial support for this study was provided by the School of Physiotherapy, Curtin University, as was part-time employment for most of its duration. An Australian Post-graduate Award assisted me throughout the intense data collection process. The Division of Health Sciences funded study leave for the preparation of the thesis. I am grateful for all of the financial and in-kind support I received both within and outside Curtin University.

Many fellow postgraduate students, staff members of the School of Physiotherapy and physiotherapy colleagues provided ongoing support and encouragement, as well as friendship and fun, and helped to place this work in context and for this I thank them.

Finally, I acknowledge the support of my family, my sister and particularly my parents, who gladly provided many hours of extra child minding in the guise of grandparenting and to my children, Michael and Jane. My wish for my children is a happy and healthy life in a world that is a kinder place for old people in their own later years.

Table of Contents

CHAPTER FOUR

CHAPTER FIVE

CHAPTER SIX

List of Tables

List of Figures

Abbreviations

Abbreviation	Definition
ADL	Activities of Daily Living
ANOVA	Analysis of variance
cm	centimetres
F-up 4	Follow-up assessment at 4 months post-intervention
F-up 8	Follow-up assessment at 8 months post-intervention
IADL	Instrumental Activities of Daily Living
ICC	intraclass correlation coefficients
kg	kilograms
LLT	Lower Limb Tiredness
MANOVA	Multiple analysis of variance
MH	Mobility Help
m/s	metres per second
MT	Mobility Tiredness
PADLH	Physical Activities of Daily Living
PAQ	Physical Activity Questionnaire
Post-intvn	Post-intervention assessment
QFA	Questionnaire of Functional Ability
s.d.	Standard deviation
SEM	Standard error of measurement
SLBEC	Single limb balance with eyes closed
SLBEO	Single limb balance with eyes open
ULT	Upper Limb Tiredness

CHAPTER ONE
INTRODUCTION

> *"All parts of the body which have a function, if used in moderation and exercised in labours to which each is accustomed, become thereby well-developed and age slowly; but if unused and left idle, they quickly become liable to disease, defective in growth, and age quickly."*
>
> Hippocrates, 3rd century BC

Older Australians overwhelming report that they wish to remain independent in their later years and to not to "become a burden on others" (Kendig, Helme, Teshuva, Osborne, Flicker and Browning, 1996). The expected ageing of the Australian population in the next 50 years has focussed attention on the need to maintain the independence and well-being of elderly people. With increasing life expectancy, the greatest change in Australia's older population will be those aged 85 years and over. This group has high rates of disability (Australian Bureau of Statistics, 1999b). The financial and other costs to the community of providing care for older disabled people has initiated discussion about alternate strategies to delay or prevent loss of the physical independence so highly prized by elderly people. One such strategy may be to increase levels of appropriate physical activity in this and younger age groups (Teshuva, Stanislavsky and Kendig, 1994).

Physically active lifestyles provide a range of benefits for older people, ranging from delayed onset of many of the physiological and physical changes associated with the usual ageing process to lower levels of institutionalisation, morbidity and mortality (Mor, 1993). Indeed, exercise is often referred to as a panacea for the detrimental effects of advancing age (Twomey and Taylor, 1984). Short-term exercise programs for older people have clearly demonstrated beneficial effects on a range of variables including muscle performance and cardiovascular endurance (Wagner, Pfeifer, Cranfield and Craik, 1994). Models of disablement hypothesise a pathway from impairment to disability, providing a basis for the underlying assumption that exercise induced minimisation of impairments might be associated with decreases in physical disability (Nagi, 1991; World Health Organisation, 1997). Currently, however, there is little evidence to support this theory.

The effect of exercise cessation on many variables of physical performance in older people is largely unknown, with the notable exception of muscle performance. Improvements in muscle performance are lost shortly after the cessation of exercise (Thompson, 2000). The detraining effect for other variables has not been reported. Balance and gait performance, in particular, have not been studied following cessation of exercise. Similarly, there are no reports of the effect of exercise cessation on functional abilities in older people.

Other forms of intervention may also be useful for older people. Socialisation and social networks have been identified as factors related to longevity, health and coping skills in later life (Kaplan, 1992). Social activity, therefore, offers specific supports to an older person and intervention programs, based on increased social activity, may provide similar benefits. There is a distinct lack of research in this specific area and the influence of social activity on functional ability in later life is largely unexplored.

The relationship between physical performance abilities, such as strength, balance and gait, and functional abilities, such as activities of daily living and mobility, has not yet been clearly defined. This is despite being advocated as potentially the variables most directly related to ongoing physical independence (Tinetti, Inouye, Gill and Doucette, 1995). Losses in the physical performance domain and related losses in functional abilities have begun to be described (Gill, Williams and Tinetti, 1995a). Whether improvement in physical performance can hinder loss of functional independence has not been demonstrated but, if so, holds potential as a strategy for elderly people who wish to remain independent.

In order to more clearly describe the influence of exercise and social activity on physical performance and functional ability in community-living elderly people, a randomised single blind controlled study with repeated measures would appear to be an appropriate research design. The purpose of such a study would be –

- to determine the effect of intervention programs on physical performance and functional ability,
- to determine the relationship between physical performance and functional ability,
- to observe parameters associated with the development of functional limitation, and
- to record falls rates in this independent community-living older group.

An obvious aim would be to describe the effect of cessation of exercise in such a cohort. Therefore, a follow-up after cessation of intervention would appear to be appropriate to monitor changes over time. The results of such a study would provide information about the influence of exercise and social intervention on functional ability in older people and may provide useful evidence about the maintenance of physical independence in the face of advancing age.

A single blind randomised controlled study was designed to evaluate the effect of participation in intervention programs offering enhanced levels of either physical activity or social activity. A lengthy assessment period, of eight months, following completion of the exercise program was included in the study design in order to evaluate the effects of intervention cessation. Potential subjects were classified as those aged 75 years and over and living independently in the community. Ethical approval was granted by Curtin University, Western Australia. Publicity, designed specifically to attract potential subjects, was carried out in the metropolitan area of Perth. In particular, suburbs with high numbers of older residents were targeted.

The exercise intervention was designed and supervised by a number of physiotherapists as a program suitable for elderly people. The intervention consisted of twice weekly supervised exercise sessions, a weekly home exercise program and was of 16 weeks duration. An Occupational Therapist assisted in the design of the social intervention program of 13 weeks duration. Venues for each program were community based and located throughout the metropolitan area. Transportation to and from intervention and assessment venues was provided for participants who were unable to access other forms of transport.

The study was specifically designed to evaluate whether functional limitations in an elderly population could be affected by an exercise or social intervention program and whether benefits persisted beyond the intervention period,

CHAPTER TWO
REVIEW OF THE LITERATURE

2.1 Older Australians – a snapshot

Australia, like many other nations in the world, is experiencing a significant demographic shift as a result of the ageing of its population. Both increasing life expectancy and decreasing fertility rates are contributing to a significant change in the age structure of the nation's population in the first half of the 21st century (Australian Bureau of Statistics, 1999a). The elderly population, defined as those aged 65 years and older, is predicted to rise in both total number and as a proportion of Australia's population.

The most dramatic change is likely to be in the cohort aged 85 years and older. Over the next 50 years, the number of people aged 85 years and over is projected to increase more than four-fold, reaching between 1.1 million and 1.2 million by 2051 and representing 1-5% of the total population (Australian Bureau of Statistics, 1999a). This growth is expected to be most rapid in the period 2031-2041 during which a 50% increase is projected in the number of people in this age group.

Growing older can have profound effects on lifestyle (Australian Bureau of Statistics, 1999a). Changes in levels of physical and economic dependence in relationships and family responsibilities, impact strongly on the living arrangements of older people. These changes become significant, not at age 65 years in Australia, but 10 or so years later. Demographic data indicate that substantial increases in disability and the associated diminished independence, both in physical activities and in living arrangements, occur after age 75 years.

The vast majority of older people in Australia live independently in the community (Australian Bureau of Statistics, 1999a). Around half (56%) of the older population were living with their partner in 1996 and in total, 65% were living with at least one relative. A further 28% were living alone and 6% lived in cared accommodation including nursing homes.

The Survey of Disability, Ageing and Carers conducted by the Australian Bureau of Statistics, from 16 March to 29 May 1998, provides the most current and comprehensive data on Australian residents with a disability, of older age and those who provide assistance to others with a disability. The Survey's findings demonstrate that the rate of disability increases with advancing age (Australian Bureau of Statistics, 1999b). Of those aged 65-74 years and over, about half reported some disability. Australians aged 75-84 years reported higher levels of disability and, of the cohort aged 85 years and over, 84% reported disability. Older females generally reported higher levels of disability than older males. A considerable proportion of disability in the older population, approximately 19% of those aged 65-74 years and 28% of those aged 75 years and over, have been classified as experiencing chronic physical conditions (Mathers, Vos and Stevenson, 1999). Almost all people in residential accommodation had significant disability and most reported a profound core activity restriction. Table 2.1 summarises the prevalence of disability in older Australians reported in 1998.

The need for assistance reported by older people increases with age, regardless of disability. Most commonly, the need for assistance relates to property maintenance and health care, with other needs related to transport, mobility, housework and self-care (Australian Bureau of Statistics, 1999b). However, less than half the population of older persons required assistance, with those aged 85 years and over having a higher need for assistance than those aged 65-74 years (92% compared with 32%). Friends and family provided significant assistance, although 59% of assistance was purchased.

Table 2.1 Disability rates and classification by age group and gender for persons aged 65 years and over (Australian Bureau of Statistics, 1999b).

Age (years)	Level of Disability (% of total cohort)				
	Profound	*Severe*	*Moderate*	*Mild*	*No disability*
Men					
65-69	3.3	4.5	10.8	16.0	56.6
70-74	7.1	4.7	10.3	21.6	48.9
75-79	10.6	8.4	15.3	20.3	39.1
80-84	16.2	8.0	7.8	24.8	36.6
85+	43.2	12.8	10.4	16.9	15.7
Women					
65-69	3.7	5.5	8.9	14.8	62.4
70-74	9.0	6.1	10.4	16.5	52.7
75-79	15.6	9.3	10.2	18.3	43.4
80-84	27.4	8.1	6.9	22.6	33.2
85+	55.4	13.4	6.9	7.5	15.8

The Health Status of Older People project which was conducted in Victoria, Australia, interviewed 1,000 elderly subjects in 1994 on topics including health related actions, functional health and prevalence of health conditions, quality of life, service use and transport (Kendig et al., 1996). The results of this study indicated that mobility impairment increased with age, more so for women than men. About one quarter of men and 38% of women aged 75 years and over were unable to walk 1 kilometre, compared with 11% of men and 23% of women aged 65-74 years. Difficulty performing instrumental activities of daily living (IADL) tasks became significant for women over 75 years of age. Further, the study revealed that while few of the elderly subjects were entirely sedentary, most carried out only light physical activity in the two weeks prior to interview. These activities included walking, housework and gardening. Subjects aged over 75 years were more likely to report participation in light physical activities only. These results, from Victorian older people, provide useful information that can be extrapolated to describe the general abilities and activities of older Australians.

A typical 85 year old Australian will be female, living alone in the community, with a high level of disability, indicating difficulty with or the need for assistance when performing one or more core functional activities, such as self-care, mobility or communication. The typical 75 year old is also likely to be female, living alone in the community but with no disability or only mild levels of disability. Therefore, it seems that the period between the ages of 75 and 80 years, or perhaps extending to 85 years, may be a crucial time in which appropriate intervention may minimise disability for longer living older Australians.

2.2 Functional Ability

Functional ability can be defined as " the performance of fundamental actions used in everyday life by one's similar age and gender group" (Verbrugge and Jette, 1994) and indicates the overall ability of body and mind to do 'useful' work. The performance of these actions can be measured and as such give an indication of an individual's functional ability, which generally falls into three broad categories – physical, social and mental. When comparing individuals with their peer group (often described by age and gender, and less often by occupation or disease etc.) limitations in function in any of these domains give rise to the concept of 'functional limitation'. Originally defined by Saad Nagi (Nagi, 1965), a sociologist, the concept of functional limitation is particularly useful for health professionals working with older people, as areas of limited function, rather than pathology, are highlighted for intervention or support.

The model provides a conceptualisation of the pathway from pathology and disease to functional outcomes (Nagi, 1965). It is based on sociological theory and has stood the test of time, becoming well established in disability research in Europe and later in the USA and other parts of the world (Mor, Murphy and Masterson-Allen, 1989). Nagi's refined model (Nagi, 1991), illustrated in Figure 2.1, takes pathology or disease as a starting point and describes the consequences for the individual. It has four central concepts – Active Pathology, Impairment, Functional Limitation and Disability.

Active Pathology →	Impairment →	Functional Limitation →	Disability
Interruption or interference with normal processes, and efforts of the organism to regain normal state	Anatomical, physiological, mental or emotional abnormalities or loss	Restrictions in basic, situation-free actions necessary for independent living	Limitation in the performance of socially defined role and tasks within a socio-cultural and physical environment

Figure 2.1 The process of disablement as described by Nagi (1991)

The active pathology (disease) stage refers to a process that alters the homeostasis within the organism that, in turn, triggers a response. Examples of diseases common within the older population include osteoarthritis, diabetes and dementia. As a consequence of the physiological or physical nature of the disease, mental or emotional abnormalities or losses in anatomical structures result. These constitute impairments. Impairments affect the ability to perform functional activities and, when significant, will likely trigger restrictions in everyday functions for an individual. This is defined as functional limitation. When the performance of tasks appropriate to socially defined roles is affected, disability follows. Documentation of the differences between functional limitation and disability is sparse. However, Lawrence and Jette (1996) clearly define functional limitations as situation-free activities whereas disabilities are situation-dependent activities. In addition, the presence of functional limitations has been demonstrated to be a significant driving force for the development of disabilities (Femia, Zarit and Johansson, 2001).

The World Health Organisation (WHO) also describes a taxonomy of the impacts of disease with three central concepts – impairment, disease and handicap (World Health Organisation, 1980). The concept of disability within the WHO model is synonymous with the concepts of Functional Limitation and Disability from the Nagi model. The WHO model describes a further stage of disadvantage, due to impairment or disability, which prevents fulfilment of a usual social role, and defines this as handicap. More recently, the terms disability and handicap have been revised to the updated synonymous terms of activity restriction (for disability) and activity participation (for handicap) (World Health Organisation, 1997).

Conceptualisation of the process, initiated by the presence of pathology or disease, which may lead to disability, is crucial to the health professional working with older people (Verbrugge and Jette, 1994). As disease, particularly chronic disease, is prevalent in this age group (Mathers et al., 1999), the emphasis for health related interventions shifts from amelioration of pathology to the reduction in its consequences – impairment, functional limitation and subsequent disability and handicap (Jette, 1994). In an older person, disease related changes might be compounded by impairments associated with the usual ageing process, commonly observed, for example, in vision, muscle strength and skin integrity (Fenske and Lober, 1990; Carlson, Ostir, Black, Markides, Rudkin and Goodwin, 1999). Thus, functional ability may be limited as a result of pathology or by the usual ageing process, or more commonly both. Additionally, physical inactivity alone is associated with functional limitations (Bassey, Bendall and Pearson, 1988; Carlson et al., 1999). Therapeutic interventions to restore complete functional ability may be unsuccessful and the focus, therefore, shifts to the reduction of impairments and the associated limitations in functional ability (Guccione, 1991).

This view has been discussed in the geriatric medicine literature in the early 1990's. Mor (1993) described a process of 'primary prevention of functional decline' focusing on functioning as a crucial aspect of health and quality of life for older people, similar to the models of compression of morbidity, (Fried and Bush, 1988) and active life expectancy (Katz, Branch, Branson, Papsidero, Beck and Greer, 1983). They argued that this would necessitate a shift from the primary prevention of disease toward the primary prevention of the functional consequences of disease in the older population. With this focus, the occurrence of disease is not as important as avoiding or minimising the impact of the disease on functional ability. In this case, the loss of usual function becomes the endpoint and the presence of disease becomes a risk factor for functional decline. The target population becomes people with a disease but without functional decline as a result of the disease. The targets of programs to prevent functional decline will, therefore, be the young or well elderly cohort rather than those already experiencing compromised functional ability. Mor's (1993) adaptation of the disease-oriented model toward a model of functional decline prevention, which was similar to that described by Nagi (1991), has now been widely accepted as the preferred model for the health care of older people.

Further refinement of the model proposed by Nagi (1991) has been described (Guccione, 1991; Jette, 1994; Jette, 1997). Both authors have used the philosophy of physical therapy and/or geriatric rehabilitation as the basis and the resultant redefined models include aspects such as environmental influences, lifestyle and behavioural factors, social supports and activity. These models acknowledge the wider influences affecting the performance of an individual.

The Nagi model provides a useful construct for the understanding of the process by which functional ability can be affected by pathological or disease processes. Functional limitations, which impact on the individual's ability to perform important daily activities, may be minimised or prevented if the effects of disease and pathology can be targeted and respond to early efforts to reduce their eventual impacts. For the older population, the prevention of limitations in functional ability may maximise independence at a time of life when increasing disability is prevalent.

2.2.1 Predictors of Functional Decline

Longitudinal health studies, primarily investigating risk factors for disease, such as cardiovascular disease and cancer, indicated, on secondary data analysis, factors associated with functional decline as subjects aged. Specific factors identified included lack of exercise (Mor et al., 1989), decreased levels of physical and social activity (Kaplan, G, Seeman, Cohen, Knudsen and Guranlik, 1987), lack of activities outside the home and increased passivity in activities (House, Robbins and Metzner, 1982). Much research has since been reported investigating predictive factors for functional decline in elderly people, although with little consensus between researchers about nomenclature and groups of factors. The resultant list of factors is both very specific and lengthy.

Results from a longitudinal study, which interviewed over 500 elderly subjects (65 years and over, 65% female) at baseline, 1.25, 6 and 10 years later in relation to impairments of the musculoskeletal origin, indicated that specific sites of musculoskeletal impairments were associated with the emergence of physical disability (Jette, Branch and Berlin, 1990). Impairment within the hand of musculoskeletal origin, classified on the basis of observed range of movement at the joints of the hand, was significantly associated with the development of limitation in ADL. Musculoskeletal impairment of the lower limb, again based on observed joint movement, was significantly associated with the development of limitations in instrumental ADL (IADL). The development or progression of sight or hearing impairment was not related to disability.

Australian data suggest that the risk of disability is associated with taking four or more medications, female gender, arthritis and a previous stroke (Collson, Cicuttuni, Mead and Savio, 1999). Of 344 subjects aged 80 years or greater, 15.9% reported significant physical disabilities. Impaired function in women aged 65 years and over has been associated with previous hip fracture, osteoarthritis, parkinsonism, slower walking speeds and decreased lower limb muscle strength (Ensrud, Nevitt, Yunis, Cauley, Seeley, Fox and Cummings, 1994). Impairments in cognitive status and physical performance are widely believed to contribute independently to the risk of functional dependence in nondisabled community-living elderly people (Tinetti et al., 1995; Gill, Williams, Richardson and Tinetti, 1996).

The results of these studies seem to indicate that cognitive impairment and physical factors, such as impairments, diseases or injuries with major physical impacts affect function much more than do sensory impairments, such as vision or hearing. However, most of these studies have specifically examined factors that are present concurrently or immediately preceding functional decline. Therefore, further broad based longitudinal studies may provide the most comprehensive data about the range of factors associated with functional declines associated with ageing. Additionally, it should be recognised that functional limitations and disability can develop rapidly, rather than as a slow decline over time. This can occur in relation to a sudden event with significant physical ramifications, such as a stroke, fracture or other rapid onset illness. These occurrences, which lead to functional decline present an entirely different aetiology from those occurring with advanced age and as a result of disease or pathology, and should be separated for study and discussion from the slow decline in function that becomes increasing prevalent with age.

A systematic literature review of 78 published longitudinal studies reporting associations between baseline factors and functional decline concluded with specific risk factors associated with functional decline (Stuck, Walthert, Nikolaus, Bula, Hohmann and Beck, 1999). The factors were – lower extremity impairment, low frequency of social contacts, low level of physical activity, smoking and visual impairment, cognitive impairment, depression, disease burden, increased and decreased body mass index, no alcohol use (compared with moderate use) and poor self-perceived health. These results, gained from a multitude of longitudinal studies provide further information about lifestyle factors associated with functional decline. Such comprehensive data indicates that there are both immediate (e.g. cognitive impairment) and past factors (e.g. smoking) associated with decline, some of which may well be amenable to intervention (e.g. lower extremity impairment, low frequency of social contacts, low levels of physical activity), whilst others are unlikely to be (e.g. visual impairment, cognitive impairment).

The order of loss of functional independence has indicated that bathing, mobility, toileting, dressing, transfers and feeding are first affected (Jagger, Arthur, Spiers and Clarke, 2001). This finding is based on observation and interview results specifically related to ADL ability, of a community-living population of over 1,300 people aged 75 years or more. Thus, elderly people may well be able to be assessed for these early losses, which may be indicative that a process of ADL loss is underway. Whether or not losses in ADL can be recovered is, as yet, largely unknown. Several factors have been identified that predict spontaneous recovery in the ability to perform ADL (Gill, Robison and Tinetti, 1997a). In a population of 213 people aged 72 years and over living within the community, few people aged more than 85 years recovered ADL ability once lost. Those younger than 85 years were more than 8 times more likely to recover ADL abilities. Intact cognitive functioning, high mobility and good nutritional status, each improve the likelihood of recovery (as does lower age), and may serve as markers of resiliency in older people.

Many authors have proposed a subclinical or preclinical state, a critical point, which identifies risk for the decline in functional ability (Avlund, Davidsen and Shultz-Larsen, 1995a; Fried, Herdman, Kuhn, Rubin and Turano, 1991; Tinetti et al., 1995; Gill, Williams, Mendes De Leon and Tinetti, 1997b; Fried, Tangen, Watson, Newman, Hirsch, Gottdiener, Tracy, Kop, Burke and McBurnie, 2001). This state might be characterised by early and/or minimal functional limitations before becoming readily apparent by markedly poorer performance of functional activities (Fried et al., 1991). Interventions at this point would likely be effective in slowing or forestalling the ensuing ADL dependence and would probably be most successful in those older people experiencing a primary pathway of slow, inexorable decline in physical abilities rather than the occurrence of a major disabling event (Gill et al., 1997b). However, other authors argue that preclinical disability may be a stage wherein impairments have a general, rather than specific, impact on functioning, such as the reduction of the number or frequency of activities and/or the use of compensatory mechanisms (Avlund et al., 1995a). Further research is necessary to describe the signs of early loss in functional ability, such as tiredness, slowing of performance or decreasing independence, to develop instruments able to measure such changes and to determine whether intervention is efficacious in preventing, minimising or slowing further functional loss.

The pathways of transition in functional limitations have been examined from data collected in relation to the Longitudinal Study in Ageing, a large prospective study, funded by the National Institute for Health and the National

Centre for Health Statistics (USA). The study involved over 5,000 subjects, aged 70 years and older, of whom 65% were female. Data were collected by bi-annual interview and constant monitoring of public Medicare and death records (Rudberg, Parzen, Leonard and Cassel, 1996). Sophisticated computer modelling was used to identify factors related to functional limitation. Subjects reporting no limitation in function were likely to have remained independent two years later but this probability decreased with age. The probability of remaining independent was related to age - those aged 70-79 years had an 86% chance, those 80-89 years had a 74% chance and those 90+ years had a 50% of remaining independent for two years. Similarly, the most dependent individuals were most likely to remain highly dependent. Subjects reporting functional abilities somewhere between independent and highly dependent were the most likely to experience change in functional ability over the ensuing two-year period. Men and women from all three groupings of functional ability demonstrated similar and low probabilities (less than 50% probability for all subjects) of improving their functional level. The data indicated again that by age group - those aged 70-79 years had a 7% chance, those 80-89 years had a 6% chance and those 90+ years had a 4% chance of improving their functional ability. The authors noted that transitions to functional limitation were extremely heterogeneous, with few pathways followed by 10 or more subjects and over 50% of pathways being unique. Gender was not influential and nearly half of the study population died never having reported functional limitations. The authors concluded that functional status among elderly people is highly dynamic. These results indicate that there is not a single or even several common pathways to functional decline. The implication, therefore, is that a single strategy for assessment for either risk or the presence of decline is unlikely to be effective and multiple assessment strategies will need to be developed.

Many risk factors associated with functional decline have been described. By identifying those risk factors amenable to intervention, such as sedentary lifestyle and physical impairments, appropriate interventions may be developed and will need to be tested for effect. There is also little evidence that once present, functional limitations are reversible, as very few reports have examined this theory. Additionally, results from a large, longitudinal and comprehensive study indicate that those with some, albeit minimal, functional limitations are those most at risk of developing further limitations. Such individuals may well be the ideal target group for studies investigating the impact of interventions aimed to slow further progressions. However, physical factors (impairments, consequences of disease and/or injury) have been reported as associated with age related functional decline and appear to be a significant factor related to the development of functional limitation in elderly people.

2.3 Relationship between Functional Ability and Physical Performance

Physical performance is the domain with the strongest associations with ADL dependence (Seeman, Charpentier and Berkman, 1994; Gill, Richardson and Tinetti, 1995b; Gill et al., 1995a; Guralnik, Ferruci, Simonsick, Salive and Wallace, 1995). Other impairments, such as cognitive, visual and affective, are also known risk factors for ADL dependence (Gill et al., 1996; Tinetti et al., 1995). However, Tinetti (1995) has suggested that the strong association between physical performance and functional ability, often reported anecdotally, may yet prove to be the most useful, population based approach to identifying older people at risk of functional decline.

Few studies have investigated the association between physical performance and functional ability in the community-living, non-disabled older population. (Gill et al., 1997b) examined the relationship between change in physical performance and functional status in 945 community-living subjects (aged 72 years and older, 74% female) who were independent in ADL on admission into the study. Assessments were completed at baseline, 1 year and 2-year periods and collected data concerning the emergence of functional dependence in ADL. Results indicated that changes over a 1-year period did not predict ADL dependence with any greater precision than data collected at the baseline assessment. In justifying this unexpected result, the authors hypothesized that for many older people, change in functional ability occurs simultaneously with changes in physical performance as a result of an intervening and significant event, such as stroke or hip fracture. Unfortunately, no data were presented to support this theory and it remains to be demonstrated conclusively. Nevertheless, change in physical performance was shown to be independently associated with concurrent ADL.

Data from the USA suggest that 10% of non-disabled community-dwelling adults aged 75 years and over lose independence in ADL each year (Gill et al., 1995a). Following an initial physical performance assessment, 664 subjects, aged 72 years and older, were followed-up for the emergence of new disabilities one year later. Over the 12 months, 27 subjects died and 74 had incomplete data and were, therefore, excluded from analysis. The remaining 563 subjects (mean age 79.1±4.7 years, 74% female) were assessed at the one-year mark. Using a modified Performance Oriented Mobility Assessment, as described by Tinetti (1986), the authors identified that several simple physical performance tests were strongly associated with the onset of functional dependence (Gill et al., 1995a). These tests included timed tests of repeated chair stand, maximal speed of walking, 360° turn, bending over, foot taps and handwriting. Subjects most at risk of functional decline generally scored within the lower quartile range for each item and the risk increased substantially for those in the lowest quartile range. Based on these findings, the use of simple timed tests of physical performance had been advocated as part of an assessment strategy to identify older people at risk of functional dependence.

The relationship between physical performance and functional ability in older people has not yet been clearly described, despite the prevalence of functional decline in the older population and the assertions of notable researchers that a strong association exists. There are few clear patterns of functional decline in older people, and perhaps even fewer clear patterns in the relationship between physical and functional parameters. Some functional decline occurs simultaneously with physical decline, as is the case with stroke. However, studies conducted in the USA suggest that older people most at risk of functional decline appear to be those with some pre-existing functional limitations. This suggests that programs designed to minimise functional decline in the older population should target those with pre-existing limitations, rather than those who report no limitations in function.

2.4 Physical Performance

The assessment of physical tasks, such as gait, is frequently advocated as a mainstay of clinical evaluation of older persons (Tinetti, 1986; Branch and Myers, 1987; Guralnik, Branch, Cummings and Curb, 1989). For many older people, quality of life is judged more by their level of functioning and ability to remain independent than by their specific disease states (Tinetti et al., 1995; Unger, Johnson and Marks, 1997). Physical performance is commonly assessed by self-report or report by proxy and either self-administered or administered by a trained interviewer (Lawton and Brody, 1982). More recently, the direct observation of performance of physical tasks has been advocated (Tinetti, 1986; Law and Letts, 1989). Physical performance measures, in which the individual is asked to perform a specific task, involve an objective evaluation using predetermined criteria that may include quality and/or timing of performance (Guccione and Jette, 1990). While substantially more time consuming, direct observation of performance is considered the 'gold standard' for physical performance assessment in older persons (Tinetti, 1986). However, the 'gold standard' instrument for the assessment of physical performance in older people has not yet been developed (Reuben, Vellas, Hays and Siu, 1995; Tinetti et al., 1995; West, Rubin, Munoz, Abraham and Fried, 1997).

The assumption that direct observation in the clinical setting reflects performance at home was tested in a convenience sample of older subjects, aged 65 years and older, who were originally recruited for a study aiming to determine risk factors for age related eye and vision impairments (West et al., 1997). The study protocol involved the observation of the same tasks in both the clinical and home environment for a cohort of older subjects. Nineteen subjects were classified as visually impaired and the remaining 133 were stratified by age (62 subjects aged 65-69 years, 32 subjects aged 70-74 years, 21 subjects aged 75-79 years and 18 subjects aged 80-84 years; 63% female). Results indicated good correlations between performances at home and in the clinic (*r*=.52-.86) with better performance at home on most tasks. The authors concluded that performances at home occur in an environment that is familiar and often individualised to allow for maximum performance of common tasks. Within this study, some subjects with visual impairment were unable to perform tasks in the clinical setting that were performed well at home with usual visual aids and appliances. This observation is almost certainly true for other impairments. If the home setting has been adapted or aids provided that are not used in the clinical setting, performances may be inconsistent. Overall, however, the results of this study indicate reasonable correlations between physical performance in the clinical and home settings. However, for data to be consistent, the choice of a single environment for observation of assessment and clear guidelines about the use of assistive and adaptive devices would be optimal.

Physical performance assessment is increasingly common in the clinical evaluation of an older person, with direct observation described as best practice. For older people, the use of usual aids and appliances and performance in the home environment maximises ability. Unfortunately, home-based assessment is not always feasible. However, a good relationship has been demonstrated between usual performance at home and performance demonstrated in the clinical setting for older persons when usual aids and appliances.

2.4.1 Muscle Performance

Age related changes in skeletal muscle are well documented, as are the resultant functional implications (Hyatt, Bhat, Scott and Maxwell, 1990; Porter, Vandervoort and Lexell, 1995; Thompson, 2000). Most of these changes occur because of the age related decline in muscle mass (Frontera, Hughes, Lutz and Evans, 1991) and most are exacerbated by inactivity and immobility (Fiatarone and Evans, 1993; Hughes, Frontera, Wood, Evans, Dallal, Roubenoff and Fiartarone Singh, 2001). Reductions in muscle dynamics, isokinetic and static muscle strength in relation to advancing age are well documented (Aniansson, Rundgren and Sperling, 1980). Neural factors as well as morphological factors are widely acknowledged to be associated with the reductions in muscle performance associated with advancing age (Carlson et al., 1999; Danneskiold-Samsoe et al., 1984; Fiatarone and Evans, 1993; Hughes et al., 2001). Table 2.2 summarises physiological skeletal muscle changes associated with ageing and the resultant functional consequences.

Studies of the relationship between muscle parameters and ageing were among the first investigations of the effects of the usual ageing process. Therefore, much has been described and confirmed in this area. The greatest contributor to change in muscle performance parameters is the decline in muscle mass. A landmark study, Frontera et al., (1991) concluded that muscle mass was the major determinant of difference in muscle strength between younger and older subjects, as well as men and women in a study of 200 healthy subjects aged 45 to 78 years. Once results were adjusted for muscle mass, strength showed little variation in relation to age.

The age related loss of muscle mass, known as sarcopenia, contributes markedly to the decline in strength commonly associated with old age. In longitudinal studies of healthy older people, losses in muscle performance associated with advancing age have been confirmed (Hurley, 1995). Annual rates of loss in isometric strength have been reported as 1-2% and power as 3.5% each year in healthy older people (Skelton, Greig, Davies and Young, 1994). The Surgeon General's Report on Physical Activity and Health, published in USA, concludes that loss of muscle strength is a major cause of disability in older adults (U.S. Department of Health and Human Services, 1996). A further comprehensive review of literature has concluded that exercise reduces age related sarcopenia for older people regardless of their previous levels of activity and physical condition (Fiatarone and Evans, 1993) and exercise designed specifically to increase muscle mass and strength is now commonly prescribed for older people (Evans, 1999). Many studies have

Table 2.2 Age related changes in skeletal muscle and resultant functional implications

Morphological and Structural Changes	Functional Significance
↓ muscle mass	↓ strength and power
↓ type 1 and 2 fibre numbers	↓ fast and strong movement
↑ connective tissue	↑ injury
↑ fat content	
↓ oxidative capacity	↓ endurance and power
↓ capillary density	
↑ contraction time	↓slowing or movements
↑ relaxation time	altered coordination
↓maximal shortening velocity	↓rapid changing movements
↓motor unit number	↓ fine controlled movements
↑ motor unit size	↓ excitability
↓ number of anterior horn cells	
↓ nerve conduction velocity	

Adapted from Thompson (2000)

reported muscle weakness responding to exercise interventions in this population and are reviewed in papers such as those authored by Carlson et al., (1999); Hakkinen et al., (1994); Porter et al., (1995); Vandervoort, (1992) and Wagner et al., (1994). Details of specific studies are reviewed in Section 2.5, as many of the relevant studies have investigated the effects of exercise on muscle performance as well as other variables of physical performance and/or functional ability.

Muscle weakness, especially decreased power, has consistently been shown to be associated with functional limitations, gait problems and falls in community-living older people (Wagner, E., Lacroix and Grothaus, 1994; Porter et al., 1995; Carlson et al., 1999). More recently, the relationship between muscle performance and physical performance for frail older people has been the focus of research. While of interest, the current review relates to the community-living older population and literature pertaining to the frail older cohort is outside the scope of the current discussion. However, in the context of the present study, muscle performance parameters are important outcomes for measurement.

2.4.2 Balance Performance

Balance has been defined as "the ability to maintain the body's centre of gravity vertically over the base of support" (Nashner, 1993, page 261). Further, the definition used by Berg, (1989) includes three explanatory situations in which balance may be challenged – during static postures, in reaction to movement produced internally or in response to external disturbances. Thus, balance is required to maintain static positions, such as standing and sitting, to react to movement produced by the individual, such as walking, climbing stairs or jumping and to react to disturbances caused externally, such as tripping over an obstacle or standing on a moving bus.

Three sources of sensory input provide information to the balance system – the visual, vestibular and somatosensory systems (Berg, 1989). Central integration of sensory information is a further, crucial component of the balance system. Finally the output of the balance system, which is aimed at restoring or maintaining balance, relies upon effective control and functioning of the neuro-musculoskeletal system (Patla, Frank and Winter, 1992).

Deterioration in the efficiency of the balance system in healthy and/or active older community-living people has been confirmed (Patla et al., 1992). There are well-defined age related changes in each component of the system. Given that there is considerable redundancy within the system, many changes go relatively unnoticed by the individual until more than one sensory system is compromised or when multiple stages of the balance process are affected (Hill, 1997).

Visual changes associated with increasing age include decreased acuity, contrast sensitivity and depth perception, restriction of visual fields and increased sensitivity to glare (Chandler, 2000). Within the vestibular system, reductions in the number of hair cells, which act as a sensory receptor to movement of the head, occur (Berg, 1989). The age related reduction in nerve conduction velocity affects both the transport of sensory information to the brain for processing and the efferent output to components of the musculoskeletal system to activate a response (Chandler, 2000). The general reduction in number and in efficiency of the neuronal and synapse components of the nervous system again compounds these changes (Vandervoort, 1992).

Poor balance performance is regarded as a key risk factor associated with falling in older people. Many prospective studies have identified poor balance as an independent and strong risk factor for falls, recurrent falls and injurious falls in community dwelling older people (Tinetti, Speechley and Ginter, 1988; Nevitt, Cummings, Kidd and Black, 1989; O' Loughlin, Robitaille, Boivin and Suissa, 1993; Graafmans, Ooms, Hosfstee, Bezemer, Bouter and Lips, 1996; Lord and Clark, 1996). As such, whether the restoration of balance function in older subjects is possible has been the focus of attention in order to minimise both falls and the associated injuries. Interventions designed to impact upon balance function will be discussed in Section 2.5.1, as the majority of well designed experimental studies aiming to improve balance function, have also included other broader aims in the realms of physical performance or functional ability.

2.4.3 Walk performance

The most consistent age-related change in gait is the decrease in customary walking speed (Hagemen and Blanke, 1986; Himann, Cunningham, Rechnitzer and Paterson, 1987; Blanke and Hageman, 1989; O' Brien, Pickles and Culham, 1996). Older individuals walk with shorter stride length and increased double support phase times (O' Brien et al., 1996), rather than decreased cadence (Winter, Patla, Frank and Walt, 1990). These changes, however, generally correlate with velocity (Prince, Corriveau, Herbert and Winter, 1997). Stride length accounts for the majority of variability in gait speeds (Hagemen and Blanke, 1986; Blanke and Hageman, 1989). The slower speed and associated changes in gait are widely believed to be an adaptation toward a more stable, less energy consuming gait pattern (Winter et al., 1990; Prince et al., 1997) as deterioration in the efficiency of the balance control system during gait occurs with advancing age. Gait problems in later life are more prevalent among women, primarily due to their lower average quadriceps power (Rantanen and Avela, 1997). Several age-related changes in kinematics of gait have been discussed in the literature with little consensus between studies (Winter, 1991). Variables such as heel contact skid velocity, head and hip accelerations have been investigated primarily to ascertain differences between older people who experience falls compared with those who do not. Limited information is available on the kinetics of gait in an older person (Prince et al., 1997).

Researchers have questioned the view that older people adopt a slower gait pattern to increase their stability. The question is related to whether changes are indicative of the adoption of a safer pattern or the development of fear of falling (Maki, 1997). In a study involving 14 male and 61 female volunteer subjects (mean age 82±6 years), Maki (1997) showed that reduced stride length, reduced speed, increased double support time, and poorer clinical gait scores were associated with fear of falling but not with falling. The results demonstrated that increased variability in stride width was independently associated with falling but not fear. Maki (1997) hypothesised that some gait changes may be adaptations related to fear of falling and concluded that wider strides were not necessarily advantageous to stability, but may be indicators of poor postural control and be predictive of future falls in such an older population.

A comprehensive study of age related changes in walking speed involving 149 females and 289 males, aged 19 to 102 years, indicated the extent of neuromuscular slowing observed with ageing (Himann et al., 1987). Six groups of subjects were asked to walk a 20-metre course with the following instructions for each trial– "walk rather slowly", "walk at a normal pace" and "walk at a fast pace without over exertion". Three groups of female subjects (aged 19-39 years, n=30, mean age 29.3 years; aged 40-62 years, n=13, mean age 50.5 years; aged 63 years and over, n=92, mean age 77.5 years) and three groups of male subjects (aged 19-39 years, n=27, mean age 26.4 years; aged 40-62 years, n=92, mean age 56.3 years; aged 63 years and over, n=154, mean age 68.8 years) participated. The results indicated that age 62 years coincided with an accelerated loss of walking speed. Before age 62, both males and females showed a loss in walking velocity of 1-2% per decade. This compares with a post 62 years of age loss of 12.4% per decade for females and a 16.1% loss for males. Older subjects had significantly slower walking speeds and smaller step lengths for slow, normal and fast paces, although heart rates did not differ significantly from those of younger subjects.

Investigation of the gait patterns of gender matched groups of younger (n=24, mean age 22 years, 50% female) and older adults (n=24, mean age 71 years, 50% females) in relation to stepping over obstacles of varying height have suggested that age had no effect on minimum foot clearance during unobstructed gait (Chen, Ashton-Miller, Alexander and Schultz, 1991). Age effects were evident among the older subjects in measures such as slower obstacle crossing speed, shorter step length and shorter heel strike distance. The findings of this small study appear to demonstrate an increased risk for obstacle contact with increasing age, but the relationship between age and obstacle clearance needs to be investigated further.

Older people have also been shown to require additional warning in time or distance when there are obstacles to be negotiated or changes in direction of gait are required (Cao, Ashton-Miller, Schultz and Alexander, 1997). Comparison of the response time to an unanticipated cue to turn suddenly while walking indicated that older subjects (n=20, mean age 73.8 years, 50% female) required approximately an extra 115 milliseconds of warning or 15 cm of distance in order to execute an unanticipated change of direction while walking accurately and safely compared with younger subjects (n=20, mean age 21.8 years, 50% female). The novel task used may simulate the demands of walking in crowded or complicated environments. The majority of failed turns related to the inability of the older subjects to slow forward momentum sufficiently in order to complete the turning manoeuvre.

These two studies, both small and using a convenience sample with a large age difference, indicate possible age related changes in gait function. Such changes may place older people at risk as a result of instability when dealing with obstacles and, also, they may respond more slowly to changes in gait when required. Further studies are needed to describe in detail the behaviours shown consistently by older subjects and to record the gait and physical characteristics that influence such performances. However, both of these studies have investigated aspects of gait function important to the community dwelling older person. It is imperative that older people can deal effectively with both obstacles and changing environmental demands when walking, not only to maintain appropriate levels of function, but also to prevent falls.

Many investigations related to gait in the older population have focussed on subjects with varying falls history, as gait impairment is generally accepted as a risk factor for falls in this population (Tinetti et al., 1988). A comparative study of young (n=22, mean age 24.6±1.9 years), elderly non-fallers (n=17, mean age 76.5±4.0 years, 47% female) and elderly fallers (n=18, mean age 82.2±4.9 years, 72% female) concluded that there were few gait differences (stride-to-stride variability, stance time and swing time) between the first two groups (Hausdorff, Edelberg, Mitchell, Goldberg and Wei, 1997). The elderly faller subjects however, showed greater variability in stride-to-stride temporal gait characteristics. No difference in gait speeds between the two groups of elderly subjects was observed. Gait problems have been shown to be significant predictors of falls in an older population (Stalenhof, Diederiks, Schiricke and Crebolder, 1999). However, as physical performance and functional ability, rather than falls, is the focus of this review, additional examination of gait and its relationship to falls in older people is outside the scope of the present work.

Although age related changes in gait parameters have been observed, there is a remarkable paucity of literature examining the effect of such changes on the overall ability of an older individual to remain physically independent or on their quality of life. Such research is important, as physical functioning is a prerequisite to continued community-living. Whether or not age related decrements in gait parameters are amenable to intervention has also yet to be fully described, however, the maintenance or restoration of gait function in older subjects has been the focus of a small number of intervention studies. These interventions will be discussed in Section 2.5.1, as the majority of well-designed experimental studies have also examined intervention effects in a number of other areas of physical performance and functional ability. Therefore, intervention studies will be collectively reviewed for overall impacts on physical performance and functional ability.

2.5 Intervention

Programs designed to impact on physical performance or functional ability in older persons have generally focused on exercise as an intervention (Keysor and Jette, 2001). Many age related physiological and physical declines are known to be exacerbated by inactivity (Lawrence and Jette, 1996). Low levels of physical activity have been identified as a risk factor for functional decline (Stuck et al., 1999). Whether increased physical activity can protect against functional decline is yet to be proven (Sarkisian, Liu, Gutierrez, Seeley, Cummings and Mangione, 2000). This is despite a large number of well-designed studies using older subjects, generally because of the focus on impairment level changes (Keysor and Jette, 2001). Only very recently, have intervention trials begun to examine the effect of exercise on functional ability and disability in older subjects.

Interventions based on increased levels of social activity may well be effective in delaying or preventing functional decline. Poor social networks and infrequent social contacts are known risk factors for functional decline in older persons (Stuck et al., 1999). The effectiveness of interventions based on increased social activity is unknown. Social activity, however, has been considered important as it provides a sense of belonging and support. It may also enhance feelings of well-being, which may be linked with enhanced physical and emotional recovery from negative life events. Social activity provides a broader reason for living than individual factors, and it may influence people to engage in other health promoting behaviours (Avlund, Damsgaard and Holstein, 1998b)

2.5.1 Exercise Intervention studies

The focus of the majority of exercise intervention studies, experimental in design and focussed on older subjects, has generally been an investigation of the effects of exercise on impairments, such as muscle strength or aerobic capacity. Relatively few experimental exercise intervention studies have reported functional ability or disability outcomes for elderly subjects. The published studies, which have involved samples of community-living, older adults, will be reviewed with reference to the Nagi model of disability (Nagi, 1965). Impairments of specific interest are muscle performance parameters, while functional limitations of specific interest are balance, gait and step height and functional ability.

One of the first well-designed experimental exercise based studies focussing on elderly subjects were part of the FICSIT trials, multi-centre trials examining the impact of exercise on frailty and injuries in later life, funded by the National Institute on Ageing in USA. One such study investigated the effects of resistive and balance exercises on muscle strength in a sample of 110 people aged 75 years and older (Judge, Whipple and Wolfson, 1994). The study investigated the relative effects of resistive exercise (n=28, mean age 80.3±4.0 years, 39% female), balance exercise (n=28, mean age 78.9±2.8 years, 43% female), a combination of the two exercises programs (n=27, mean age 79.5±4.1 years, 44% female) and a control group (n=27, mean age 80.6±4.5 years, 41% female). Further investigation related to this initial study examined the effect of a longer-term maintenance activity (Wolfson, Whipple, Derby, Judge, King, Amerman, Schmidt and Smyers, 1996). All subjects were offered a 6-month program of Tai Chi Chuan following completion of the initial intervention phase.

The balance training program offered three 45-minute sessions of individually supervised activities weekly over a three-month period (Judge et al., 1994). Approximately half of the exercise period was spent training balance on a computerised balance platform with centre of pressure feedback and the remaining time on balance activities in sitting and standing with varying visual conditions, base of support, self-initiated or mechanical disturbances. The strength intervention offered sessions in small groups with individually prescribed resistance, according to one repetition maximum (1RM) results, provided by gymnasium equipment, sandbags or body weight. Resistance was continually increased and 1RM values rechecked throughout the study. Participants in the combined balance and strength intervention group completed a balance session followed by a strength session three times each week for three months.

Following completion of the initial intervention program, all subjects, including controls, participated in the maintenance phase of the study (Wolfson et al., 1996). Tai Chi Chaun is a form of Chinese martial art and offers a safe and highly structured training technique that uses sound principles of balance and posture and aims to achieve improved stability around the trunk and pelvis. Integral to the practice of Tai Chi Chuan is a focus on body awareness, relaxation, imagery and breathing. Group sessions consisted of a highly structured class with slow weight shifts, steps and turns while maintaining a lowered base of support by mild knee and hip flexion. Subjects attended for one hour each week and were asked to complete a further two sessions at home.

Ninety-three per cent of these subjects completed all required sessions throughout the study. The balance intervention resulted in significant improvements in balance measures specific to dynamic balance, limits of stability and stability on a narrowed base. The strength intervention significantly improved the summed peak joint moment for hip, ankle and knee movements at velocities similar to those occurring during functional activities. In addition, performance of stability on a narrowed base improved in this group. The authors concluded that each intervention program was highly specific – balance intervention improved balance, strength training improved strength. A single exception, stability on a narrowed base of support demonstrated improvement in both groups, suggesting that this performance may benefit from both enhanced balance and strength abilities. No interaction between strength and balance training was reported. Interestingly, the significant gains of both balance and strength programs were maintained by the Tai Chi Chuan program and remained evident at six months.

The effect of a 12-week exercise intervention program on strength, power and functional abilities of women over the age of 75 years was investigated by Skelton, Young, Greig and Malbut (1995). Based on an experimental study design, the intervention program consisted of one supervised and two unsupervised (but directed by use of a video and instructions) exercise sessions each week. The exercise group followed a typical resistance training program with initial resistance individually prescribed, allowing for three sets of four repetitions to be performed. Resistance, provided by bags filled with rice or elastic tubing, was increased when the subject could complete three sets of eight repetitions at the resistance level. Muscle groups trained were shoulder abductors, adductors, flexors and extensors; hip abductors, adductors, flexors and extensors; elbow flexors and extensors and knee flexors and extensors. Training was specific to the muscle groups important to physical function rather than repetition of the functional activities themselves.

The supervised exercise class resulted in heart rates of less than 70% estimated maximal rate and consisted of a 10 minute warm-up and stretch, 30-40 minutes of the resisted exercise program followed by a further 10 minute warm-down component. Subjects were matched with control subjects on age and habitual exercise before random allocation to either the control or the exercise group. An initial sample of 52 healthy women aged over 75 years was reduced by illness to 40 subjects who completed the study protocol.

Twenty exercise group subjects completed a median of 10.5 exercise sessions (of a possible 12) and 24 home sessions, adding to a median of 35.5 sessions for the study (range 31-40 sessions). Evaluation of benefits of the exercise program indicated significant improvements in isometric knee extensor strength, isometric elbow extensor strength, handgrip strength and leg extensor strength standardised for body weight. Improvements in leg extensor power did not reach significance. Functional abilities did not demonstrate significant improvement as a result of the training program. The authors concluded that isolated increases in muscle performance did not translate into significant improvements in functional ability in older women. Thus, this study showed some significant benefits of exercise for impairments (muscle strength) but did not affect the level of functional limitation.

Most intervention studies reported have been completed in countries other than Australia. However, an Australian study investigating the effects of a 12-month exercise intervention program on strength, balance and falls in elderly women has been reported (Lord, Ward, Williams and Strudwick, 1995). One hundred women aged over 60 years, were randomly recruited from a larger epidemiological study related to falls and participated in an exercise program. An additional 76 subjects acted as controls. The intervention program was conducted with supervised 1 hour exercise sessions twice each week for four 10 week terms, interrupted by school holiday periods, over a 12 month period. Each class included a warm-up component before focussing on aerobic, strengthening, balance, flexibility, endurance and coordination activities, concluding with a cool-down period. Aerobic and endurance activities focussed on continuous trunk and limb movements designed to strengthen muscles and aid flexibility. Generally, body weight was used as the resistance in strengthening activities. Balance and coordination activities involved standing on one leg, ball games requiring body movement to catch or kick or for skipping etc.

Of the initial 100 subjects, 75 completed the study and participated in a median of 60 classes (73.2%), with the range of 26-82 (32-100%) of the classes. Exercise intervention participants demonstrated significant improvements at the midpoint of the program. Improvements were noted in lower limb strength measures, reaction time, neuromuscular control, and body sway on firm and compliant surfaces with eyes open and sway on compliant surface with eyes closed. These improvements were maintained for the rest of the study. Hip flexion strength was still demonstrating improvement at the 12-month mark. Although not significant, a trend towards decreased fall frequency and program adherence was evident.

Further evaluation of this large study population investigated the effect of the exercise intervention on gait patterns (Lord, Lloyd, Nirui, Raymond, Williams and Stewart, 1996). Gait variables of velocity, cadence, stride length, stance duration, stance percentage, swing duration and left-right step were evaluated. Significant group differences were evident in measures of lower limb strength between the exercise and control subjects. Post-intervention data demonstrated significant improvement for exercise subjects for every variable with the exception of stance duration. The results of this study indicate that a well-designed exercise intervention can significantly ameliorate age related declines in walk performance in a community dwelling female population. It offered a lengthy intervention but reported high adherence. The community setting of the program and the relatively small geographical area of subject recruitment potentially aided attendance. Functional outcomes were not evaluated.

The specific effect of a resistance training program in a small sample of 24 older people (11 women) on walking endurance has also been investigated (Ades, Ballor, Ashikaga, Utton and Nair, 1996). Twelve healthy, sedentary, community-living older subjects (70.4±4 years of age) participated in a 12-week program of resisted exercise of lower (knee extension, leg curl) and upper limbs (arm curl, lateral pull downs, bench press) and squat exercises. Participants began at 50 % of 1RM and progressed intermittently to 90% by week 9 of the program. Sessions were conducted 3 times per week in a supervised setting.

The results indicated significant improvements in muscle performance for exercise subjects as a result of the intervention, specifically in leg extension, leg flexion and bench press. The control group did not demonstrate strength changes over the same period. Between group comparisons of strength were not reported. Walking endurance significantly improved in the intervention group by 38%, while no change was reported in the control group. Increased endurance was primarily due to improvements amongst men rather than women. The difference in walking endurance between the two groups at the completion of the intervention program was significant. Significant, but not strong, correlations between change in walking endurance and change in strength measures for leg extension (r=.48) and leg flexion (r=.46) were also reported.

While this study involved a small sample, the results indicate that significant improvements can be made in leg strength and walking endurance in older subjects as a result of a resistance training program. Improvements in impairments led to improvements in physical functional performances and this was confirmed by significant associations between change in strength and change in endurance.

Supervised exercise interventions are usually costly and can initiate potential barriers to exercise participation for older people because of lack of transport and other factors that limit adherence. A home based exercise program, providing the intervention on videotape was investigated for its effects on strength, psychological well-being and health status in older people (Jette, Harris, Sleeper, Lachman, Heislein, Giorgetti and Levenson, 1996). One hundred and two non-disabled community-living older people (age range 66-87 years of age) were recruited for the study. The exercise intervention was based on a 30-minute program of 10 exercises using elastic bands to provide resistance. It involved 42 subjects with a mean age of 71.0±4.3 years, of whom 55% were female. The control group consisted of 51 subjects, mean age 73.2±5.4 years, of whom 71% were female. Subjects were requested to complete the program three times per week for the 12 – 15 weeks of the study duration. Graded resistance was available by increasing the resistance offered by the elastic bands. Before participation in the video-led exercise sessions, subjects completed a training session with a physiotherapist. This novel approach offered a successful intervention which was low-cost and that minimised many of the potential barriers to exercise participation, which exist for older people.

Significant benefits were evident at the conclusion of the intervention period, especially for men. While younger subjects (aged less than 72 years) demonstrated a significant improvement in knee extensor strength, older men demonstrated changes in perceived control, anger, perceived vigour and overall social functioning. When compared with the declines in the control group subjects over the intervention period, these improvements were significant.

However, women participants reported no significant psychological benefits as a result of the program. This intervention demonstrated that people of different age groups might achieve differing types of benefits. Impairment level changes (strength) in younger male subjects and disability level changes (psychological and social functioning) occurred primarily in older male subjects.

A similar protocol was used to evaluate the same videotaped exercise instruction on a sample of 215 subjects with some degree of physical disability over a six month period (Jette, Lachman, Giorgetti, Assman, Harris, Levenson, Wernick and Krebs, 1999). One hundred and eight subjects participated in the intervention group with a similar number of control subjects. Before starting the program, each exercise subject was visited by a physiotherapist. Exercise instruction and advice regarding progression to increased resistance by use of the elastic bands was provided. Cognitive and behavioural strategies were used to increase motivation and program adherence. These strategies were not used in the previous study and may have increased the compliance of subjects in the present study. Measurements of strength, balance, functional mobility and disability status were collected before, during and after intervention.

Exercise subjects achieved significant improvements on measures of lower extremity strength, tandem gait and physical and overall disability at the completion of the program. The results of this further study provide evidence for the suggestion that home-based exercise programs are effective for older person with disabilities.

Variations in the intensity of exercise protocols for older subjects have shown that self-paced programs may offer considerable benefits (Rooks, Kiel, Parsons and Hayes, 1997). A randomised trial of self-paced resistive exercise and self-paced walking was conducted with 131 elderly subjects. Subjects were randomly assigned to either a resistance training (n=37, mean age 72.7±4.6 years, 59% female), walking (n=25, mean age 72.9±5.4 years, 52% female) or control group (n=44, mean age 75.1±6.0 years, 82% female). The two intervention programs were conducted for three hours per week for a 10-month period. The resistance training group focussed on lower limb muscle strengthening exercise and included resisted stair climbing, resisted seated knee extension exercise, standing plantar flexion and resisted knee raises which were performed at an intensity chosen by the individual. The instructor provided strong verbal encouragement throughout every session. The walking intervention commenced with a 12-minute session and increased weekly, reaching a final 45-minute session. Participants were instructed to choose their own pace, again with strong encouragement from the instructor to increase the pace.

Results indicated strength improvements in the exercise group, whilst subjects from the other two groups demonstrated small losses in strength over the 10-month study period. A significant improvement was evident for exercise subjects in comparison with the other two groups. Handgrip did not differ among groups. Exercise and walking subjects significantly improved their static and dynamic balance performance (with the exception of single limb balance with eyes closed), while control subjects' balance performance declined. Subjects who completed either of the interventions performed significantly better on balance tests than did control subjects, as a significant group difference was noted among all groups. Stair climbing speed improved in both intervention groups and declined in control subjects. Significant differences between the two intervention groups and the control group were demonstrated for stair climbing speed. A significant group difference was evident between the exercise group and the control group but not the walking group for reaction time and picking up a pen from the floor.

The results of this study indicate that a relatively low cost resistive muscle strengthening intervention protocol improves muscle performance, static and dynamic balance, reaction time, stair climbing and ability to pickup an object from the floor. The walking intervention demonstrated significant effects on static and dynamic balance, reaction time, and stair climbing speed, but not muscle performance, nor picking up an object from the floor. The study used a lengthy duration and the authors described the self-paced protocol as a major variable in achieving the 85% compliance rate in the exercise group and 82%

compliance in the walking group. Participants reported that the physical benefits, social interaction, camaraderie, personal attention and fun were the most important aspects of the programs.

The authors (Rooks et al., 1997) indicated that a lengthy intervention of self-paced exercise could influence both impairments and physical functioning. A self-paced walking intervention program influenced physical functioning. Thus, it appears evident that improvements in physical functional performance may occur in the absence of detectable changes in specific impairments.

A further variation involving exercise intensity has been reported. A one year physical activity intervention was provided in a rural setting and based on low intensity exercises, performed in sitting or standing with the additional use of hand held weights when appropriate, and coordination and endurance activities (Sharpe, Jackson and White, 1997). A home program manual was provided to participants. In addition, participants were asked to set their own goals in relation to the exercise participation, consistent with the principles of behaviour change. Sixty-one intervention subjects (aged 73.7±6.5 years, 89% female) and forty-nine comparison subjects (aged 77.9+7.8 years, 84% female) participated. After completion of the one-year intervention, participants and comparison subjects were assessed on mobility performance (Tinetti, 1986), grip strength, motor coordination, balance – tandem and one limb stance and timed walk at maximal and usual speeds. Data collected at interview included perceived change in physical status, and the responses to open ended questions related to overall impressions of the class, perceived difficulty, barriers to attendance etc.

Statistical analysis of results indicated that the only significant difference in physical performance as a result of the intervention was usual walking speed. Qualitative analysis suggested participants perceived greater improvements in physical functioning over the one-year period than comparison subjects. In addition, participants reported perceived benefits of pain reduction, increased flexibility, muscle strengthening, increased walking speed and improved mental outlook. Additionally, the participants' and staff's perception of the intervention outcomes were stronger than those indicated by quantitative analyses.

The study provided support for the idea that low intensity programs of long duration can achieve physical improvements. However, this outcome depended on the qualitative information provided. Exercise participants reported significant perceived benefits, not evident on quantitative analyses. High levels of satisfaction along with perceived benefits are important outcomes of an exercise program, but are rarely measured. This study provides valuable information about the perceptions of older adults and the benefits of exercise participation.

A further study funded as part of the FICSIT program, involved an investigation of the effect of strength and resistance training on gait, balance, physical health status, falls risks and health service use by elderly people aged between 68 and 85 years of age (Buchner, Cress, Wagner, Delateur, Price and Abrass, 1993). One hundred and five subjects were randomly assigned to one of four groups – three who received an intervention program of exercise and a control group. The intervention consisted of either endurance training (n=25, mean age 75 years, 52% female), strength training (n=25, mean age 74 years, 52% female) or a combination of the two (n=25, mean age 75 years, 52% female). The control group consisted of 30 subjects with a mean age of 75 years, of whom 50% were female. Programs were offered for one hour, three times a week for 24 to 26 weeks. All three exercise programs contained common elements, warm-up and cool-down components, in addition to the specific exercise protocol. The exercise training group completed 30-35 minutes of endurance exercise each session, the strength training group completed two sets of 10 repetitions per set of upper and lower limb exercise prescribed at 50-60% of 1RM. The combined group completed 20 minutes of endurance training and one set of strength training exercises.

Results of the strength training program indicated significant improvement in strength of all muscle groups with the exception of the muscle groups around the ankle at six months. The combined training group showed improvement, but this was not significant, except at the knee. The endurance training group generally did not show significant strength gains, except at the knee. Aerobic capacity significantly improved in both the endurance and combined training groups.

Measures of balance, gait and physical health status did not show significant change over the intervention period. A beneficial effect on falls rates and health care utilisation was reported for the intervention groups. Thus, this study demonstrated resistive exercise intervention significantly affected muscle strength, but that the exercise programs did not affect gait or balance performance or physical health.

The effect of an exercise program on the physical functional abilities of independent older adults has been reported (Cress, Buchner, Questad, Esselman, Delateur and Scharwtz, 1999). A program of exercise, offered three times per week over a six-month period, focussed on both strength and endurance of muscle groups important to everyday physical performance. Strength training was completed at 75-80% of 1RM on standard gymnasium equipment and using some free weights. Endurance training involved simulated kayak and stair climbing equipment and was completed at 75-80% of heart rate reserve values for each participant.

Twenty-three subjects were randomised to the exercise program (mean age 75.6±3.6 years) and seven did not complete the study. A further 26 subjects acted as control subjects (mean age 76±5.1 years). No information was available about the gender distribution within the study sample, or within each group. Results obtained on completion of the six-month intervention indicated significant improvements in maximal oxygen consumption and muscle performance (with the exception of isokinetic knee and elbow strength) compared with control group subjects who showed declines from initial values over the six-month period. Measured gait parameters, including usual walking speed did not show significant change. Balance performance, measured on the Functional Reach test, indicated significant improvement for exercise subjects only. Self-reported levels of physical activity were not different between groups. Ratings of physical functional performance, measured on a newly devised measure (the Continuous Scale-Physical Functional Performance test), indicated significant improvement within the exercise group, although no difference between the exercise and control group post-intervention was evident. The intervention had no effect on scores on the Sickness Impact Profile or SF-36 scales. This study showed no group differences in physical functional performance as a result of the six-month intervention program. These results confirm the relative ease of improving muscle strength in an elderly population with an appropriately devised program and the lack of translation of improvements to show functional limitations of physical disability.

A further study comparing exercise programs for older people investigated the differences in outcomes following a program of moderate intensity endurance and strengthening exercise and a program of stretching and flexibility exercises (King, Pruitt, Phillips, Oka, Rodenburg and Haskell, 2000). One hundred and three subjects aged over 65 years who were regularly active (no more than twice per week) were randomly assigned to either strengthening or flexibility exercise programs. Fifty subjects were assigned to the strengthening program, thirty-three were women, with a mean age of 70.7±4.0 years and 17 were men with a mean age of 68.1±3.4 years. Forty-six subjects were assigned to the flexibility program, 29 were women with a mean age of 70.6+4.4 years and 17 were men with a mean age of 70.6±4.0 years. Ninety-three per cent of subjects completed the assigned exercise program and final assessment. Program adherence rates were high at 79%(±43%) and 80(±39%) respectively. Both programs consisted of supervised exercise sessions and home exercises. Both exercise protocols offered two supervised classes each week to be supplemented by a home exercise session at least twice each week.

The first exercise program, 'Fit and Firm' focussed on endurance and strengthening exercise and used gymnasium equipment, resistive bands and homemade weights for resistance. Muscle groups of focus included shoulder, elbow, knee extensor, calf, and trunk muscle groups. Each class consisted of a warm-up, 40-50 minute aerobic and strength component followed by a cool-down period. Participants monitored their heart rates and did not exceed 60-75% of heart rate reserve based on their most recent exercise stress test. Additionally, 'Fit and Firm' participants were instructed to exercise for two sessions at home each week, at their target heart rate. Recommended exercise was brisk walking. However participants also had access to a videotape of the class exercises and were provided with either hand weights or resistive bands for home use.

The second exercise protocol, 'Stretch and Flex' aimed to improve flexibility. A similar class format was offered twice each week with the emphasis on stretching activities for major muscle groups. Heart rates were monitored in order to ensure maximal heart rates were not exceeded. The home program for this protocol consisted of twice weekly stretching sessions, based on those used in the supervised classes and again participants were provided with a videotape of the class for reference.

Results of this study indicated that the 'Fit and Firm' exercise subjects demonstrated significantly greater improvements in functional capacity and endurance, upper body strength, walking distance, self-efficacy for physical performance, and self-rated physical health assessment at 12 months than the 'Stretch and Flex' participants. Neither group showed significant improvements in lower body strength. 'Stretch and Flex' participants showed significantly improved flexibility and an overall improvement in levels of bodily pain when compared with other subjects. The majority of these changes were not discernible at the 6-month assessment, suggesting that exercise and activity programs for older adults may need to be lengthy in order to achieve significant results.

Other studies have investigated the efficacy of exercise as an intervention for physically frail subjects. The effects of a low-moderate intensity group exercise program for fall-prone elderly men were investigated (Rubenstein, Josephson and Trueblood, 2000). Fifty-nine community-living elderly men with specific risk factors for falls, including leg weakness, balance impairment, gait impairment, or history of previous falls, were randomly assigned to either an exercise or control group. Exercise subjects participated in three, 90 minute exercise sessions each week for 12 weeks, which focussed on progressive resistive exercise of lower limb muscle groups and squats, stationery cycling or treadmill walking. Balance training increased in difficulty throughout the program and included mainly dynamic balance activities. The participation rate was 91% for all sessions. Post-intervention physical performance assessments included isometric muscle performance assessment, static balance tests, a sit-to-stand test, six minute walk test, an obstacle course and the performance oriented assessment of mobility tasks (Tinetti, 1986). In addition, three subscales of the SF-36 were used to measure physical functioning, role limitations and perceptions of general health.

Minimal group effects were evident for strength between groups following intervention. However, significant group differences were demonstrated for muscle endurance measures, especially around the knee joint. Participants of the exercise program demonstrated significant improvement on gait and endurance measures, including the six minute walk, and the sit-to-stand test. Performance in the performance oriented assessment of mobility, obstacle course and one-legged balance tests did not vary between groups. Global ratings of health were significantly higher in the exercise subjects. However, the SF-36 subscales did not demonstrate group differences.

The results of this small study, primarily focussed on falls outcomes, demonstrated that a low-moderate intensity exercise program could improve muscle and walking endurance. These benefits however did not translate to improved functional abilities in the broader sense, as complex balance and gait manoeuvres did not improve as a result of the intervention. Falls rates decreased, however, per unit of activity, in the elderly male study sample.

A recent review of exercise studies with older subjects aimed to appraise critically the effects of exercise to improve functional ability and prevent or minimise disability (Keysor and Jette, 2001). Experimental studies that included older subjects from varied living arrangements were reviewed, including those with elderly subjects living in care environments, such as nursing homes or aged care hospitals. The review examined 31 studies over the past 15 years – 97% of which reported impairment level outcomes, 81% reported on functional outcomes and, in contrast, 50% reported disability outcomes. The authors identified that current evidence does not yet support exercise as a means of reducing disability associated with advancing age. Most of the studies reviewed (including some of those mentioned in this review) offered exercise interventions of 8-12 weeks. However, interventions of longer duration may be required to allow for improvements in impairments to translate to changes in disability status despite the fact that some studies of longer duration of intervention have not shown such disability level impacts (King et al., 2000). In contrast, a relatively short intervention has indicated that it is possible to diminish social and emotional disability within a cohort of the sample studied (Jette et al., 1996). Further issues raised in the critical review included the relatively small sample sizes of most studies, generally due to the intensive nature (both in time and cost) of the intervention program and measurement issues related to the instruments currently available for disability. Many of the instruments measuring physical disability in particular, demonstrate strong ceiling and floor effects, especially in studies of community dwelling older people

In contrast, numerous studies provide evidence that amelioration of impairments and some functional limitations are possible through exercise. Of the 15 studies reviewed above, all showed significant change in impairments and 10 demonstrated improvement in at least one measure of functional limitation. Specific variables and additions to a usual exercise intervention program that might reduce disability in older people have yet to be clearly identified. Table 2.3 reviews the studies that have been discussed in this paper and summarises the reported exercise related intervention effects on impairments and functional limitations in the study populations.

There appears to be little interest in the effect of cessation of exercise programs specifically in older subjects. Cardiovascular outcomes have shown resilience to the cessation of intervention for a period of 10 weeks in 99 subjects aged over 60 years of age following a cardiovascular training program (Sforzo, McManis, Black, Luniewski and Scriber, 1995). Strength gains from a resistance program remained evident for up to five weeks post-exercise cessation. Further, the authors argued that there was some crossover between training programs in elderly subjects, with those completing cardiovascular training exhibiting some improvements in strength and those completing resistance training exhibiting small changes in cardiovascular parameters.

2.5.2 Social Intervention Studies

Initial interest in the influence of social factors in the older population arose from large cross-sectional studies examining risk factors for cardiovascular and other diseases that demonstrated a significant relationship between social networks and mortality (Blazer, 1982; House et al., 1982; Mor et al., 1989). Social networks and interactions significantly decreased mortality in each of the studies. Specifically, social activity has been linked with decreased incidence of cardiovascular disease and cancer survival, as well as buffering the effects of stress, minimising the effect of negative life events and depression (Unger et al., 1997).

The paucity of literature on the effects of social intervention on older adults is disappointing. Cross-sectional studies have clearly identified positive associations between social participation and a number of health benefits. Further, declines in social participation, so often observed in association with advancing age, have been attributed to education, income and possibly health resources. Thus, the focus of worthwhile interventions might be expected to be on alleviating some of these resource deficits and providing opportunities for older adults to form new networks, especially of age-peers. Social activity programs, also, can provide an effective control group for studies that provide specific interventions that contain a social element. Whether or not social activity participation alone offers benefits to functional ability, quality of life, life satisfaction or depression are important, but as yet unanswered, questions.

Table 2.3 Summary of reported exercise intervention effects on impairment and functional limitations in older participants. (Italics indicate nonsignificant results)

Study	Subject characteristics	Exercise Intervention	Duration	Impairment	Functional limitation	Disability
Ades et al., 1996	24 subjects, 65-79 years Mean age 70 years	Resistance exercise	12 weeks 3 x week	Strength (women)	Walking (men)	
Buchner et al., 1997	105 subjects with impaired balance, strength, gait 68-95 years Mean age 75 years	1: Strength exercise 2: Endurance exercise 3: Strength and endurance training	6 months 3 x week	1: Strength 2: aerobic capacity 3: Strength aerobic capacity	Balance, walking, stair climbing	*Physical disability*
Cress et al., 1999	49 subjects, 70+ years Mean age 76 years	Aerobic and strength training	6 months 3 x week	Strength, flexibility, aerobic capacity	Mobility, balance walking	*Physical disability*
Jette et al., 1996	102 nondisabled subjects 66-87 years Mean age 72 years	Home based resistance exercise based on videotaped instruction	12-15 weeks 3 x week	Strength among those <72 yrs		*Physical disability*
Jette et al., 1999	215 subjects with functional; impairment, 60+ years Mean age 75 years	Home based resistance training program, based on cognitive/behavioural theory, presented on videotape	6 months	strength	balance Sit/stand with walk	Physical Disability
Judge et al., 1994	110 subjects aged 75 yrs+ Mean age 80 years	1: resistance exercise 2: balance exercise or 3: resistance + balance exercise	3 months 3 x week	1: Muscle strength	Walking, chair rise	
Wolfson et al., 1996	110 subjects aged 75 yrs+ Mean age 80 years	Tai Chi Chaun following completion above exercise intervention	6 months 1 x week	Muscle strength	Balance Gait	
King et al., 2000	103 subjects 65+ years Mean age 70 years	1: Aerobic and strength training 2: Stretch and relaxation program	12 months 2 x week	1: Flexibility, aerobic capacity	Weight lift Walking, sit-stand	*Physical disability*

Table 2.3 (cont).

Study	Subject characteristics	Exercise Intervention	Duration	Impairment	Functional limitation	Disability
Lord et al., 1995	197 women, 60+ years Mean 72 years	Aerobic, flexibility and resistance exercise	12 months 2 x week	Strength Reaction time Neuromuscular control	Balance	
Lord et al., 1996a	160 women, 60-83 years Mean age 71 years	Aerobic, flexibility and resistance exercise	22 weeks 2 x week	strength	Balance, walking	
Rooks et al., 1997	131 subjects, 65-95 years Mean age 74 years	1: self-paced strength exercise 2: self-paced walking program	10 months 3 x week	1: strength, reaction time	1: mobility 1+2: balance, stairs	
Rubenstein et al., 2000	59 men at risk of falling, 70+ years Mean age 76 years	Resistance, endurance, balance training	12 weeks 3 x week	Strength	Walking, sit-stand, mobility, balance	Physical disability
Sharpe et al., 1997	139 subjects randomised by centre attended, 60-91 years Mean age 76 years	Low-intensity exercise program designed to enhance behavioural change	12 months 2 x week	Strength, coordination	Balance, walking	
Skelton et al., 1995	52 subjects, 75-93 years Mean age 79.5 years	resistance exercise	12 weeks 3 x week	Muscle strength	Kneel rise time Walking, balance, sit-stand, stair climb, weighted lift	

Adapted from Keysor and Jette, (2001)

In the absence of direct intervention studies involving older subjects and the measurement of physical or functional outcomes, literature that describes the influence of usual social activity on age related outcomes will be reviewed. The association between social networks and mortality has been reported as independent of self-reported physical health, socio-economic status, smoking, alcohol consumption, obesity, physical activity and health service utilization in a large prospective study of 6,928 subjects with a nine-year follow-up period (Berkman and Syme, 1979). Men with significantly higher levels of social networks have lower mortality regardless of age, occupational and health study groups (House et al., 1982). Social activity also exerted an independent influence on functional decline and buffered the effects of widowhood on functional decline, especially in men (Unger et al., 1997).

The data obtained by the Longitudinal Study on Ageing, conducted in the USA, confirmed that physical and social activity each influence independent effects on functional decline in older subjects over a six year period, regardless of age, gender, education, income, survival, minority status and medical history (Unger et al., 1997). Participation in social activity also aided the transition to widowhood and minimised its effect on functional ability, especially in men and those with poorer health status. The results of this study confirmed that while those who are physically active are also usually socially active, each acts individually in the decline of functional activities, thus negating common beliefs that physical activity alone provides health benefits. However, the effects of physical activity were more pronounced than those of social activity, suggesting that an active lifestyle offers additional benefits for physical functioning. The results of this study provide evidence for both physical and social activity in maximising physical function.

The confounding effects of many of the circumstances that change along with age often make the identification of pure age effects difficult to determine. A large study, conducted in USA, selected subjects randomly from the general non-institutionalised population, and interviewed 1,393 respondents on aspects related to social networks (Morgan, 1988). Of this large study population, one quarter were aged 60 years and over. (Specifically, 183 subjects were aged 60-

69 years, 111 were aged 70-79 years and 47 subjects were aged 80 years and older.) Participants were questioned about the level of activity within their social networks (e.g. number of times others discussed important matters with participant, number of roles present within the social network). In addition, the sources of participation were identified (e.g. family/nonfamily members, age peers, recent contacts). Independent variables were age, education, health, income and gender.

Despite being a cross-sectional study and, therefore, unable to provide information about the process by which social networks may suffer in later life, data showed that when compared with the younger subjects, older subjects demonstrated smaller networks with whom to discuss important matters, played fewer roles and have less frequent contacts within each network. Older participants also reported increased reliance on family members, non-age peers and long term relationships for the sources of their networks. For each analysis, the effect of age was statistically significant after controlling for the other independent variables. These other variables indirectly accounted for up to half of the total effect of age. Income level was shown to have the most consistent effect on social network participation, with the exception of family member contact. The overall drop in income associated with increased age was theorised to lessen the ability to substitute for losses (by the recruitment of new members) within the network. Similarly, education was shown to be a resource that increased participation in social networks. Many of the older generation had lower levels of education and were, therefore, theoretically less able to substitute due a relative deficit in this resource. Health demonstrated the smallest effect, however, but was not further analysed to ascertain age related effects.

The authors concluded that income and education resources, rather than a pure age effect, were important in the substitution process within social networks to ensure the maintenance of the network's size. Those without these resources suffer from difficulty or inability to maintain their network's size and incur losses including fewer contacts and age-peers. Thus, losses noted in later life were often and incorrectly associated with increased age, whereas many losses were mediated by the inability to substitute for losses explained by paucity of resources such as lower levels of income or education.

Few studies have reported outcomes following the provision of intervention designed to impact upon social activities or networks. The effect of a program of occupational therapy, social activity or no activity was examined in a group of 361 elderly subjects living in government subsidised accommodation or those living in the community and using the senior citizens facilities of the apartment buildings (Clark, Azen, Zemke, Jackson, Carlson, Mandel, Hay, Josephenson, Cherry, Hessel, Palmer and Lipson, 1997). Subjects were randomly assigned to one of three groups for the duration of the study. Occupational therapy (OT) group subjects (122 subjects, 24% aged less than 70 years, 49% aged 70-79 years, 27% aged 80 years or over, 64% female) received 9 hours of individual and 2 hours per week of group intervention while social activity subjects (120 subjects, 33% aged less than 70 years, 47% aged 70-79 years, 20% aged 80 years or over, 67% female) received 2.25 hours per week of a group program over a 9 month period. Control subjects (119, 23% aged less than 70 years, 50% aged 70-79 years, 27% aged 80 years or over, 64% female) received no intervention.

The OT intervention focussed on providing participants with a better appreciation of the importance of meaningful activities in their lives. The social activities intervention was designed to encourage social interactions among group members and included activities such as community outings, craft projects, games, films etc. Average compliance for the OT intervention was 60% and for the social activities intervention was 61%. Evaluation at nine months was completed by 85% of subjects. For analysis, results of both the social activities program and control subjects were combined, rendering description of potential changes related to social participation difficult to discern. Results indicated significant improvements for OT participants in areas of functional ability, quality of life outcomes, social activities, depression and life perception. The authors concluded that the individualised nature of the OT intervention provided a more superior outcome than a group based, non-individualised social program. However, no information was published about the outcomes of social participation subjects, as these results were combined with control group results. As such, this study may over emphasise the effect of the OT intervention when compared with the social intervention program, or indeed de-emphasise the effect of the social program.

There is clearly a need to examine and describe the effects of interventions based on increased levels of social activity in older subjects. Whether social activity as an intervention has an impact on functional ability is an important question that needs to be answered. In comparison with the literature describing exercise interventions, there is clearly a lack of well-designed studies to elucidate the influence of social factors that may occur during any intervention studies. Most intervention studies of exercise have included a control group receiving no intervention. A more useful design would be the inclusion of a group receiving intervention that offers the same social activities without the specific exercise interventions, in order to clearly define the effects of each component.

2.6 Measures of Functional Ability

The functional capacity of the older population extends over a broad range, from being independent but also vigorous, to inactivity and through a continuum to the frail and severely dependent. Functional ability is a strong predictor of quality of life (Boult, Kane, Louis, Boult and McCaffrey, 1994), institutionalisation (Hawker, 1993), mortality (Guralnik and Kaplan, 1989) and future deterioration in functional ability (Avlund et al., 1995a). Numerous scales of functional ability have been developed for the older population, however, many tend to measure ability at its lowest end, on a 'can/cannot' scale of performance, indicating any degree of dependence as 'cannot' (Lawton and Brody, 1982; Katz, 1983; Applegate, Blass and Williams, 1990), Most of these measures were designed for frail or institutionalised older people and are not useful as discriminatory measures of function in community-living older people (Siu, Reuben and Hays, 1990). As older people spend comparatively more time performing ADL and less time performing IADL activities and sleeping (Ashworth, Reuben and Benton, 1994), questions rating difficulty and dependence provide complementary information about an older person's level of disability (Avlund, Schroll, Davidsen, Lovberg and Rantanen, 1994; Langlois, Maggi, Harris, Simonsick, Ferruci, Pavan, Santori and Enzi, 1996; Gill, Robison and Tinetti, 1998).

Measurement of functional ability, such as ADL, using questionnaires has shown little short-term variability in older males and females (Smith, Branch, Scherr, Wetle, Evans, Hebert and Taylor, 1990; Crawford, Jette and Tennstedt, 1997), However, studies comparing this methodology with direct observation of physical functional performance have reported either weak relationships (Reuben et al., 1995) or good reproducibility (Hoeymans, Wouters, Feskens, Vandenbos and Kromhout, 1997). Reuben (1995) and Hoeymans (1997) both concluded that differing methodologies of assessment of physical function, utilising different instruments, do not measure the same construct. However, this view has not been widely reported. Many authors, however, recommend that multiple measurement strategies should be utilised in order to build a true picture of functional ability within the physical domain (Reuben et al., 1995; Tinetti et al., 1995; Merrill, Seeman, Kasl and Berkman, 1997).

2.6.1 The Questionnaire of Functional Ability

The Questionnaire of Functional Ability (QFA) (Avlund, Kreiner and Schultz-Larsen, 1993a) was devised specifically to measure dimensions of physical function relevant to healthy elderly people. The QFA was devised with further dimensions of functional ability in mind than the usual dichotomous rating scale. Specifically, the scale developed was designed to measure tiredness and dependency in relation to physical functional activities, with the authors arguing that tiredness often precedes functional loss (Avlund et al., 1995a). The QFA, therefore, enquires about tiredness and dependency related to specific functional activities. These dimensions indicate points along the continuum from 'can do' to 'cannot do' in functional activities and are useful when related to a population known to be at risk for development of limitations in functional ability. The tiredness scales of the QFA are more suitable for measuring change among well elderly people, while the dependency scales measure changes among the less well elderly. Therefore, the QFA is more sensitive than other measures to change in relation to early functional loss (Avlund et al., 1995a). Further work has established a similar scale for the measurement of IADL (Avlund, Shultz-Larsen and Kreiner, 1993b). While of interest, Instrumental ADL is not of relevance to the present study.

Construct validity and criterion-related validity of the QFA have been established in studies which also indicated that the QFA was a useful discriminator in large elderly study populations (Schultz-Larsen, Avlund and Kreiner, 1992; Avlund et al., 1993a). The QFA has been further tested using the Rasch model for item analysis, specifically to address the homogeneity of items (Avlund, Kreiner and Schultz-Larsen, 1996). This analysis indicated that two items – washing hair and cutting fingernails – were a poor statistical fit with other items and were, therefore, excluded from the QFA. The analysis also confirmed that the QFA was formed by five separate subscales – three measuring tiredness (in relation to upper limbs, lower limbs and mobility tasks) and another two subscales related to the need for assistance (in relation to mobility tasks and physical ADL). For each activity, the QFA asks about associated tiredness and the need for assistance. The subscales count the number of functional items within their domains where function is not reduced. Higher scores on the QFA subscales are indicative of better function. Table 2.4 lists the specific items addressed within each subscale.

Avlund and co-authors (1995) investigated changes in functional ability in older Danes by following almost 600 community-living subjects (52% female), of whom 30% lived alone and 7 % received home help, from the age of 70 to 75 years. QFA scores were collected at age 70 years and again at age 75 years. QFA scores demonstrated both deterioration and improvement in abilities over the 5-year period. The largest changes over time were noted in the Mobility Tiredness scale, with more than half of the participants recording deterioration in scores. Thirteen per cent reported improvement in tiredness associated with mobility tasks. Significant gender related differences were reported for changes in Upper Limb Tiredness, Lower Limb Tiredness, Mobility Help and Physical ADL Help scores. Table 2.5 summarises the five-year changes in QFA scores reported by this study.

Results from this study indicated that for both men and women, tiredness in functional activities at age 70 years strongly influences dependency at age 75 years (Avlund et al., 1995a). Among men, tiredness during mobility tasks at age 70 years was directly related to assistance needed for mobility performance five years later. Similarly, Lower Limb Tiredness scores at age 70 directly influenced Physical ADL Help scores at age 75 years. For women, the need for assistance with mobility tasks at age 75 years was associated with tiredness in both the lower limb and mobility tasks at age 70. Dependence in physical ADL at age 75 years was directly associated with earlier Mobility Tiredness scores. Further analyses indicated that less than the maximal score for Mobility Tiredness increased the later risk of dependency in mobility by more than ten times in men and more than six times in women. In women alone, it doubled the risk of the need for help with ADL five years later. Less than the maximal score of the Lower Limb Tiredness scale increased the risk of being dependent in ADL nearly 17 times in men and nearly 7 times in women and increased the risk of mobility dependence more than 4 times in women. The results of this study clearly indicate that a preclinical state exists, that the QFA is a useful measure of functional abilities and able to identify those at later risk of physical dependency. The usefulness of the QFA also relates to its ability to measure dimensions of functional ability appropriate to a population known to be at risk for developing disability. Thus, the QFA would be a useful instrument when assessing the functional ability of individuals over the age of 75 years.

Secondary data analysis, specifically conducted to explore the validity of the QFA, utilised data discussed earlier and collected by Avlund and colleagues in 1995. Results indicted that the Mobility Tiredness scale demonstrated the best discrimination between the two age groups, with Upper Limb Tiredness being the poorest discriminator (Avlund et al., 1996). In addition, this study confirmed the internal validity for distinguishing between mobility and general ADL function as two separate and important items in functional assessment of the older population. The authors concluded that the QFA was suitable for measuring change in function over time and as an outcome measure to identify the effect of intervention or prevention on functional ability in elderly community-living people. Additionally, tiredness during mobility among 70 year old subjects was a significant predictor of mortality within the next ten years (Avlund, Schultz-Larsen and Davidsen, 1998a).

One of the threats to the validity of the QFA is that of ceiling effects i.e. inability of the scale to measure the full range as it is limited to a total possible score in each subscale (Portney and Watkins, 1993). However, in the context of measuring physical functional ability in the elderly population, ceiling effects should be limited, as total possible scores represent no influence of tiredness or need for assistance for physical function. In a study of 405 75 year old Danish community-living subjects (58% female), ceiling effects on the QFA were reported (Avlund et al., 1994). Statistically significant differences in the number of men and women reaching total possible scores were evident for each subscale. Table 2.6 summarises the ceiling effect numbers reported in this study.

Studies utilising the QFA have reported associations between scores on the subscales of functional ability and strength indicators (Avlund et al., 1994). Significant correlations (p<.01) have been reported between functional ability and strength. Upper Limb Tiredness scores and hand grip, as well as knee extension in men and hand grip and shoulder flexion in women were significantly associated with one another. Lower Limb Tiredness scores and hand grip, shoulder flexion, knee extension, trunk flexion and extension were significantly associated in men while hand grip, shoulder flexion, knee extension and trunk extension were associated in women. Mobility Tiredness was significantly associated with knee and trunk extension in men and shoulder flexion and knee extension in women. Mobility Help scores, shoulder flexion and trunk extension were significantly associated in men and shoulder flexion, knee extension, trunk extension and flexion in women. Personal ADL Help was significantly associated with hand grip and all strength measures previously mentioned in both men and women.

Table 2.4 Items within each subscale of the Questionnaire of Functional Ability

Dependency	Tiredness
Mobility Help	*Mobility Tiredness*
Transfer	Transfer
Walk indoors	Get outdoors
Get outdoors	Walk indoors
Manage stairs	Walk outdoors – nice weather
Walk outdoors – nice weather	Manage stairs
Walk outdoors – poor weather	Walk outdoors – poor weather
	Lower Limb Tiredness
Physical ADL Help	Go to the toilet
Comb hair	Dress lower part of the body
Wash upper parts of the body	Wash lower part of the body
Go to the toilet	Put on/ take shoes on/off
Dress upper part of the body	Cut toenails
Dress lower part of the body	
Wash lower part of the body	*Upper Limb Tiredness*
Put on/ take shoes on/off	Comb hair
Cut toenails	Wash upper parts of the body
	Dress upper part of the body
	Wash hair

Table 2.5 Change in functional ability over a five-year period as reported by Avlund et al., (1995)

		Women (%)	Men (%)
Upper Limb Tiredness	Deterioration	24	13
	No change	70	85
	Improvement	7	2
Lower Limb Tiredness	Deterioration	41	23
	No change	55	71
	Improvement	4	6
Mobility Tiredness	Deterioration	55	47
	No change	33	40
	Improvement	12	13
Mobility Help	Deterioration	21	13
	No change	77	87
	Improvement	1	0
Physical ADL Help	Deterioration	18	32
	No change	80	66
	Improvement	2	1

Table 2.6 Percentages of subjects achieving the maximal score on QFA subscales reported by Avlund et al., (1994).

Functional Ability	Women (n=209)	Men (n=196)
Upper Limb Tiredness	31.6	44.9
Lower Limb Tiredness	22.5	34.2
Mobility Tiredness	13.9	22.4
Mobility Help	39.2	45.9
Physical ADL Help	30.1	39.3

The discriminatory power of the QFA was examined by comparing scores obtained by three subject groups, again based in Denmark (Avlund and Holstein, 1998). All subjects were aged 60 years and older. One hundred and two subjects from sheltered housing (similar clientele to nursing home residents) (70% female), 435 community-living consumers of home care services (63% female) and 501 community-living subjects who did not use home care services (58% female) participated. QFA scores were calculated following an interview for the first group of subjects and following completion of self-administered questionnaires for the second and third groups of subjects. Both the Mobility Tiredness and Mobility Help scales were demonstrated to be able to distinguish between elderly people on the basis of their living situation.

The results of all of the studies specifically examining the QFA demonstrate that the scale has construct validity (Avlund et al., 1996), criterion-related validity (Schultz-Larsen et al., 1992; Avlund et al., 1994) and reliability (Avlund, Thudium, Davidsen and Fuglsang-Sorenson, 1995b). In addition, the scale has proven to be a good discriminator of age in large, independent community populations (Avlund and Schultz Larsen, 1991; Avlund et al., 1996), a strong predictor of the need for assistance five years later (Avlund et al., 1995a) and of mortality in the following 10 years (Avlund et al., 1998a). As such, the QFA is a useful and appropriate measure of functional ability in an older community-living population, whether subjects are independent in functional activities or require assistance.

Although all of the studies currently reporting on QFA use have been conducted on an elderly Danish population and in the absence of international comparative research, it is reasonable to conclude that there is little difference between Western populations with regard to the development of functional limitations associated with advancing age. Of vital importance, is the ability to measure small but significant clinical change in functional ability, such as increasing tiredness or decreasing independence associated with functional performance and thus highlight potential functional decline.

2.7 Measures of Physical Performance

Observation and measurement of physical performance have been strongly advocated as essential components of clinical evaluation of an older person (Branch and Myers, 1987). Aspects of physical performance commonly assessed include parameters of muscle and balance performance and gait function (Tinetti, 1986). Clinically appropriate measurement strategies and tools are advocated in assessment of the older persons as they provide information directly associated with physical performance and can be performed in many environments, including the home (Tinetti, 1986).

2.7.1 Muscle Performance Measures

In the clinical setting, there are relatively few choices for instruments with which to measures muscle performance. Laboratory based systems such as the isokinetic dynamometers are expensive and neither readily available in clinical settings nor portable (Hurley, 1995). Several methods of measuring muscle performance in older people have been reported in the literature. These include simple strain gauges (Sherrington and Lord, 1997) and modified sphygmomanometers (Sonn, 1996). Others have inferred muscle performance from physical abilities such as rising from a chair (Chandler, Duncan, Kochersberger and Studenski, 1998).

One clinically appropriate measurement tool for muscle performance in older people is a hand-held dynamometer. The Nicholas Manual Muscle Tester[1] is a

---

[1] Model 01160, Lafayette Instrument Company, PO Box 5729,, 3700 Sagmore Parkway North, Lafayette, Indiana, USA 47903

hand-held dynamometer that was designed to objectively quantify eccentric muscle strength by measuring the peak force required to overcome the subject's isometric muscle contraction. The Nicholas Manual Muscle Tester (MMT) is a lightweight, portable and battery operated unit and as such is suitable for use with a relatively large study sample and the need for all measurements tools to be portable. The Nicholas MMT measures maximum force between 0 – 199.9 kilograms with a digital accuracy of up to ±0.5% of the full scale.

Initial studies of reliability were completed by the developers of the unit (Nicholas, Marino and Gleim, 1987) who reported correlation coefficients of .81-.87 for test-retest reliability and .80-.93 for inter-tester reliability in a sample of mainly young subjects. Normative values were also described, however, the wide age groupings render much of the data of little use. However, the authors did report that neither height nor weight correlated with the muscle performance measures obtained.

The lower limb muscle performance of 96 active and healthy older Australian women has been specifically examined with the Nicholas MMT (Hill, 1997). Retest reliability coefficients varying between r=. 35-.76 for ankle dorsiflexion, r=.71-.81 for knee extensors and r=.65-.83 for hip abductors were reported. The author concluded that the poor reliability for ankle dorsiflexion was possibly due to the testing order as this muscle group was tested first and the subjects may have still have been familiarising themselves with the procedure. Therefore, several practice trials were recommended before the commencement of formal testing to ensure optimal performance.

A cross-sectional study of muscle performance in twenty subjects (mean age 72.5 ± 6.27 years, 75% female) and two testers, examined the reliability of the Nicholas MMT, using the elbow and knee extensor muscle groups (Richardson, Stratford and Cripps, 1998). A standardised test protocol, including two trials of isometric ('make') and eccentric ('break') contractions was used. Inter-tester reliability of the elbow extensor muscle group was high, (r=.87 for 'make' contractions, r=.87 for 'break' contractions). Inter-tester reliability of the knee extensor muscle group was lower (*r*=.67 for 'make' contractions, *r*=.74 for 'break' contractions). The results of this small but well designed study indicate that the Nicholas MMT is an appropriate instrument for the assessment of muscle performance in an elderly community-living population.

Normative values from tests of muscle performance with a hand-held dynamometer, albeit not the Nicholas MMT, have been reported (Andrews, Thomas and Bohannon, 1996). Using a similar device, data were collected from a large convenience sample aged over 50 years with no health problems (n=156, 51% female), who were stratified by age into three groups – 50-59 years, 60-69 years and 70-79 years. Following a standardised protocol including positioning subjects in gravity neutral positions, subject stabilisation and dynamometer placement, isometric muscle actions were tested. Analysis of results indicated that neither height nor weight was correlated with the muscle performance values obtained. Table 2.7 summarises the data reported for the age group of 70-79 years. It should be noted that the original data reported force in pounds (lbs) and has been converted in kilograms (kg) to be consistent with data reported using metric measures. An equation of 1 lb = 0.45359 grams was used to convert the data (Fyfe, 1995).

Although specific reports of the Nicholas MMT are few, a hand-held dynamometer provides an opportunity to collect data on muscle performance that is not reliant on subject's attendance at a specific testing location. As such it is a useful instrument for the assessment of parameters of muscle performance for clinical studies. This instrument has also been demonstrated to be useful when assessing a population of healthy older people.

Table 2.7 Muscle performance values (converted from pounds to kilograms) measured by the Nicholas Manual Muscle Tester in subjects aged 70-79 years as reported by Andrews, Thomas and Bohannon, (1996)

Muscle Group	Gender	Performance (kg)
Shoulder abduction	Male	19.60±3.08
	Female	10.93±2.13
Hip abduction	Male	25.63±5.53
	Female	17.51±3.49
Knee flexion	Male	22.04±4.17
	Female	13.97±3.49
Dorsiflexion	Male	22.59±5.76
	Female	16.28±4.49

2.7.2 Balance Measures

Use of complex tests, such as force platforms, stabilometers and ataxiameters (Balogun, Akindele, Nihinlola and Marzouk, 1994) are often recommended for the evaluation of balance in the older population. However, they are neither readily available in the clinical setting nor portable which limits their use in clinical studies. Furthermore, the relationship between simple, clinically useful balance tests and computerised balance tests has not been demonstrated to be significant (Frandin, Sonn, Svantesson and Grimby, 1995; Ringsberg, Gerdhem, Johansson and Obrant, 1999). Balance tests that assess both the ability to maintain a static posture and the limits of postural stability are required to adequately assess the balance system (Patla et al., 1992).

In studies of balance intervention, improvements have been noted in control subjects over time and in the absence of intervention. This effect has been noted by several authors (Hu and Woolacott, 1994a; Hu and Woolacott, 1994b; Seidler and Martin, 1997) and implies that improvement in balance performance on the chosen outcome measures was responsive to practice alone. Therefore, care must be taken to select balance measures that do not respond readily to practice and can be relied upon to measure true improvement in balance abilities. Many laboratory measures of balance have not yet been shown to posses this characteristic (Seidler and Martin, 1997) and are therefore of limited use in the measurement of potential changes in balance as a result of intervention or over time. Since the focus of the present study was clinical, the literature related to clinically useful measures of balance is the main focus. A discussion of laboratory based instruments is outside the focus of this review.

Specific measures useful to a clinical study would be those able to measure potential improvements or decreases in balance ability and without potential ceiling or floor effects. Measures such as the Balance Scale (Berg, Wood-Dauphinee, Williams and Gayton, 1989) and Performance Oriented Assessment of Mobility (Tinetti, 1986) were therefore unsuitable. The Balance Scale, although specifically designed for an older population, assesses balance ability on an ordinal scale during the performance of 14 common daily tasks along a continuum of increasingly difficult tasks (Berg et al., 1989). However, elderly people living in the community may well easily perform many of the included tasks, such as transfers, reaching and turning. It is relatively common, therefore, for community-living elderly people to achieve a high score on the scale. Stevenson, (2001) has demonstrated that a change in score of six points is required on the Balance Scale to reflect a clinically significant change in subjects undergoing rehabilitation following stroke. Thus, the Balance Scale may not be sensitive to higher levels of balance performance that may be demonstrated in a community-living older population, nor may it be able to measure subtle balance improvement in this population. Similar concerns can be raised about Tinetti's (1996) Performance Orientated Mobility Assessment. This tool assesses items of balance and walk performance on a rating scale of two or three descriptors for each task. Often these descriptors provide information only on 'normal' performance versus 'unsafe' performance. Again, an ordinal scale is used. Devised as a screening tool for mobility and gait impairment, the tool provides qualitative information about a range of components of balance and walk performance in an elderly population at risk of, or with a history of falls (Tinetti, 1986). A community-living older person may well score the highest maximum score.

Timed tests of sufficient complexity to be challenging to a community dwelling elderly population, such as timed stances in different positions are considered to be appropriate tests of static balance ability (Shumway-Cook, Gruber, Baldwin and Liao, 1997). Although the time spent in single limb positions during functional activities including gait is limited, numerous authors have concluded that single limb balance tests are useful in clinical assessment, especially in older people (Bohannon, Larkin, Cook, Gear and Singer, 1984; Briggs, Gossman, Bircg, Drews and Shaddeau, 1989; Furuna, Nagasaki, Nishizawa, Sugiara, Okuzumi, Ito, Kinugasa, Hashizume and Maruyama, 1998; Heitmann, Gossman, Shaddeau and Jackson, 1989; Iverson, Gossman, Shaddeau and Turner, 1990). The Functional Reach test (Duncan, Weiner, Chandler and Studenski, 1990) was specifically devised for an older population and was found to be useful as a measure of dynamic balance abilities. Additionally, timed stance and the Functional Reach tests are readily portable, inexpensive and valuable for use with a large number of subjects within a constrained timeframe.

Single limb balance tests require the subject to stand erect on one limb, with eyes either open or closed. The time of successful single limb stance is recorded. Most reported single limb balance tests are criterion related – i.e. with the upper time limit set to a maximal value, most commonly 30 seconds for eyes open tests and 10 seconds for an eyes closed test (Bohannon et al., 1984; Briggs et al., 1989; Heitmann et al., 1989; Hill, Schwarz, Flicker and Carroll, 1999). Longer time periods have been used when testing a wider age range of subjects (Ringsberg, Gardsell, Johnell, Jonsson, Obrant and Serbo, 1998). Single limb tests of balance require several components of the balance system to work effectively and efficiently together. These components include the proprioceptive, visual and vestibular systems, muscle strength and general flexibility (Berg, 1989).

Bohannon et al., (1984) investigated the relationship between performance of single limb balance tests and age in a population of 184 volunteer subjects, aged between 20 and 79 years of age, with no vertigo, other balance problems or lower limb disorders who performed single limb balance tests. The maximum time for tests with eyes open or closed was set at 30 seconds. Thirty-one of the subjects, aged between 70 and 79 years (mean age 75.6±2.2 years, 77% female), were tested with eyes open and then eyes closed.

Summary data suggest that declines in the ability to stand on one leg, with or without vision were age related. Younger subjects were observed using multiple strategies and often maximal effort to maintain their position. All subjects aged 20-29 years were able to stand for greater than 30 seconds with eyes open. The authors suggested that many of the elderly subjects appeared unwilling or unable to do whatever was necessary to maintain balance when compared with younger subjects. It may be that older subjects are less willing or able to take risks when in less stable positions. The mean performance time for the elderly subjects for the eyes open single limb balance test was 14.2±9.3 seconds. Ninety per cent of these subjects were unable to maintain the test position for greater than 30 seconds. The minimum result was 1.2 seconds and quartile scores (from the lowest to highest) were 4.9, 12.2, 21.6 and greater than 30 seconds. Results from the eyes closed test indicated a mean time of 4.3±3.0 seconds, with the lowest score recorded as 0.7 seconds. Quartile scores were 2.3, 3.4, 5.4 and 12.7 seconds respectively. No subject in the 70-79 year old group was able to maintain greater than 30 seconds with eyes closed.

Briggs and colleagues (1989) investigated balance abilities of an older female population on both sharpened Rhomberg (feet placed in tandem, heel to toe with the dominant foot placed in front) and single limb tests. Seventy-one female subjects, aged 60-86 years, independent in ADL and living in the community were recruited for the study and performed the tests in random order, wearing usual footwear. Data were collated to represent five age groupings – 60-64 years (n=14), 65-69 years (n=13), 70-74 years (n=16), 75-79 years (n=16) and 80-86 years (n=12). The results indicated little difference in performance on the sharpened Romberg test between age groups, with the only significant difference being between subjects aged 60-64 years and those aged 70-74 years. Performance on the single limb tests was significantly different between the youngest age group and those aged 70-74, 75-79 and 80-86 years. Additional data reported by this study indicated the percentage of subjects in each age group who were able to maintain balance for the maximal time of 45 seconds. However, the authors concluded that in the clinical setting a cut-off time of 30 seconds would seem appropriate as it provides an indicator of those with poorer balance performance.

The results also indicated that the effect of standing limb (left or right/dominant or non-dominant) was not significant and did not vary according to footwear type, including barefoot. Additionally, poorer performance was noted when vision was occluded than when vision was available to the subject. The impact of the removal of one of the three sensory components of the balance system had a marked effect in older subjects. Poorer performance when vision was occluded indicated that the input provided by the visual system is important to the maintenance of static postures. Descriptive data from this study are presented in Table 4.8.

Briggs and colleagues (1989) concluded that the single limb balance tests were more likely to be useful in evaluating balance impairments related to falls or improvements in balance performance as a result of intervention. In contrast, the sharpened Rhomberg test was recommended as best suited to detecting major abnormalities in balance. The results of this well designed clinical study indicate the usefulness of single limb tests, with and without vision, for older women and highlight the advantages of these tests over the sharpened Romberg test in older populations.

Recommendations for single limb balance tests have included a maximal time of 30 seconds for the majority of healthy subjects (Potvin and Tourellottee, 1975; Heitmann et al., 1989; Bohannon, 1994). Only Briggs et al (1989) has exceeded this value by using a cut-off time of 45 seconds for tests including vision. The mean performance time of greater than 30 seconds was observed only in the group of subjects aged 60-64 years. Only two subjects aged 75-79 years and one subject aged 80-86 years were able to utilise the extra time.

There are few reports of reliability or validity of single limb balance tests. Inter-rater reliability between two raters was reported by Briggs et al., (1989) to be r=.99. Single limb stance tests have been reported as a significant predictor of falls associated with injury in the older population but failed to predict all falls (Vellas, Wayne, Romero, Baumgartner, Rubenstein and Garry, 1997b). Subjects who were unable to balance on one leg experienced, over the next three years, twice the risk of incurring an injury as a result of a fall compared with those assessed as having normal balance. This study used a maximum time of 5 seconds for the single limb test. The majority of subjects, aged 72.7(±6.1) years were able to complete the test and were classified as having normal balance. Those not able to complete the test were classified as having abnormal balance. This arbitrary grouping is a potential limitation of this study, as there is little evidence provided which might support such groupings.

Heitmann, (1989) reported significant differences in performance between the first and subsequent trials in community-living older women for single limb tests both with and without vision. This author recommended an assessment protocol in which subjects were not allowed to practice test positions, so that the effects of practice and learning did not confuse the results. Hence, he recommended timing of the first performance. Further reports have indicated that performance on a single limb balance test can improve after several days of practice of the specific testing position (Fransler, Poff and Shepard, 1985). Hence, it is inappropriate to offer practice trails prior to measuring balance ability using single limb stance tests.

Briggs et al., (1989) concluded that single limb balance tests were difficult for subjects to complete and, as such, may be more useful in evaluating treatment effects. However, they expressed concern over the use of these tests for subjects with significant lower limb muscle weakness or recent hip replacement surgery due to the need to position the hip joint in adduction to perform the test successfully.

Table 2.8 Descriptive data for single limb balance tests (eyes open and eyes closed) including ceiling effect data for elderly women subjects as reported by Briggs et al., (1989).

Age Group	Condition	Dominant Limb		Ceiling effect	Non-dominant Limb		Ceiling effect
		Mean	s.d.	%	Mean	s.d.	%
60-64	Eyes Open	38.48	11.56	13	34.13	14.02	9
	Eyes Closed	5.74	4.21	0	8.33	5.89	0
65-69	Eyes Open	24.31	16.79	6	23.88	18.56	6
	Eyes Closed	4.27	2.10	0	4.49	4.49	0
70-74	Eyes Open	18.46	14.85	3	19.60	16.61	5
	Eyes Closed	3.68	2.10	0	2.82	2.82	0
75-79	Eyes Open	10.81	11.80	1	11.97	12.95	2
	Eyes Closed	2.34	1.05	0	3.21	1.76	0
80-86	Eyes Open	10.65	11.33	1	10.17	12.23	1
	Eyes Closed	2.80	1.72	0	2.74	1.83	0

Another clinical test of balance relevant to older subjects is the Functional Reach test, first described by Duncan, (1990). Developed as a clinical measure of the margins of postural stability in the anterior/posterior direction, the Functional Reach test (Functional Reach) has gained widespread clinical acceptance. The test assesses the maximal distance a person can reach forward beyond arm's length whilst maintaining a fixed base of support in the standing position. It is a portable, inexpensive and dynamic balance test. The test has shown significant correlation with centre of pressure excursion (COPE) measured on a force platform system (*r*=.71) in a population of 75 females and fifty males aged 20-87 years (Duncan et al., 1990). The authors concluded that Functional Reach was a more precise and reliable measure than COPE. Additional results from the study indicated that Functional Reach was highly reliable with test-retest intraclass correlation coefficients (ICC) =.82. Intra-tester reliability was reported as ICC=.98. Age and height were seen to influence performance, with Functional Reach excursion decreasing with age. Test-retest reliability in both younger and older subjects was reported as ICC=.98 (Duncan et al., 1990).

Concurrent validity for Functional Reach was established in a study of 45 frail community dwelling subjects, aged 78±8.4 years (Weiner, Duncan, Chandler and Studenski, 1992). Data were examined in relation to performance on a mobility skills test, physical and instrumental activities of daily living scales, walking speed, one leg stance, life space diameter and tandem walk. Functional Reach performance ranged from 10.9 - 41.9 cm with a mean of 27.7±7.9 cm for the study population. After controlling for age, the relationship between Functional Reach and other tests remained strong. As the sample represented a diverse range of abilities, the author concluded that Functional Reach correlated with physical abilities more strongly than with age, indicating concurrent validity. Table 2.9 summarises the correlations reported between Functional Reach and other measures (Weiner et al., 1992).

Further reports have demonstrated the predictive validity of Functional Reach with respect to recurrent falls in an elderly male veteran population (Duncan, Studenski, Chandler and Prescott, 1992). The falls history of 215 subjects was collected prospectively over a six-month period following Functional Reach assessment. Functional Reach was found to be predictive of multiple falls over the ensuing six months in isolation and also when the confounding variables of age, depression and mental test score were added to the regression equation. Comparison of Functional Reach scores for groups described as high functioning/low falls risk and impaired mobility/high falls risk indicated significant differences between the groups with scores of 30.84(±6.86) cm and 18.80(±11.94) cm respectively.

The clinical usefulness of Functional Reach in measuring change in balance over time was examined in 28 male subjects (aged 40-105, mean age 67.3 years) undergoing rehabilitation and 13 comparable control subjects. All subjects were tested at least twice, four weeks apart on Functional Reach, mobility skills, walking speed and a portion of the Functional Independence Measure (Weiner, Bongiorni, Studenski, Duncan and Kochersberger, 1993). Performance on Functional Reach, walking speed and mobility skills changed significantly in intervention subjects, but not control subjects. Correlations between Functional Reach and other physical performance results was moderate to poor, indicating that the measures were measuring different domains of physical performance. The correlation between initial score and change in score was not significant. Functional Reach was, however, sensitive

Table 2.9 Correlations (Pearson's r) between Functional Reach and other test data as reported by Weiner et al., (1992).

	r	Partial r*
Walking speed	.71	.66
PADL	.48	.52
IADL	.66	.60
Tandem walk	.67	.53
Mobility skills	.65	.62
One legged stance	.64	.53
Age	-.05	

*calculated after controlling for age

Table 2.10 Reported values for Functional Reach performance (centimetres) in older subjects

Study	Subjects	Mean	s.d.	Range
Duncan et al, 1990	20 males aged 70-87	33.43	3.94	24.97-39.37
	14 females aged 70-87	25.6	8.97	4.24-38.94
Weiner et al, 1992	45 elderly aged 66-105 years	27.69	7.87	10.92-58.41
Duncan et al, 1992	191 elderly recurrent non-fallers	25.32	10.92	
	26 elderly recurrent fallers	16.86	13.46	
	*99 elderly, high functioning, low-risk	30.84	6.86	
	*118 elderly, low functioning, high risk	18.80	11.94	
Weiner et al, 1993	28 elderly males, undergoing rehabilitation	21.59	4.98	9.65-32.51
	13 elderly controls	24.6	9.32	6.35-39.84
O'Brien et al, 1996	13 females, aged 76(±6.7) years, fallers	22.2	5.9	12.9-31.6
	23 females, aged 73.8(±4.1) years, non-fallers	27.7	4.9	17.2-36.0

* reclassified from original data set

to change over time, with differences of –4.01 – 21.59 cm being recorded. The clinical group showing the greatest changes were those subjects who had experienced a stroke. While Functional Reach was shown to be sensitive to change, the authors were not able to demonstrate that Functional Reach performance could be improved with rehabilitation.

Recent studies involving the Functional Reach test have shown that the test fails to discriminate between healthy older people and those with vestibular dysfunction (Wernick-Robinson, Krebs and Giorgetti, 1999). In addition to arm excursion, these authors suggested that the balance strategy (hip or other) to achieve forward reach should also be recorded. O' Brien, (1996) reported that Functional Reach can identify elderly non-fallers with a specificity of 87%. Sensitivity was 62%, indicating that the test failed to identify several subjects as fallers. However, other clinical tests including the Balance Scale (Berg, 1989) and the Get Up and Go test (Podsiadlo and Richardson, 1991) examined in this study of community-living females aged over 75 years also rated poorly for sensitivity at 54% and 62% respectively. Table 2.10 summarises Functional Reach scores for older subjects reported by the studies previously discussed.

2.7.3 Gait Speed Measures

Walking speed has been cited as a valid and practical measure of mobility (Friedman, Richmond and Baskett, 1988). Gait speed provides a simple, quick and portable measure of general mobility. The measurement of gait speed in elderly individuals has widespread clinical application and is most commonly assessed in the clinical setting by measuring the time taken to complete a 10 metre walking path (Barratt, Ismail, Louie, Tai, Talebi and Westall, 1996). The test is widely used for patients with varying pathologies as well as healthy elderly persons to provide a measure of physical performance. Gait speeds calculated from data collected using the 10 metre walk test have shown significant differences in speed between elderly people with and without a history of falls (Piotrowski and Cole, 1994).

The 10 metre walk test procedure has been described by Colleen, Wade and Bradshaw, (1990). The test measures both the steps and the time taken to complete the 10 metre distance. The 10 metre path is the central part of a 14 metre pathway that includes two metres at each end to allow for acceleration and deceleration outside of the central 10 metre distance (Cerny, 1993; Piotrowski and Cole, 1994). Gait speed (in metres per second) is calculated by dividing the distance by the time taken to complete the 10 metre path (Piotrowski and Cole, 1994). Gait speeds measured on the 10 metre walking test have been shown to have high inter-rater reliability (r=.95-.99) (Colleen et al., 1990) and retest reliability (r=.89-.99) (Wade, Wood, Heller and Hewer, 1987). Concurrent validity has been demonstrated using different timing systems including a light beam, a single physiotherapy student or a group of physiotherapy students. No significant difference between any of the methods of timing was reported (Jeitz, Khoo, Lee, Lim and Low, 1997).

The majority of studies evaluating gait speeds in elderly subjects have used customary or usual walking speeds, also known as self-paced tests (Winter et al., 1990). In these tests, the subject is instructed to complete the test at their usual or comfortable walking pace. Such data provide information on the preferred walking speed of elderly people. A further method for evaluating walking speeds focuses on the maximal speed with which elderly subjects can walk (Winter et al., 1990). Himann, (1987) varied the instructions to subjects and was able to report data on slow, normal and fast pace gaits in elderly subjects. This approach could be considered more relevant to maximal effort over a short period. Thus, maximal walking speeds may provide information about power and balance since the testing protocol asks for a maximal effort. It seems reasonable to conclude, therefore, that self-paced walking speeds and maximal walking speeds provide information about different physical capacities within the same subject.

2.7.4 The Step Test

The step test, described by Avlund et al., (1994) as a measure of physical performance, assesses the maximal height step able to be completed safely without additional upper limb or hand support. Simple equipment consisting of 3 wooden boxes, two boxes of 20 cm and one of 10 cm in height, able to be locked together to form a steady step is required. Thus, step heights of 10 – 50 cm, in 10 cm increments can be prepared for testing of maximal step height.

The step test was devised by the authors of the QFA (Avlund et al., 1994; Avlund et al., 1996), therefore, most reports related to its use with elderly people report the relationships between performance on the test and functional ability scores. The step test is otherwise relatively unknown and few reports related to its use are available. However, in all three known studies, the test was associated with significant results and appears to be a useful assessment for older community-living people. In a study of 405 75 year old Danish community-living subjects (58% female), 81% of men and 55% of women were able to manage the 40 cm step height independently (Avlund et al., 1994). When compared with results of the QFA, male subjects who were unable to achieve a step height of 40 cm were more likely to report dependence in mobility (Mobility Help scale) and physical ADL tasks (Physical ADL Help) than subjects who were able to step up 40 cm, while women unable to step 40 cm demonstrated more tiredness during mobility tasks (Mobility Tiredness scale) than women successful at 40 cm step heights. Results on the step test showed stronger associations with QFA results than with muscle strength, indicating the relationship between simple tests of physical function and everyday functional ability. These results indicate that the step test can be performed by people aged 75 years and that most of this age group can successfully complete a number of the 10 cm step increments. In addition, the step test may yet prove useful in identifying older individuals with early declines in muscle performance. However, it is a relatively new test in the assessment of physical performance of older community-living persons.

Thus, physical performance measures that are clinically relevant and applicable to older people have been described for muscle performance parameters, balance performance and gait function, as well as a relatively new and novel test of step height. Data collected from the combination of these measures can provide a comprehensive description of the physical performance abilities of an older community-living person.

2.8 The Physical Activity Questionnaire

Measurements of physical activity levels in the elderly community-living population are often inaccurate as they underestimate the time spent in completing domestic tasks by focussing on activities outside the home (Avlund and Schultz Larsen, 1991; Avlund et al., 1994). With increasing age, people tend to spend more time in domestic activities than activities outside the home (Berkman and Syme, 1979). A simple questionnaire, the Physical Activity Questionnaire, devised by the authors of the Questionnaire of Functional Ability, was designed to measure physical activity levels in elderly community-living subjects. The questionnaire rates physical activity on an ordinal scale from 1 to 6 and has established reliability (Avlund et al., 1994). The measure provides examples of activities (such as easy gardening, dusting, making beds, home repairs and weekly cleaning tasks) and their weighting. Therefore, the Physical Activity Questionnaire measures appropriate activities for an elderly cohort.

Although limited report are available about its use, results on the Physical Activity Questionnaire have demonstrated a significant relationship with results on the Questionnaire of Functional Ability in community-living people aged 75 years and over (Avlund et al., 1994). Results also provided the strongest predictor of future disability. The odds ratio for disability was more than twice for those ranked as sedentary (scores of 1 or 2) than those performing light activities (scores 3 or 4) and more than four times for sedentary individuals when compared with those undertaking moderate or heavy activities (scores of 5 or 6). Avlund et al., (1994) concluded that participation in light activity protects against functional loss and that this protection increases for those performing heavier activities. They surmised that levels of physical activity were strongly influential of variables in the disablement process for older people.

The Physical Activity Questionnaire was selected as a quick, age specific and useful measure for an older community-living population. Using an ordinal rating scale of 0 – 6 and, with the inclusion of domestic tasks, makes it an easy test for most older people to complete.

2.9 Falls among older people

Falling among elderly people constitutes a serious issue with potential consequences of injury, disability and challenges to independence.
Falls occur with high frequency in the elderly population and often result in significant disability (Tinetti and Williams, 1998). Within the Australian community-living elderly population, approximately thirty per cent of those aged 65 years and older experience a fall every year (Lord, Ward, Williams and Anstey, 1993; Kendig et al., 1996; Dolinis, Harrison and Andrews, 1997). The risk of falling increases dramatically with advancing age. Most epidemiological studies of falls have used subjective recall up to a year following the event and this methodology has been reported to underestimate true falls rates by 15 to 20 per cent (Cummings, Nevitt and Kidd, 1988; Hill et al., 1999). Therefore, true falls rates may be between 45 and 50 per cent of those aged over 65 years. Further, Australian data suggest that almost 50% of the healthy and active female population aged 70 years and older fall each year (Hill et al., 1999). Overseas data reports falls rates for the population aged 75 years and over as varying between one third (Blake, Morgan and Bendall, 1988) and the majority experiencing a fall annually (Tinetti et al., 1988).

Falls are often associated with the devastating and longer term impacts of restricted activity, persisting disability and vulnerability to loss of independence (Kellog International Work Group on the Prevention of Falls by the Elderly, 1987). Approximately one third of those who experience a fall express a fear of further falls, regardless of the seriousness of the initial fall outcome (Tinetti, Mendes De Leon, Doucette and Baker, 1994; Vellas, Wayne, Romero, Baumgertner and Garry, 1997a). An additional one third of elderly people who have not previously fallen also report fear related to future falls

(Tinetti et al., 1988). Factors associated with self reported fear of falling reported by Vellas and colleagues (1997) include female gender, advanced age, balance and gait abnormalities, poor self-assessed health and limited economic resources. Fear has been shown to be strongly related to activity restriction and to marginally affect activities of daily living (personal and instrumental) (Tinetti et al., 1994).

Several large prospective studies have identified risk factors for falls in the elderly community-living population (Tinetti et al., 1988; Nevitt et al., 1989; O' Loughlin et al., 1993; Graafmans et al., 1996; Lord and Clark, 1996). These studies have confirmed the complex interplay between falls, impairment resulting from disease, inactivity and the ageing process. It should be noted, however, that while these researchers have evaluated different factors, the underlying changes resulting in increased fall risk are related to neurological, musculoskeletal and cognitive impairment. Therefore, there is no one set of universally accepted risk factors for falls (Oakley, Dawson, Holland, Arnold, Cryer, Doyle, Rice, Hodgson, Sowden, Sheldon, Fullerton, Glenny and Eastwood, 1996). This fact is a direct result of the complexity of the problem and the many ways of identifying systemic changes using clinical and performance based assessment (Tinetti, 1986). The most recent Cochrane Collaboration document on the Prevention of Falls in Elderly People (Gillespie, Gillespie, Robertson, Lamb, Cumming and Rowe, 2001) concludes that exercise alone is not an effective strategy to reduce falls. Exercise, in addition to education, is cited as the intervention with the greatest evidence for the prevention of falls in elderly people.

The association between falls and frailty, so often observed clinically, is complex and is not fully understood. Tinetti and Williams (1998) reported strong evidence for falls and resultant injuries as precursors of functional decline in a community-living elderly population. Falls resulting in injury were associated with deterioration in physical abilities. Recurrent falls were associated with deterioration in both physical and social functioning. Frailty may be preceded by falls that occur as balance, strength and gait impairments develop. Frailty results from greater losses of physical abilities, as well as many other factors, and is likely to be exacerbated by low levels of confidence in the performance of activities essential to continued independence (Vellas, Wayne, Garry and Baumgertner, 1998).

2.10 Summary

The increasingly older population and the associated high levels of disability are cause for concern. As independence and quality of life diminish with increasing disability, it is timely to investigate the relationship between disability, functional declines and physical performance and to ascertain whether improved performance can diminish functional limitations and in turn reduce disability.

Interventions likely to be successful include those based on exercise and social programs, as each of these factors exerts an independent influence on functional decline in older people. Well-designed intervention studies have frequently focussed on outcomes at the impairment or physical performance level (such as strength, balance and gait). Few exercise intervention studies have investigated outcomes relevant to functional ability (such as ADL or IADL). There is a need for the impact of exercise intervention on functional ability in community-living older people to be evaluated.

Similarly, evidence for the efficacy of social intervention on functional ability in the older population is scant. There is also a need for the impacts of social intervention on functional ability to be described.

The relationship between changes in physical performance and functional ability has been examined in the light of general age related changes. However, there is little evidence to confirm whether improved physical performance leads to improved functional ability.

Appropriate clinical measures of physical performance for a community-living older population have been identified and described. Additionally, a relatively unknown measure of functional ability, with ratings for both tiredness and dependence in a range of functional activities relevant to community-living older people, has been identified. Although untested outside Scandinavia, the QFA appears to be a most useful instrument. Similarly, a questionnaire related to physical activity suitable for use with elderly community-living people, with demonstrated reliability and predictive of disability, has been described.

A further issue of concern for the older population is that of falling and the associated serious consequences. Falls are generally under-reported, but more than half of those aged 70 years and more fall every year.

There is a need to answer important questions regarding the influence of intervention on functional ability in community-living older people and whether changes in physical performance related to intervention can diminish the functional declines that are common with advancing age.

CHAPTER THREE

METHOD

The purpose of the study was to determine the effect of intervention programs on physical performance and functional ability, to observe parameters associated with the development of functional limitation and to record falls prevalence in a group of independent community-living older adults.

The study was designed to fulfil the following aims:

1. To determine the effect of two intervention programs, the first based on increased levels of exercise and the second based on increased social activity, on physical performance and functional ability in an elderly community-living population.

2. To evaluate the relationship between physical performance and functional ability in an elderly community-living population.

3. To evaluate the relationship between changes in physical performance and the development of functional limitation in an elderly community-living population.

4. To record prevalence of self-reported falls in an elderly community-living population.

3.1 Hypotheses

Specific hypotheses identified for the study were:

1. Participation in an exercise intervention program, based on increased levels of physical activity, will improve physical performance parameters (muscle performance, balance, gait and step) in persons aged 75 years and older.

2. Participation in an exercise intervention program, based on increased levels of physical activity, will improve functional ability in persons aged 75 years and older.

3. Participation in the social intervention program, based on increased levels of social activity, will not influence physical performance parameters (muscle performance, balance, gait and step) in persons aged 75 years and older.

4. Participation in a social intervention program, based on increased levels of social activity, will not influence functional ability in persons aged 75 years and older.

5. The relationship between physical performance and functional ability will be significant for all subjects.

6. The development of functional limitation in persons aged 75 years and older will be associated with declines in physical performance (muscle performance, balance, gait and step).

7. The rate of falls in subjects aged 75 years and older be similar to rates reported in the literature.

3.2 Research Design

A randomised single blind controlled study with a repeated measures design was utilised to investigate the effect of the two intervention programs on functional ability. One intervention provided increased physical activity by way of an exercise program designed and supervised by a physiotherapist. The second intervention provided a social program based on increased levels of social activity. A non-intervention control group will also be included. Subjects were recruited from the community, assessed as being at risk of functional limitation and were randomised to groups for intervention. All assessors were blind to group assignment.

3.3 Subjects

Appropriate subjects for the study were aged 75 years or older and living within the general community. Criteria used to determined suitability as a subject for the study were designed to be inclusive, with a number of specific exclusion criteria used to ensure an acceptable and stable state of general health. In addition, a number of withdrawal criteria were used to monitor health over time during the study.

3.3.1 Inclusion Criteria

Four inclusion criteria were specified:

1. Aged 75 years or older
2. Community-living in house, unit, flat or retirement villa.
3. Independent in basic activities of daily living.
4. Able to walk 20 metres independently i.e. without personal assistance.

3.3.2 Exclusion Criteria

Criteria adapted from Greig, Young, Skelton, Pippet, Butler and Mahmud, (1994) were used to identify subjects who would not be physically able to complete the assessment procedures safely or participate in the exercise intervention group. Specific exclusion criteria used were:

1. Resident of a care facility (hospital, hostel, nursing home) on a permanent basis.
2. Cognitive impairment (measured by a score of 24 or less on the MiniMental State Exam (Folstein, Folstein and McHugh, 1975). A copy of the test is contained in Appendix 4).
3. Any of the following health states:
   a. aneurysm, angina, uncontrolled dysrhythmia,
   b. claudication, thromboplebitis,
   c. pulmonary embolus,
   d. cerebrovascular disease,
   e. resting systolic blood pressure >200mmHg ,
   f. resting diastolic blood pressure >100mmHg,
   g. severe airflow obstruction,
   h. major systemic disease diagnosed or active within the previous five years (e.g. cancer, rheumatoid arthritis),
   i. significant emotional distress,
   j. previous mental illness, including anxiety or depression requiring medication within the previous two years.

3.3.3 Withdrawal Criteria

As subject participation in the study could last up to two years, a number of criteria, adapted from Greig et al., (1994) were used to ensure that those who had demonstrated a significant decline in general health status during the study period were withdrawn from further participation. Specific criteria were:

1. Change in independent living status from community-living to institutional or care facility residence on a permanent basis.
2. Development of, or increase in cognitive impairment (measured by a score of 20 or less on the Mini-Mental State Exam (Folstein et al., 1975).
3. Development of any of the following acute health states:
   a. myocardial infarction,
   b. aneurysm, angina, uncontrolled dysrhythmia,

    c. claudication, thromboplebitis,
    d. pulmonary embolus,
    e. cerebrovascular accident,
    f. uncontrolled resting systolic blood pressure >200mmHg,
    g. uncontrolled resting diastolic blood pressure >100mmHg,
    h. severe airflow obstruction,
    i. major systemic disease,
    j. significant emotional distress,
    k. psychotic or depressive illness.
4. Change in residential address from the Perth metropolitan area.
5. Withdrawal of consent.

3.3.4 Subject Recruitment

Recruitment efforts were aimed at the community-living population of elderly people within the Perth metropolitan area. A press release, prepared with the assistance of Public Affairs, Curtin University of Technology, was distributed to the Community Newspaper Group, publisher of free, weekly, regional newspapers. The press release contained information describing the study, its general aims and inviting people aged 75 years and over and living in the general community and concerned about the ageing process and its impact on them to contact the researcher at the University for further information. This information was published in 11 newspapers over a period of four months.

In addition, information brochures about the study were printed and distributed to General Practice surgeries, senior citizens' social and recreational organisations, community based services including Meals on Wheels, local government community workers, domiciliary nursing services and community based podiatry services.

A total of 187 individuals contacted the researcher and after a brief telephone interview, 154 were identified as potential subjects. The telephone interview was used to describe the study in detail, answer questions, review inclusion and exclusion criteria and to ascertain whether a health assessment by a medical practitioner should be completed before inclusion in the study. If a health assessment was recommended, the potential subject was able to choose either to visit a doctor of their choice or to attend a medical assessment, organised by the researcher through the Department of Geriatric Medicine, Royal Perth Hospital. Twenty-seven potential subjects were requested to undergo a health assessment with 22 of these eventually admitted to the study. (Two subjects did not undergo the assessment and the remaining three subjects were advised not to take part in the study based on the results of the medical assessment.) Health assessments were requested for those who were experiencing blood pressure problems (poorly controlled by medication), who had a previous diagnosis of malignancy, were experiencing dizzy spells or complained of joint pain impacting upon activities of daily living. Table 3.1 outlines the reasons for exclusion of the 33 individuals who responded to recruitment activities but were not accepted for the study.

3.3.5 Study Sample

The total number of subjects accepted into the study was 149. Figure 3.1 illustrates the study design, timing of assessment, and total subject numbers for each assessment. Age and gender characteristics of subjects are outlined in Table 3.2.

3.3.6 Randomisation

Subjects were randomly assigned to one of three groups by a physiotherapist uninvolved in the study using a table of random numbers as described by (Portney and Watkins, 1993) with a small number of exceptions. Couples who lived at the same address were, for the purpose of allocation to group, numbered as a single subject and then included in the usual randomisation process. In these circumstances, it might be difficult for potential subjects to accept the assignment of each individual to a different group for up to a 16-week period of intervention. There were 12 subjects who were treated in this way and taking into consideration their co-habitor reduced 12 to 6 for the randomisation process. Once randomisation was completed, the geographical location of subjects assigned to the intervention groups determined the localities in which the interventions were run to minimise travel for participants.

Table 3.1 Reasons for exclusion of interested persons (n=38)

Reason for Exclusion	Number
Younger than 75 years	14
Previous myocardial infarct	8
Cardiovascular disease	4
Uncontrolled angina	5
Declined random assignment to group	5
Declined health assessment	2

Table 3.2 Age and gender characteristics of the study population

Age group	Female	Male
75-70 years	47	21
80-84 years	30	3
85-89 years	38	7
90-94 years	3	0

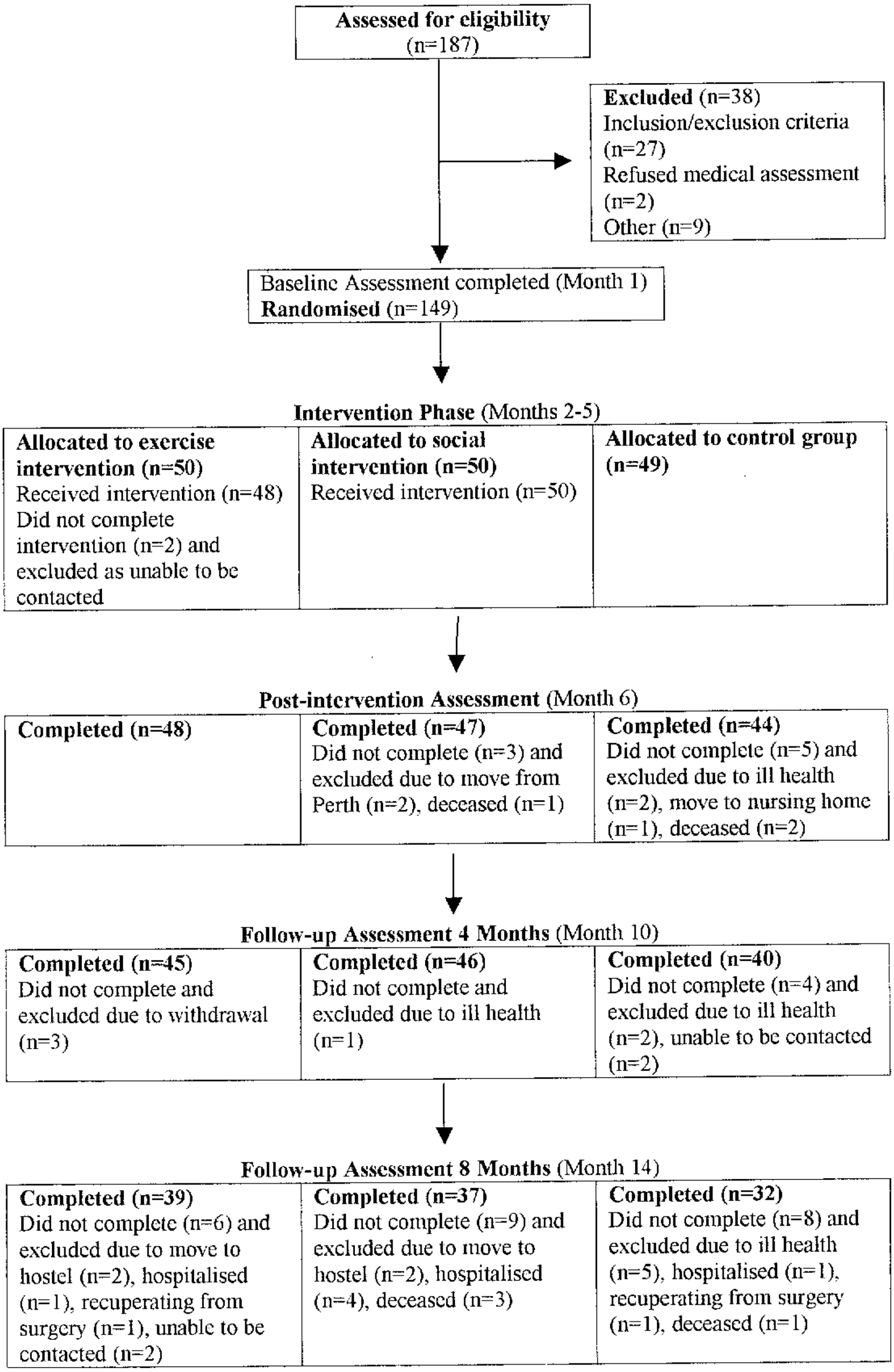

Figure 3.1 Flow chart of timing of assessments and interventions, subject numbers, withdrawals and reasons.

3.3.7 Ethical Considerations

Ethical approval to conduct the research was granted by the Human Research Ethics Committee of Curtin University of Technology. Prior to participating in the study, the purpose and procedures to be used and the advantages, disadvantages and risks related to participation were explained to each subject and an opportunity to ask questions was provided. The process and implications of randomisation to group for either an intervention (exercise or social) or no intervention was explained in detail. Further, the implications of the intervention ceasing after 16 weeks and no further intervention being made available was clearly discussed with each participant. No attempt was made to encourage participants to continue or discontinue exercise following the intervention phase. Potential subjects were informed that transport to and from the intervention and assessment venues could be provided if required. In addition, individual subjects were advised whether participation in the study would require a medical assessment and that suitably qualified medical practitioners would provide this assessment at no cost. Subjects were also given the option of attending their usual General Medical Practitioner for the health assessment if they preferred.

The Subject Information Form was given to each subject for personal use. A Consent Document was then read and signed by each subject and retained by the researcher. Subjects were told that they could withdraw their consent at any time during the study without explanation or penalty. In addition, those subjects who agreed to be involved in photographic records of the study were required to sign an Audiovisual Consent Document. A copy of each of these documents is contained in Appendix 1. Subjects' details were kept separate from other data. Code numbers identified subjects only. All information and data relevant to the study were stored on computer requiring password access.

3.3.9 Subject Withdrawal and Loss

One hundred and forty-nine subjects completed baseline assessments and were admitted into the intervention phase of the study. Allocation to group resulted in 50 participants in each of the intervention programs and 49 control subjects.

The post-intervention assessment, held immediately after completing the intervention program, involved 139 subjects (48 of whom had participated in the exercise intervention program, 47 of whom had participated in the social program and 44 control subjects).

The follow-up assessments were held at four and eight months post intervention. One hundred and thirty-one subjects completed the four-month assessment (45 from the exercise intervention group, 46 from the social intervention group and 40 control group subjects). The final assessment, at 8 months post intervention, was completed by 108 subjects (39 from the exercise intervention group, 37 from the social intervention group and 32 control groups subjects). The reasons for non-attendance/withdrawal are summarised in Figure 3.1.

Data analyses, using cross tabulation and chi square, were conducted to identify any differences between the 108 subjects who completed the 12 month study compared with the 41 subjects who did not. Results are presented in Section 3.11.1.

3.4 Variables

Independent, dependent and derived variables essential to the research design were identified. Independent variables included age (which provided continuous data), gender (of which there were two levels – male and female), intervention (of which there were three variables – exercise intervention, social intervention and no intervention or control) and repeated measures (of which there were four levels). Dependent variables for the study consisted of the measures of physical performance, functional ability, activity measures and self-reported falls. Derived variables consisted of the dependent variables that required mathematical manipulation before being used in analyses. Maximal and self-paced walking velocity was derived from the time taken to complete the 10 metre walking test at each speed. Step height results were normalised by dividing the result by the lower limb length of the preferred limb. Variables representing the change in physical performance measures and functional ability scores were also derived to measure decreases in performance and scores over the study period.

3.5 Methods and Measures

Throughout the study, subjects attended a maximum of four assessments – baseline (month 1), post-intervention (month 6, immediately following completion of the intervention programs), follow-up at 4 months (month 10 from the baseline assessment) and follow-up at 8 months (month 14 from the baseline assessment). Each session consisted of responding to health and activity questionnaires, measurement of muscle, balance, timed walk and step height performance. The intervention programs for physical and social groups, took place in months 2 through 5. Additionally, throughout the study period, subjects were required to return a monthly report with details of health, falls and functional activity changes. The general testing procedure and detail of specific procedures for each questionnaire and physical test, as well as the intervention programs and monthly reports, are outlined below.

3.5.1 Health Questionnaire

All subjects were interviewed with regard to their health at each assessment. The questionnaire used was based on that used in the FICSIT, multi-centre collaborative trails conducted in USA to investigate frailty and injuries associated with old age (Ory, Schechtman and Miller, 1993). A copy is provided in Appendix 5. Subjects were asked to rate their health status over the four-month period between assessments and over the month immediately prior to assessment. They were also asked to provide a list of current prescribed medications and report any falls experienced since the previous assessment.

3.5.2 Muscle Performance Tests

Isometric force of selected upper and lower limb muscle groups was measured using a hand-held dynamometer. The instrument used was a Nicholas Manual

Muscle Tester[2], a hand held dynamometer. This digital strain gauge dynamometer displays the force measurement to the nearest 0.1 kg, up to a maximum of 199.9 kg.

One upper limb and three lower limb muscle actions on the dominant limb were measured on each subject on each testing occasion. Dominance was assessed by asking each subject to identify their preferred arm for throwing (this became the dominant arm) and the preferred leg for single limb stance when kicking a ball (this became the dominant leg).

Prior to each episode of testing, the instrument was prepared according to the manufacturer's instructions. Table 3.3 summarises the muscle actions, subject, and dynamometer and stabilisation positions used. The dynamometer position was standardized with specific landmarks. The instrument shaft remained perpendicular to the limb segment and parallel to the plane of movement. Isometric force was measured for one dominant upper limb muscle action, shoulder abduction, and three dominant lower limb muscle actions – hip abduction, knee flexion and ankle dorsiflexion according to a standard protocol (Andrews et al., 1996). Subjects were positioned according to the gravity eliminated position for each muscle action which was supine for all except knee flexion which was tested in the high sitting position. Neutral rotation was maintained at the trunk for all tests. An assistant provided additional stabilisation for each subject to maintain position as required.

Subjects were given a brief familiarisation session outlining the testing procedure, muscles to be tested and positions used and three practice trials for each muscle test. A 'break' test was used. For each muscle action the investigator placed the limb in the specific position and manually resisted the required action. Subjects were then asked to maintain the limb in the stipulated position and to hold that position while an increasing force was

---

[2] Model 01160, Lafayette Instrument Company, PO Box 5729,, 3700 Sagmore Parkway North, Lafayette, Indiana, USA 47903

Table 3.3 Subject, limb and dynamometer positions used for muscle strength assessment

Muscle Action	Subject Position	Limb Position	Dynamometer Position	Stabilisation
Shoulder abduction	Supine	Shoulder abducted 20° elbow flexed 90°	Immediately proximal to lateral epicondyle of humerus	Superior aspect of shoulder
Hip abduction	Supine	Hip abducted 20° knee extended	Lateral femoral condyle	Opposite lower limb held in neutral
Knee flexion	High sitting	Hip and knee flexed 90°	Posterior aspect over musculotendinous junction of calf muscles	Subject holds onto side of bed
Ankle dorsiflexion	Supine	Ankle and lower limb in neutral	Distal portion of 1st metatarsal	Knee maintained in full extension, leg supported off table

applied through the dynamometer. Once the investigator overcame the muscle action force, the subject was told to relax the muscle as the test was finished. Two tests of each muscle action were performed with the highest peak force result recorded. Testing of a particular muscle action ceased immediately if the subject reported any discomfort.

3.5.3 Balance Performance Tests

The balance tests consisted of timed single limb balance with eyes open, timed single limb balance with eyes closed and maximal functional reach. All tests were performed by subjects wearing their usual shoes.

Single limb balance tests were conducted on the subject's preferred leg. Subjects were instructed to stand on their preferred leg with their arms by their sides and to maintain this position for as long as possible, up to a maximum of 30 seconds. The eyes closed test instruction also included the subject closing his/her eyes before attempting to stand on a single limb, for a maximum of 10 seconds. No practice trials were allowed as previous studies have highlighted the significant effect of practice on single limb balance tests (Fransler et al., 1985; Heitmann et al., 1989). Timing began immediately the subject assumed a single limb position. Timing ceased when the subject's other foot retouched the ground, the arms were raised from the sides, when the assessor physically assisted the subject to remain upright, when the assessor decided it was not safe to continue, or after 30 seconds (or 10 seconds with eyes closed) of continuous single limb balance. The single performance was recorded as the subject's ability on the test.

The Functional Reach test (Duncan et al., 1990) was performed standing next to, but not touching, a wall on the side of the subject's preferred arm. The subject was instructed to stand in an upright position, feet no more than shoulder width apart, with 90^0 shoulder flexion and the arm fully extended. The position of the distal end of the limb was marked. The subject was then asked to lean forward as far as possible, without moving his/her feet or losing balance, and the position of the distal end of the limb was marked. The performance was defined as the final position minus starting position. Three practice trials were allowed and of the two subsequent attempts, the highest value was recorded.

3.5.4 Walk Performance Tests

Performance on three timed walk tests was assessed. The self-paced walk test and the maximal paced walk test covered a central distance of 10 metres. A further test, designed specifically for the study to measure functional gait parameters, and called the circuit test, involved walking a five metre path, turning around and walking the same five metre path back to the start point and so on, until the completion of ten laps. Start and stop marks were clearly marked on the floor.

The self-paced walk was a ten metre distance with an extra two metres marked at each end. Subjects were instructed to start at the two metre line and to walk at their usual, comfortable walking pace until they had stepped over the two metre line at the far end. This allowed the subject to be at their chosen speed when walking over the central ten metre course which was timed. Subjects were not allowed a practice and the time of the first attempt of the walking path was recorded.

The maximal paced walk test covered the same course as the self-paced walk test. Subjects were instructed to walk at their fastest pace while covering the course. The inclusion of the two metres at each end of the course allowed for acceleration and deceleration to be outside the central timed 10 metre distance. Only one attempt (no practice) was allowed.

The third test, the circuit walk, was a novel test. Specifically designed for this study as a measure combining multiple elements of maximal walking speed, turning around to change direction and the associated deceleration (followed by acceleration), it was proposed that the circuit walking test might prove more useful as a measure of physical performance over time than walking speeds alone. As a novel test, there is no known literature discussing the impact of ageing on performance, such as reports of normative age related data or intervention effects. The circuit test commenced at a start line and subjects walked to a line five metres away, turned around once they were fully past the line and returned to the start line again, turning when they had stepped over the line with both feet. This was the completion of one lap. The test continued for another nine laps and timing was concluded as the subject stepped over the final line with both feet. Subjects were allowed one practice followed by only one performance and were instructed to complete the test as fast and as safely as possible whilst walking.

3.5.5 The Step Test

The step test was devised by Avlund et al., (1994). A specific set of equipment was manufactured consisting of three wooden boxes. Two boxes were 20 cm in height and the final box was 10 cm in height. The boxes were manufactured so as to be easily locked together and to have a surface area of $60cm^2$. The standing surface was covered with a rubberised strip flooring material and all edges marked with white tape. The boxes in isolation or combination could be locked together to provide a step height of 10, 20, 30, 40 or 50cm.

Subjects were required to step up onto the box without arm support of any kind. All subjects started with the box set up at 20 cm. Two attempts at each height were allowed. If successful, the box height was increased by 10 cm until an unsuccessful attempt occurred or the maximal step of 50 cm was scaled. If unsuccessful at 20 cm, the box was set up at 10 cm for a further attempt. Inability to step up the 10 cm box resulted in a score of 0. Lower limb length was also measured. Landmarks of the great trochanter of the femur and the lateral malleoli of the fibula were marked on the skin of the leg used to step with and the distance between each point measured using a standard tape measure. The step height result for each subject was normalised for height before analysis.

3.5.6 Functional Ability and other Questionnaires

The Questionnaire of Functional Ability (QFA) (Avlund et al., 1996) was used as the measure of functional ability. Subjects were asked to indicate their ability to complete certain activities as of the week before the assessment, thus negating fluctuations in ability over the previous four months. If the subject was unable to answer the questions spontaneously, the interviewer prompted them by asking about their ability to do the activity over the previous week. The questionnaire has been previously described in Section 2.2.3 and a copy is provided in Appendix 6.

Usual physical activity was assessed utilising the Physical Activities Questionnaire (PAQ) (Avlund et al., 1994). Subjects were asked to rate their usual level of activity over the past four months. This measure has been previously described in Section 2.8 and a copy is appended (Appendix 7).

3.5.7 Monthly Report Sheets

Subjects were provided with a set of report sheets during each assessment. The set consisted of four monthly report sheets and four reply paid addressed envelopes. At the end of every calendar month, subjects were asked to complete a report sheet and return it by post, in the envelope provided, by the middle of the following month. The report asked questions about visits to the doctor, hospitalisation, periods of ill health, changes in abilities and the occurrence of any falls. When any of these events occurred, the subject was asked to provide further details. If further information was required on receipt of the report, the researcher telephoned the subject to discuss their report. On non-receipt of the report by the middle of the following month, the researcher contacted the subject to collect the appropriate information by telephone. A copy of the instruction and report sheets issued to subjects is provided in Appendix 8a and 8b.

3.6 Pilot Study

Pre-testing of all questionnaires, physical tests and functional measures, as well as the general procedure, was undertaken prior to subject recruitment for the study. Some of the measures identified for use in the study had not been specifically used with an independent elderly population. While physiotherapists when assessing performance of people of differing ages and abilities commonly used many of the physical tests, the protocols for use of these measures with a community-living elderly population were not always consistent. Therefore, the applicability and usefulness of the tests for the age group of interest to this study required further investigation.

3.6.1 Stage 1

Each of the physical tests was performed on a group of physiotherapy students to finalise equipment, positioning and formal instructions prior to pre-testing with an elderly sample group. At the same time, several people were trained in the use of all measures and tests, as several assessors were needed for the study.

3.6.2 Stage 2

This session involved five elderly subjects recruited from a local retirement village. Each subject underwent the entire testing protocol on one occasion to assess ease of use of questionnaires, suitability of the testing equipment and venue, levels of fatigue during the physical assessment procedures and to finalise instructions for each procedure. The monthly record sheets were included with the other questionnaires during this session. The subjects who participated in this session did not take part in any further activities related to the study. Following the completion of this session, the wording of all questionnaires was finalised and the wording of the monthly report sheet was revised.

3.6.3 Stage 3

The aim of this final stage of the pilot study was to investigate reliability between trials, between testing days and between raters. The study involved 13 subjects from the same retirement village who did not participate further in the study. Three testers were involved. Subjects attended three sessions scheduled over a four week period, with sessions at least one week apart. Testers were allocated on a random basis for each subject at each occasion, with two testers involved at each session. The subjects underwent the finalised test protocol and were asked to complete all questionnaires and tests, including a monthly report sheet.

Results of the questionnaires and monthly report sheets were reviewed and showed highly consistent answers in all sections. Further analysis was therefore not carried out. The format and content of the questionnaires were not altered as a result of this pilot test.

Tables 3.4 and 3.5 present the results obtained from analysis of data by correlation and *t*-tests within testers and between occasions (intra-tester) and between tests (inter-tester). Intra-tester correlations were significant and generally strong, with values ranging from r=.70-.97 which was deemed acceptable for the study. *T*-test results indicated no significant difference between testers and assessment days. Inter-tester correlations were also significant and generally strong with correlation ranging between r=.62-.99. *T*-test results indicated no significant difference between testers.

3.7 General Procedure for the Repeated Measures of Physical Performance and Functional Ability

Data collection took place during four sessions throughout the study period. The first session provided information, allowed for completion of consent documents and provision of explanations concerning the monthly report calendars. The first session lasted approximately 90 minutes for each subject, with subsequent sessions lasting approximately 65 minutes.

Each session commenced with an interview to ascertain changes in health and activity levels since the last assessment. A health questionnaire, Physical Activities Questionnaire and Questionnaire of Functional Abilities were completed for each subject. A review of prescribed and other medication alerted the researcher to possible changes in health status. Any significant changes in medication or health and activity levels were discussed with the

Table 3.4 Summary of results of correlation and t-tests for intra-tester reliability

Test	r	p	$t_{(12)}$	p
Shoulder abduction				
Tester 1	.98	<.001*	1.060	.310
Tester 2	.97	<.001*	.449	.662
Tester 3	.96	<.001*	1.741	.107
Hip abduction				
Tester 1	.89	<.001*	.794	.422
Tester 2	.84	<.001*	.099	.923
Tester 3	.86	<.001*	.466	.649
Knee flexion				
Tester 1	.97	<.001*	.059	.954
Tester 2	.97	<.001*	.830	.423
Tester 3	.93	<.001*	.738	.474
Dorsiflexion				
Tester 1	.97	<.001*	1.643	.126
Tester 2	.97	<.001*	1.082	.301
Tester 3	.96	<.001*	1.129	.281
Single limb balance eyes open				
Tester 1	.97	<.001*	.28	.785
Tester 2	.97	<.001*	1.68	.119
Tester 3	.94	<.001*	1.79	.099
Single limb balance eyes closed				
Tester 1	.88	<.001*	.346	.091
Tester 2	.79	<.001*	1.839	.736
Tester 3	.89	<.001*	1.535	.151
Functional Reach				
Tester 1	.93	<.001*	.396	.046
Tester 2	.96	<.001*	2.229	.699
Tester 3	.92	<.001*	2.470	.029
Usual gait speed				
Tester 1	.68	.98	1.765	.103
Tester 2	.64	.133	.554	.590
Tester 3	.86	<.001*	1.336	.206
Maximal gait speed				
Tester 1	.89	<.001*	.045	.965
Tester 2	.95	<.001*	1.824	.093
Tester 3	.93	<.001*	1.434	.177
Circuit walk				
Tester 1	.96	<.001*	.228	.823
Tester 2	.95	<.001*	.227	.824
Tester 3	.92	<.001*	.331	.746
Step height				
Tester 1	.84	<.001*	.098	.924
Tester 2	.70	<.001*	1.097	.294
Tester 3	.74	<.001*	.446	.664

*p<.01

Table 3.5 Summary of results of correlation and *t*-tests for inter-tester reliability

Test	*r*	*p*	$t_{(12)}$	*p*
Shoulder abduction				
Tester 1 & 2	.995	<.001*	.325	.196
Tester 2 & 3	.994	<.001*	1.369	.751
Tester 3 & 1	.982	<.001*	.259	.800
Hip abduction				
Tester 1 & 2	.93	<.001*	.606	.556
Tester 2 & 3	.98	<.001*	.929	.371
Tester 3 & 1	.95	<.001*	.036	.972
Knee flexion				
Tester 1 & 2	.99	<.001*	.089	.931
Tester 2 & 3	.98	<.001*	.996	.339
Tester 3 & 1	.99	<.001*	1.580	.140
Dorsiflexion				
Tester 1 & 2	.98	<.001*	1.698	.115
Tester 2 & 3	.98	<.001*	.478	.641
Tester 3 & 1	.99	<.001*	.468	.648
Single limb balance eyes open				
Tester 1 & 2	.98	<.001*	1.158	.269
Tester 2 & 3	.99	<.001*	1.509	.157
Tester 3 & 1	.99	<.001*	1.350	.202
Single limb balance eyes closed				
Tester 1 & 2	.94	<.001*	1.908	.081
Tester 2 & 3	.76	<.001*	2.287	.041
Tester 3 & 1	.98	<.001*	.771	.456
Functional Reach				
Tester 1 & 2	.96	<.001*	2.772	.017
Tester 2 & 3	.96	<.001*	1.382	.192
Tester 3 & 1	.96	<.001*	.352	.731
Usual gait speed				
Tester 1 & 2	.62	.126	1.357	.200
Tester 2 & 3	.97	<.001*	.832	.421
Tester 3 & 1	.76	<.001*	.035	.972
Maximal gait speed				
Tester 1 & 2	.94	<.001*	2.152	.052
Tester 2 & 3	.98	<.001*	1.261	.231
Tester 3 & 1	.95	<.001*	1.341	.205
Circuit walk				
Tester 1 & 2	.97	<.001*	.105	.918
Tester 2 & 3	.97	<.001*	.187	.855
Tester 3 & 1	.96	<.001*	.706	.493
Step height				
Tester 1 & 2	.87	<.001*	.559	.586
Tester 2 & 3	.89	<.001*	.228	.823
Tester 3 & 1	.73	.005	.972	.350

*$p<.01$

Table 3.6 Test protocols and measurement results

Test	Trials	Range and Units
Muscle performance		
each muscle group	2	0.1 - 199.9 kg
Balance		
Single limb balance eyes open	1*	0 - 30.0 seconds
Single limb balance eyes open	1*	0 - 10.0 seconds
Functional reach	2	centimetres
Timed walk		
Usual gait speed	1*	time/10 m $=ms^{-1}$
Maximal gait speed	1*	time/10 m $=ms^{-1}$
Circuit walk	2	seconds
Step height	2**	0, 10, 20, 30, 40 or 50 cm

* no practice allowed
** two attempts at each height

subject and medical assessment was offered to those subjects who had not seen their preferred doctor since the previous assessment.

The physical tests were completed following the interview. Subjects were instructed to wear comfortable walking shoes and all physical assessment procedures were completed wearing footwear. The physical tests were performed in random order. The protocol for each test, number of practices allowed and final performance from which data were recorded has been previously described. Some tests had maximal values stipulated and once these were reached, no further trials were necessary. Table 3.6 summarises these tests and maximal values. Between trials on the same test, subjects were given a mandatory rest of 30 seconds and were allowed a maximum of five minutes rest. Following completion of data collection for a test, subjects were given a mandatory two minute rest and were allowed a maximum ten minutes rest before moving onto the next test. These periods were scheduled to minimise fatigue throughout the lengthy assessment session.

3.8 Intervention Programs

The intervention program was conducted during months 2 through to 5 of the study. Subjects had undergone one baseline assessment prior to being randomly allocated to one of three groups following the first assessment. The exercise intervention group completed a 16-week exercise program of twice weekly exercise sessions each of one hour duration. The social intervention group participants attended once a week for a two hour session for 13 weeks. This discrepancy was due to availability of venues and assistance with transport services being more limited in relation to the social program than the exercise program. Control subjects received no intervention. However, all subjects were asked to complete monthly written reports.

3.8.1 Exercise Intervention Program

Subjects randomly allocated to the exercise intervention program participated in a twice weekly exercise session of 60 minutes over a 16-week period (total intervention time = 32 hours). Identical programs were offered at two venues within the Perth metropolitan area in order to minimise travelling time for participants. Transport by taxi was offered to subjects who were unable to provide their own transport.

Each session was planned by the investigator and based on exercise guidelines for older adults published by the American College of Sports Medicine (Mazzeo, Cavanagh, Evans, Fiatarone, Hagberg, McAuley and Startzell, 1998; Pollock, Gaesser, Butcher, Despres, Dishman, Franklin and Garber, 1998), with input from the two physiotherapists employed to co-ordinate and lead the sessions. The focus of the overall program was to improve cardiovascular endurance, general muscle performance, balance, co-ordination and flexibility. As such, each session was typical of physiotherapy exercise programs for healthy elderly people.

Participants were provided with written information about exercise, safety and level of exertion. In addition, they were instructed on monitoring their own level of exertion, both by recognising breathlessness and by the taking of radial or carotid pulses. Resting and exercise heart rates were monitored throughout each session. Modifications in position or specific exercise were taught to individual subjects where pain or other difficulties made this appropriate. Participants were encouraged to exercise at their own rate, to rest whenever necessary and to rejoin the group when able. Each physiotherapist monitored participants for signs of overexertion, pain, discomfort and the need for further exercise modification.

Each session commenced with 10 minutes of warm-up activities and stretches of major muscle groups. The muscle strengthening component followed. Each participant had been assessed on his or her personal one repetition maximum and the value was used to prescribe the resistance. Individuals completed the strengthening exercises with their individualised resistance that was increased once a threshold of repetitions was met. Muscle groups strengthened were those creating movement around the shoulder, elbow, trunk, hip, knee and ankle. All movements were completed throughout the full or a large proportion of the full range for the joint to mimic functional requirements.

A 'low-tech' approach was utilised. Resistive muscle work was performed with elastic tubing of varying resistance and sand or rice bags. The important variable in the muscle performance program was the ongoing increments in resistance provided, both in the exercise session and for home use. These increases were individually monitored and prescribed by the physiotherapist. The principle of training overload was utilised.

Balance activities were also individually prescribed for each individual and progressed from altered base of support, altered standing surface to dynamic activities such as stepping up a small step, obstacle negotiation, combined balance and neck movements and altered walking patterns (such as sideways or backwards).

Endurance activities consisted initially of five minutes and progressed eventually to 15 minutes of continuous movements, again at an intensity appropriate for each individual. Activities such as marching combined with arm movements and dancing movements (e.g. barn dance steps) were used. Participants were instructed on monitoring heart rate and each participant was educated about their own target training heart rate. Training heart rates were calculated for each individual (according to principles stated by Mazzeo et al., 1998) and generally exceeded 65% of training heart rate.

Co-ordination activities included hand-eye activities, such as bat and ball games, passing of balls, batting balloons, throwing beanbags etc. As the weeks progressed, these activities were combined with balance activities, so that participants were required to stand with feet together, one foot in front of the other or on foam while participating.

Each session concluded with warm-down activities and muscle stretches of the major muscle groups. Stretching was done in the standing position wherever possible. By the completion of the program, all but two participants were able to complete stretches while standing and all but five participants were able to get down onto the floor as required for stretching. Participants were taught methods of getting down to and back up from the floor as part of the intervention. Additionally, each session participants were given one functional activity as a home exercise. In the first few weeks, such activities included picking up an object from the floor while seated, forward reach while seated and progressed to similar activities in standing. Instructions on safe completion of tasks were given as part of the activity.

A total of 26 exercise sessions were held with a mean attendance 84.6% (22 sessions) and a range of 100% - 62% (16 sessions). Reasons for non-attendance included illness, illness of spouse, transport difficulties, other appointments and holidays.

3.8.2. Social Intervention Program

The social program was run over a 13-week period, with a single two hour session per week (total intervention time = 26 hours). Again, two venues were used in order to increase the convenience for participants and transport arranged where necessary. Each session was co-ordinated by a physiotherapist, under the supervision of the investigator.

The content of the social intervention sessions involved slide and video presentations by the participants of their recent (and not so recent) travels. Participants were invited to present for one hour. Only two subjects declined to present to the group. All of the others were very willing. Several participants presented more than once.

3.9 Data Management

A number of test results required manipulation to a more appropriate scale before statistical analyses were carried out. Scores for the PAQ and QFA were calculated by totalling the item scores and reports of falls were coded for each assessment. Timed physical test scores were recorded in seconds, muscle performance scores in kilograms and step and leg length scores in centimetres. Data obtained for the step test were normalised by dividing each result by the lower limb length of each subject to neutralise the obvious advantage of longer lower limbs.

Statistical analyses of data collected during the study involved firstly an approach to missing data followed by multivariate analysis and secondly an intention to treat analysis including all data, whether complete or not.

3.9.1 Missing Data

Forty-one of the initial 149 subjects withdrew or were lost during the duration of the study. Subject loss occurred throughout the study and for initial statistical analyses, subjects were grouped according to their status at the final assessment as either "missing" or "complete". Analysis was conducted to establish firstly whether there were group differences in loss and secondly to establish whether there were differences in performance at the baseline assessment between subjects who completed compared with those who did not complete the study. Cross tabulation of loss by group is summarised in Table

3.7. A chi-square test was performed to examine group differences in subject loss throughout the study period. Assumption testing indicated that data were appropriate for this test. The result ($\chi^2_{(2, n=149)}=2.086$, $p=.352$) indicated that subject loss was not different among groups over the study period.

Further analyses determined the extent of differences in age, gender, physical performance and functional ability at baseline between missing and complete subjects. As data met the assumptions of independence of groups and homogeneity of variance was assessed for each dependent variable, an independent samples t-test was used to compare dependent variable data between two groups – those who completed the study (n=108) and those who did not (n=41). A significant result following Levene's test, indicating violation of the assumption of homogeneity of variance, was demonstrated for dorsiflexion ($p<.001$) and gender ($p=.002$) data. For these two variables, equal variance was not assumed. Results demonstrated no significant difference between subjects who completed the study in its entirety and those subjects who did not. Results are summarised in Table 3.8. Descriptive data for the two groups recorded at baseline are summarised in Table 3.9.

As there were no differences in age, gender, physical performance and functional ability at baseline between subjects who continued in the study, compared with those who did not, cases with incomplete data (n=41) were excluded from further multivariate analyses. The final number of cases used in multivariate analyses was 108 with group sizes of exercise = 39, social = 37 and control = 32. However, an intention to treat analysis was also performed following the analysis of intervention effects and is described below.

Table 3.7 Cross tabulation of subject loss throughout the study period.

		GROUP			
		Exercise	Social	Control	Total
Missing	Count	11.0	13.0	17.0	41
	Expected Count	13.8	13.8	13.5	41
Complete	Count	39.0	37.0	32.0	108
	Expected Count	36.2	36.2	35.5	108
Total	Count	50.0	50.0	49.0	149
	Expected Count	50.0	50.0	49.0	149

Table 3.8 Summary of independent samples t-test results for dependent variables measured at baseline between subjects who completed and those who did not complete the study

Variable	*df*	*t*	*p*
Age	61.14	1.719	0.122
Gender*	147	2.305	0.023
Shoulder abduction	147	-0.342	0.733
Hip abduction	147	1.633	0.105
Knee flexion	147	1.477	0.142
Dorsiflexion*	53.47	2.514	0.015
Single limb balance eyes open	147	0.519	0.604
Single limb balance eyes closed	147	-1.004	0.317
Functional Reach	147	0.211	0.834
Usual gait speed	147	-0.105	0.916
Maximal gait speed	147	-0.827	0.410
Circuit walk	147	1.143	0.255
Step height	147	1.081	0.282
Upper limb tiredness	147	-0.131	0.896
Lower limb tiredness	147	0.910	0.364
Mobility tiredness	147	-0.185	0.853
Mobility help	147	0.303	0.762
Personal activities of daily living help	147	-1.109	0.269

*equal variances not assumed *$p<.01$

Table 3.9 Descriptive data for dependent variables measured at baseline between subjects who completed and those who did not complete the study

	Did not complete		Completed	
	Mean	s.d.	Mean	s.d.
Age	82.2	3.9	80.7	3.5
Shoulder abduction	28.6	8.1	29.1	7.5
Hip abduction	19.6	5.7	18.0	5.6
Knee flexion	16.8	5.4	15.5	4.7
Dorsiflexion	19.7	7.3	16.6	4.8
Single limb balance eyes open	21.0	10.0	20.0	10.4
Single limb balance eyes closed	4.8	3.5	5.4	3.7
Functional Reach	26.1	7.4	25.8	7.7
Usual gait speed	0.93	0.23	0.93	0.21
Maximal gait speed	1.44	0.23	1.50	0.37
Circuit walk	67.6	13.6	64.8	13.8
Step height	0.99	0.21	0.95	0.24
Upper limb tiredness	3.1	0.9	3.1	0.9
Lower limb tiredness	3.5	0.7	3.4	0.6
Mobility tiredness	15.8	0.8	15.8	0.9
Mobility help	11.8	0.4	11.8	0.4
Personal activities of daily living help	5.1	0.5	5.2	0.6

3.9.2 Intention to Treat Analysis

An intention to treat analysis was performed in order to ascertain true effect and to report the most clinically useful results. The primary outcome for the intention to treat analysis was defined as an improvement in functional ability measured at three time periods on each of the five subscales of the Questionnaire of Functional Ability. Each outcome had been measured on four occasions and three steps of data representing change, between baseline and post-intervention assessment, between follow-up 4 month assessment and baseline assessment and between follow-up assessment at 8 months and baseline assessment, calculated for each subscale. Improvement in functional ability was rated as a favourable outcome while deterioration or no change was recorded as an unfavourable outcome. As the 41 subjects who did not complete the study were not able to record improvement in functional ability over time, each subject was rated as no improvement in functional ability for each subscale and time period. Chi square analysis was performed to ascertain group differences with 149 subjects included and results compared to the chi square result when 108 completing subjects were included. Results of the intention to treat analysis appear in Chapter 4, Section 4.1.4.

3.9.3 Statistical Methods

Multivariate analyses were used for examination of the effects of the intervention programs on physical performance and functional ability. Dependent variables were grouped for each multivariate analysis (with the exception of step height performance which was analysed using ANOVA) consisting of a 3 (group) x 4 (time) MANOVA. Table 3.10 indicates the dependent variables included in each MANOVA. Significant MANOVA results were further analysed by a 3 (group) x 4 (time) ANOVA for each dependent variable. Post hoc tests for significant between-subjects main effects and tests of contrasts for significant within subjects effects and interactions were utilised where appropriate. Further, one-way ANOVAs were conducted to ascertain group differences for each dependent variable at each assessment to assist in the determination of intervention effects. A potential limitation of this approach relates to the number of statistical procedures being performed which may increase the chance of significant findings. PAQ data were examined using a one-way ANOVA to ascertain changes over time and within groups.

As a number of dependent variables was analysed, the Bonferroni correction (Portney and Watkins, 1993) was used to adjust the alpha level for the intervention program component of the study. As there were five dependent variables (muscle performance, balance, walk, step and functional ability), alpha was divided by five and set at $p<.01$, with the exception of post hoc and contrasts tests where a less conservative alpha of $p<.05$ was accepted. For other analyses including examination of the relationship between measures of physical performance and functional ability, including those related to the development of functional limitation, the alpha level was accepted as $p<.05$.

Table 3.10 Dependent variables (including relevant abbreviations) as grouped for MANOVA

Muscle performance	Balance performance	Walk performance	Functional ability
Shoulder abduction	Single limb balance with eyes open (SLBEO)	Usual gait speed	Upper limb tiredness (ULT)
Hip abduction	Single limb balance with eyes closed (SLBEC)	Maximal gait speed	Lower limb tiredness (LLT)
Knee flexion	Functional Reach	Circuit	Mobility tiredness (MT)
Ankle dorsiflexion			Mobility help (MH) Physical activities of daily living help (PADLH)

Prior to conducting the MANOVA, the assumptions of univariate and multivariate normality, linearity, homogeneity of variance-covariance matrices, multicollinearity and singularity were tested. An examination of descriptive statistics and graphical presentation of data indicated that univariate distributions across groups were relatively normal at the first and both follow-up assessments, but not normal for most data at the post-intervention assessment for the exercise group. These data showed little variability as a result of the exercise intervention program maximising physical performance and functional ability. Since the exercise intervention was expected to have this impact, data were not transformed. Assumptions tested prior to the ANOVA procedure confirmed normality of distribution and homogeneity of variance for walk data.

Outliers were examined by calculating the Mahalanobis distance. The critical value of chi-square was used to evaluate outlying data. For muscle performance, no distances exceeded 13.28 and for balance and walk performance no values exceeded 11.35. Therefore, no outliers were identified. Within-cell scatterplots between pairs of dependent variables were generated and confirmed linearity between the dependent variables of muscle performance across assessments.

Multivariate homogeneity of variance-covariance was examined using Box's M test. This test, known to be extremely sensitive to violations of the assumption of normality (Coakes and Steed, 1999), was violated by all physical performance data at an alpha level of .001, thus, multivariate homogeneity of variance could not be assumed. It is possible that the violation of the assumption of normal distribution of data for the post-intervention assessment, outlined above, affected the results of Box's M test. Levene's test was used to test the assumption of univariate homogeneity of variance, as it is the most robust in the face of non-normality of the data. Results indicated, at an alpha level of .05, univariate homogeneity of variance for all data, with the exception of shoulder abduction performance at the post-intervention assessment and single limb balance with eyes closed at the post-intervention and follow-up 4 month assessments (which at an alpha level of .001, violated the assumption of homogeneity of variance). Testing of the assumptions of multicollinearity and singularity utilised the correlation matrix and examination of correlation values between dependent variables. No intercorrelation values above .80 were demonstrated, thus this assumption was confirmed.

The result of Mauchly's test of sphericity was significant for all variables indicating that sphericity was violated. Therefore, the Huynh-Feldt correction was used to adjust the degrees of freedom (Tabachnick and Fidell, 1989).

Scores obtained from the scales of functional ability provided ordinal data. For analyses, however the data were treated as continuous data to allow rigorous statistical analysis including MANOVA and ANOVA. Both of these statistics are robust in violation of the assumptions of continuous data (Coakes and Steed, 1999). Prior to conducting MANOVA, assumption testing was performed and as functional ability data were not continuous, these assumptions were violated. Graphical representation of the data indicated that univariate distributions across groups were relatively normal with the exceptions of Upper Limb Tiredness, Lower Limb Tiredness and Mobility Tiredness for the exercise group at the post-intervention assessment. This was an expected effect of the exercise intervention program and data were not, therefore, transformed.

As cell sizes were greater than 30 and similar between groups (exercise = 39, social = 37, control = 32) assumptions of normality and equal variances were of little concern prior to analysis using the MANOVA statistic (Coakes and Steed, 1999). MANOVA continues to be robust in the face of most violations of multivariate normality, especially when univariate normality is accepted (Coakes and Steed, 1999). It was, therefore, determined that MANOVA was an appropriate statistic for the examination of intervention effects on physical performance and functional ability data.

Further analysis was performed to ascertain the relationships between physical performance and functional ability. The Spearman's rank correlation coefficient was calculated for each appropriate combination of physical performance result and functional ability score, as functional ability data represented an ordinal scale.

The third objective of the study was to investigate the development of limitations in functional ability and to evaluate the relationship with changes in physical performance over time. Additional variables representing change in functional ability and physical performance were calculated. These derived variables measured the change in each measure of physical performance and functional ability from the baseline assessment to the final assessment. The relationship between these derived variables was calculated using the Spearman's rank correlation coefficient as functional ability change was measured on an ordinal scale.

The final objective related to self-reported falls throughout the study period. Self-reported falls per group were tallied and rates calculated.

3.10 Summary

The study aimed to provide data on the effect of two forms of intervention, increased levels of exercise or social activity, on the physical performance and functional ability of elderly subjects and to examine the relationship between these two domains. A randomised, single blind clinical trial with repeated measures was designed. Community-living subjects, aged 75 years or more, who were generally healthy but not active, either physically or socially, were recruited. One hundred and eight subjects, from a total of 149 who were originally accepted, completed the study. Subjects underwent a maximum of 16 weeks of intervention (exercise, social or no intervention) after completing baseline assessments. A further three assessments, immediately post-intervention, four months later and again at eight months later, were also held. At each assessment, data were collected on aspects of physical performance and functional ability, as well as self-reports of falls.

Two approaches to the management of missing data, from the 41 subjects who did not complete the study, were performed. Firstly, data from subjects who completed the study were compared with data collected from those subjects who did not complete the study. No significant differences were evident, either in loss in relation to intervention group, or on a range of variables measured at baseline. It was concluded that there was no difference between these two groups of subjects. Non-completing subject data were, therefore, excluded from ensuing multivariate and correlational analyses. The second approach utilised an intention to treat analysis, with a primary outcome of improved functional ability, in order to determine real intervention effects and report on the clinical usefulness of the intervention programs.

Multivariate analyses were used to examine intervention effects and where results were significant, progressed to univariate analyses. The relationship between physical performance and functional ability at each assessment was examined, as was the relationship between changes over time in these two domains. Subject reports of falls data were collected and tallied within each group from baseline to study completion.

CHAPTER FOUR
RESULTS

The study aimed to investigate the effect of two intervention programs, the first based on increased levels of exercise and the second based on increased levels of social activity, on physical performance and functional ability in an elderly community dwelling cohort aged over 75 years. The study also aimed to identify the relationship between changes in physical performance and changes in functional ability. Further, the falls rate of the study sample population was recorded in order to enable comparisons with the rates from a similarly aged group published in the literature. A randomised, single blind, controlled study was conducted with subjects assigned to one of three groups for a maximum of 16 weeks of intervention consisting of an exercise intervention, a social intervention or a control group. Assessments were held at baseline (prior to the commencement of intervention), immediately post-intervention and at two follow-up periods four months apart i.e. at 4 months and again at 8 months following the cessation of intervention.

The effect of the intervention programs on measures of physical performance and functional ability was analysed using multivariate and univariate analysis of variance. The relationship between change in physical performance and functional ability over time was examined by correlational statistics. Self-reported falls data collected at baseline were compared to final assessment data by non-parametric statistics and compared with rates reported in the literature.

Results for each dependent group will be presented, with physical performance (muscle performance, balance, gait and step height performance) followed by functional ability (Upper Limb Tiredness, Lower Limb Tiredness, Mobility Tiredness, Mobility Help, Physical Activities of Daily Living Help). These results will describe multivariate analyses of complete data and followed by an intention to treat analysis. The relationship between physical performance and functional ability will be clarified and the ability of changes in physical performance to predict changes in functional ability described. Finally, self-reported falls data will be presented.

4.1 The Intervention Program

The intervention programs provided 16 weeks (32 hours) of either an exercise intervention program, based on increased levels of physical activity, or 13 weeks (26 hours) of a social intervention program, based on increased levels of social activity.

4.1.1 Physical Activity Questionnaire

The Physical Activity Questionnaire (PAQ) was used to measure the subjects' levels of physical activity throughout the study. Of particular interest, was the comparison among groups in relation to physical activity and specifically whether the exercise intervention increased the levels of physical activity of participants. Further, it was anticipated that exercise subjects would return to their pre-intervention physical activity levels following completion of the exercise program. PAQ data was collected for all subjects at each assessment. Descriptive statistics are presented in Appendix 9, Table 5.1.

The basic assumptions related to physical activity levels during the study were two-fold. Firstly, that the exercise intervention would significantly increase physical activity levels among participants, while the social intervention program would not affect physical activity levels. Secondly, that in the absence of continuing exercise post-intervention, exercise group subjects would return to former physical activity levels. Thus, differences among groups were expected at the post-intervention assessment, but not at either of the follow-up assessments, at four and eight months later. Data collected from the Physical Activity Questionnaire (PAQ) were examined to ascertain physical activity levels of all participants throughout the study.

Scores obtained from Physical Activity Questionnaire provided ordinal data. For analyses, however the data were treated as continuous data to allow rigorous statistical analysis including ANOVA. The ANOVA statistic is robust in violation of the assumptions of continuous data (Coakes and Steed, 1999). Assumptions tested before the ANOVA procedure included normality of distribution and homogeneity of variance. As data were not continuous, these assumptions were violated. Graphical representation of the data indicated that univariate distributions across groups were relatively normal, with the exceptions of PAQ for the exercise group at the post-intervention assessment. This was an expected effect of the exercise intervention program and data were not, therefore, transformed. The group effect was examined using a one-way ANOVA with data collected at each assessment. Results of the analysis are summarised in Table 4.1.

The ANOVA result showed that there was no significant group difference at the baseline assessment, indicating that there was no difference among groups on levels of physical activity at the start of the study. A significant group effect was evident at the post-intervention assessment. Post hoc analysis, using the Tukey HSD test, indicated significant differences ($p<.05$) between the exercise and social groups and between the exercise and control groups but not between the social and control groups. The mean PAQ score for exercise subjects was 3.11 compared with 2.08 for social intervention participants and 2.50 for control subjects. Exercise subjects had significantly higher physical activity levels post-intervention than subjects from the other two groups. This result confirms that the exercise intervention increased the usual amount of physical activity that subjects completed. Additionally, it confirms that the social intervention program did not influence levels of physical activity.

At the two follow-up assessments, there was again no significant group effect on PAQ scores. At four months post-intervention, exercise intervention subjects had decreased their levels of physical activity to be similar to those recorded by subjects from the other two groups. Thus, there was no difference in levels of physical activity before the intervention programs, nor during the study's follow-up period. The exercise intervention significantly increased the

Table 4.1 Summary results of between groups ANOVA for PAQ data for each assessment

	df	*F*	*p*
Baseline Assessment	2,105	1.585	.210
Post-intervention Assessment	2,105	7.812	.001*
Follow-up 4 months Assessment	2,105	1.215	.301
Follow-up 8 months Assessment	2,105	2.712	.071

*$p<.01$

levels of physical activity reported by participants at the end of the intervention period. The validity of the exercise program as an intervention providing increased levels of exercise/physical activity was, therefore, confirmed. The social program did not influence physical activity levels confirmed by the lack of a significant group difference between the social and control groups at the post-intervention assessment.

4.1.2 Physical Performance

Domains of physical performance of interest were muscle performance, balance, walk and step height performance. With the exception of step height performance, each domain consisted of multiple variables. Each variable was measured at four points during the study. Muscle performance included four independent variables of specific muscle group performance. Balance and walk performance each consisted of three individual dependent variables. Results of multivariate analyses determined the need for further univariate analyses. Step height performance data underwent separate univariate analysis.

Two hypotheses proposed a relationship between the intervention programs and physical performance parameters (muscle performance, balance, gait and step). The first suggested that participation in the exercise intervention program would be associated with improved physical performance. The third hypothesis proposed that the social intervention program would have no effect on physical performance. The relationship between the intervention programs and each variable, or group of variables, which indicates whether the hypotheses will be accepted or rejected, will be described.

4.1.2.1 Muscle Performance

The domain of muscle performance included data for shoulder abduction, hip abduction, knee flexion and ankle dorsiflexion performance collected over the four assessments of the study. Descriptive data for muscle performance are presented in Table 4.2. Figures 4.1 through 4.4 illustrate the outcome of each muscle performance variable by group throughout the study period.

The MANOVA result demonstrated a significant interaction between group and time, a significant main effect for group and a significant main effect for time. The significant interaction indicated that the three groups responded differently from one another over time. Results of the MANOVA are summarised in Table 4.3. Data analysis proceeded to an examination of the four dependent variables of shoulder abduction, hip abduction, knee flexion and ankle dorsiflexion. Univariate analyses, utilising a 3 (group) x 4 (time) ANOVA, demonstrated a significant time by group interaction for each variable as well as a significant main effect for time for each variable. ANOVA results are summarised in Table 4.4.

The interaction between time and group demonstrated significance for each variable and was further examined using within-subjects contrasts. For shoulder abduction the interaction was significant between baseline and post-intervention assessments and also between the post-intervention and follow-up at 4 months, but not between follow-up assessments at 4 and 8 months. The results are summarised in Table 4.5.

Figure 4.1 illustrates these interactions for shoulder abduction performance clearly. At the baseline assessment, the ANOVA result indicated that there was no difference between groups. The exercise group demonstrated an increase in performance between the baseline assessment and the post-intervention assessment, i.e. the intervention period, whereas the social and control groups demonstrated little or no change over this period. This interaction was significant. There was a significant main effect for group on

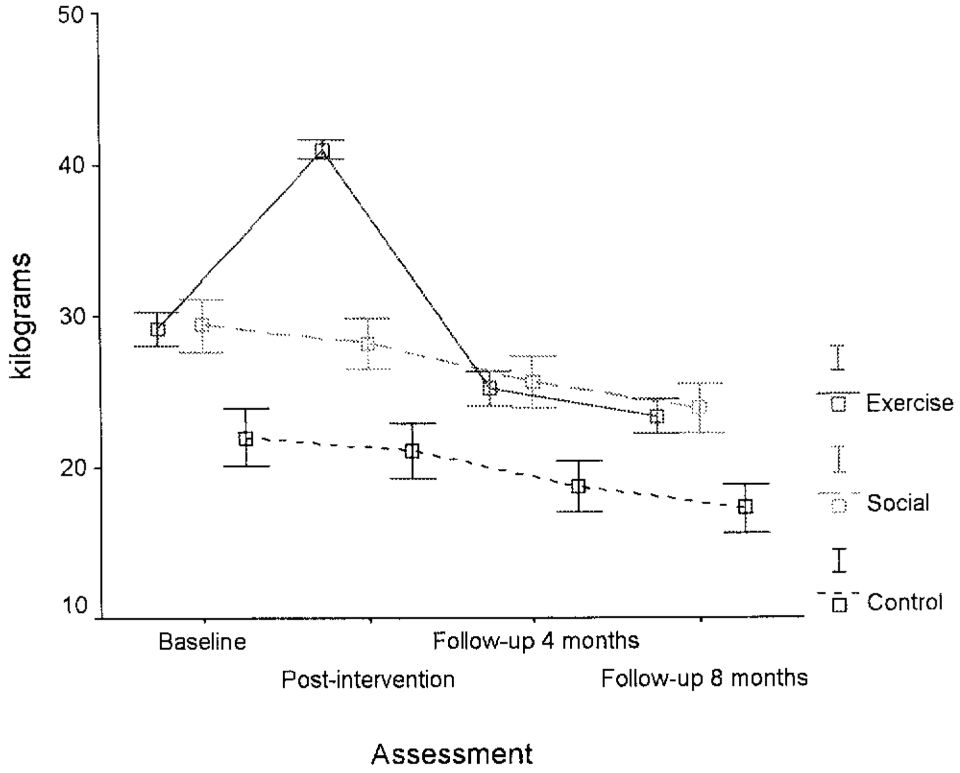

Figure 4.1 Shoulder abduction muscle performance (mean±SEM) by group throughout the study period

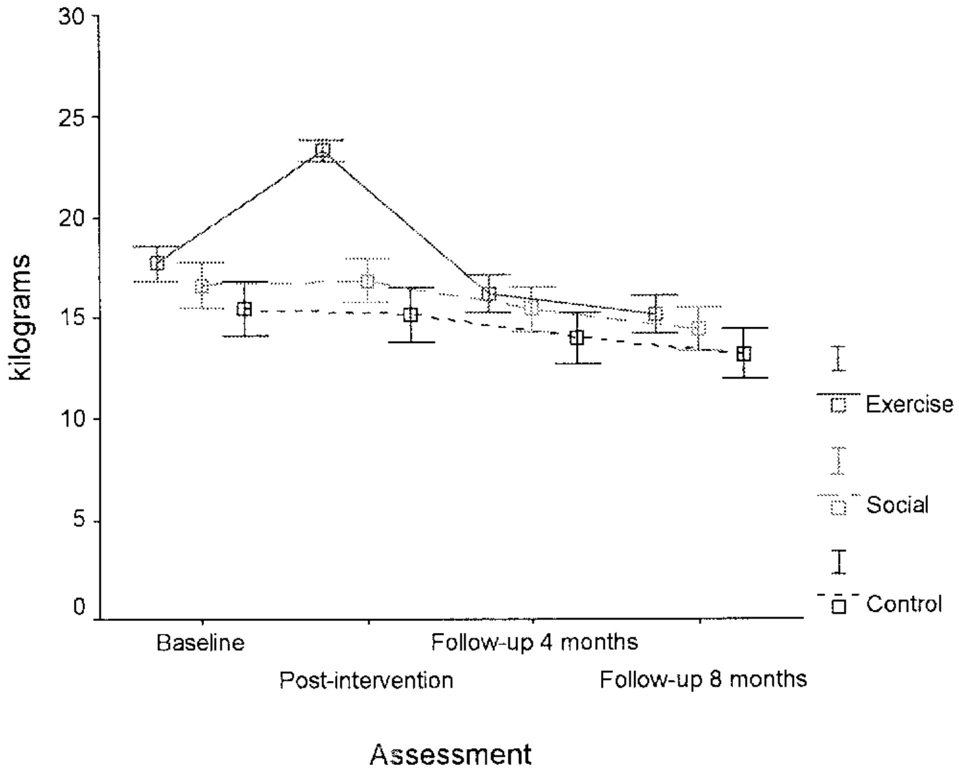

Figure 4.2 Hip abduction muscle performance (mean±SEM) by group throughout the study period

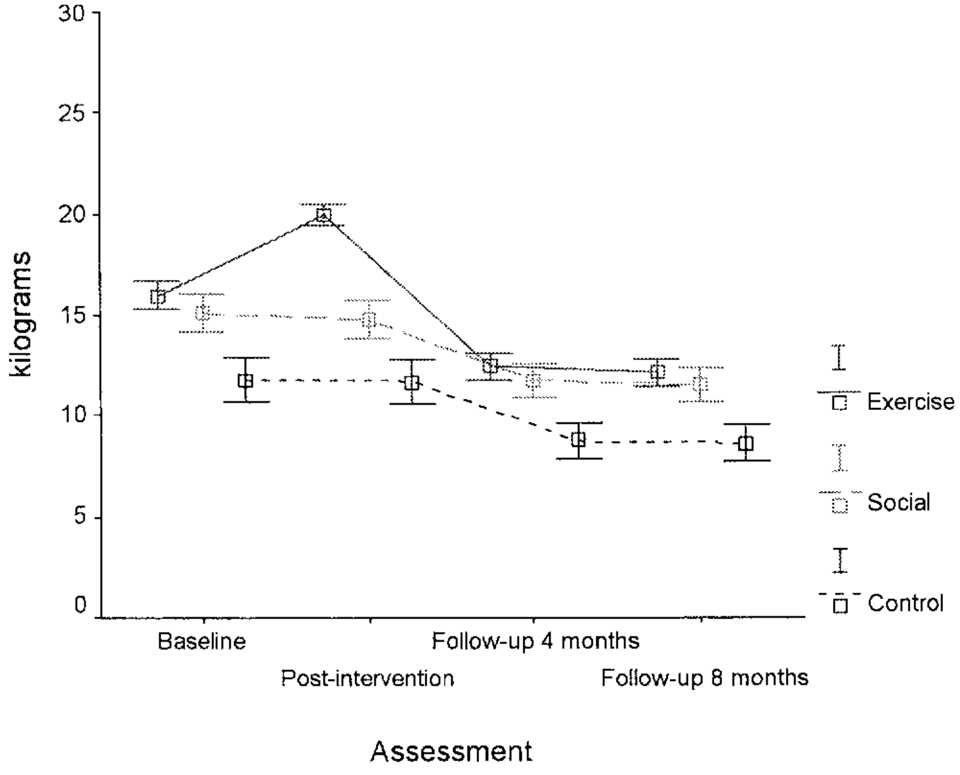

Figure 4.3 Knee flexion muscle performance (mean±SEM) by group throughout the study period

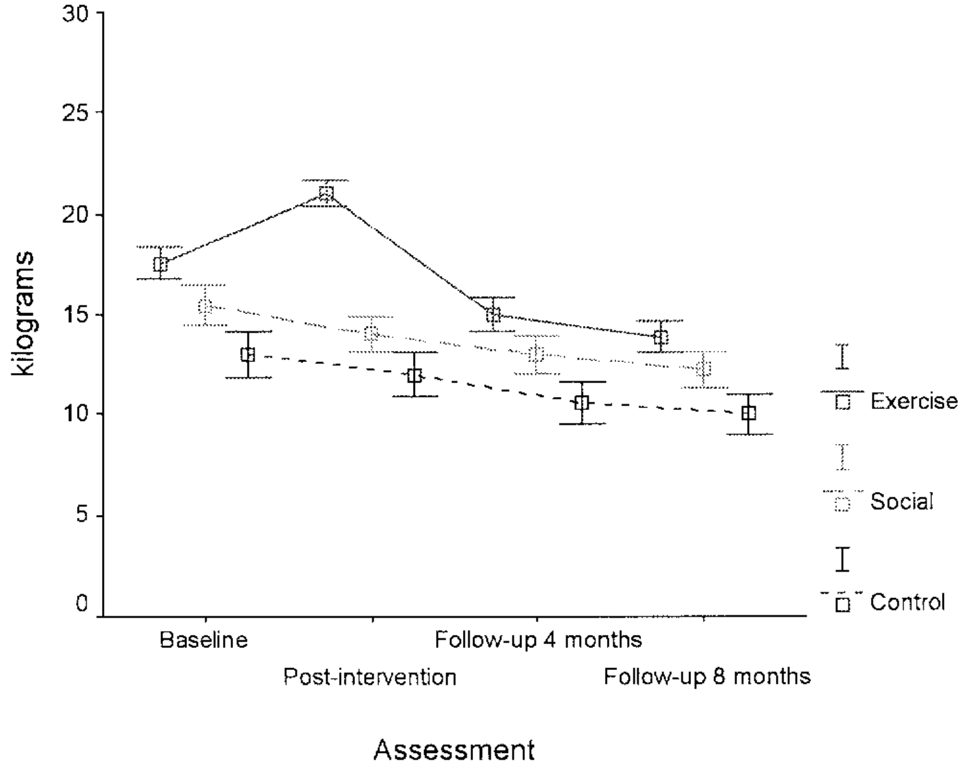

Figure 4.4 Ankle dorsiflexion muscle performance (mean±SEM) by group throughout the study period

Table 4.2 Descriptive data (mean, standard deviation, 95% CI) in kilograms for muscle performance

	Exercise Group		**Social Group**		**Control Group**	
	Mean (sd)	95% CI	Mean (sd)	95% CI	Mean (sd)	95% CI
Shoulder abduction						
Baseline	29.1 (7.0)	26.8-31.4	31.0 (8.8)	28.0-33.9	26.8 (6.0)	24.7-29.0
Post-intvn	41.0 (3.9)	39.8-42.3	29.7 (8.4)	26.9-32.5	25.7 (5.8)	23.7-25.4
F-up 4	25.1 (7.0)	22.9-27.4	27.0 (8.8)	24.1-29.9	22.8 (6.0)	20.7-25.0
F-up 8	23.3 (7.0)	21.1-25.6	25.2 (8.8)	22.3-28.1	21.0 (6.0)	18.9-23.2
Hip abduction						
Baseline	17.7 (5.6)	15.9-19.6	17.5 (6.1)	15.5-19.6	18.8 (5.2)	16.9-20.6
Post-intvn	23.4 (3.4)	22.3-24.5	17.7 (5.8)	15.8-19.7	18.4 (5.2)	16.6-20.3
F-up 4	16.2 (5.7)	14.3-18.0	16.2 (5.8)	14.3-18.2	17.0 (5.1)	15.2-18.9
F-up 8	15.1 (5.8)	13.2-17.0	15.1 (5.8)	13.2-17.0	16.0 (5.1)	14.2-17.8
Knee flexion						
Baseline	16.0 (4.4)	14.5-17.4	15.9 (4.9)	14.3-17.5	14.3 (4.8)	12.6-16.1
Post-intvn	20.0 (3.4)	18.9-21.1	15.6 (4.9)	14.0-17.2	14.2 (4.8)	12.5-16.0
F-up 4	12.4 (4.4)	11.0-13.9	12.4 (4.7)	10.8-13.9	10.6 (4.5)	9.0-12.2
F-up 8	12.1 (4.3)	10.7-13.5	12.1 (4.6)	10.6-13.7	10.5 (4.5)	8.8-12.1
Ankle dorsiflexion						
Baseline	17.5 (4.9)	15.9-19.1	16.3 (4.8)	14.7-17.9	15.8 (4.4)	14.3-17.4
Post-intvn	21.0 (4.1)	19.7-22.3	14.8 (4.8)	13.2-16.4	14.6 (4.5)	13.0-16.2
F-up 4	15.0 (5.2)	13.4-16.7	13.7 (5.0)	12.0-15.3	12.9 (4.6)	11.2-14.5
F-up 8	13.9 (4.8)	12.3-15.4	12.9 (4.8)	11.3-14.5	12.2 (4.4)	10.6-13.8

Table 4.3 Summary result of MANOVA for muscle performance

	df	*F*	*p*
Time	12,94	60.647	<.001*
Group	8,206	2.809	.006*
Time*Group	24,1260	15.844	<.001*

*p<.01

Table 4.4 Summary results of ANOVA for the four dependent variables of muscle performance

	df	*F*	*p*
Shoulder abduction			
Time	1.02,107.02	1193.833	<.001*
Group	2,105	5.693	.004*
Time*Group	2.04,107.02	365.657	<.001*
Hip abduction			
Time	1.54,161.56	266.243	<.001*
Group	2,105	0.717	.491
Time*Group	3.08,161.56	68.321	<.001*
Knee flexion			
Time	1.63,170.93	1094.816	<.001*
Group	2,105	3.249	.043
Time*Group	3.26,170.93	88.168	<.001*
Dorsiflexion			
Time	2.90,304.66	309.077	<.001*
Group	2,105	4.406	.015
Time*Group	5.80,304.66	58.190	<.001*

*p<.01

Table 4.5 Summary results of tests of within-subjects contrasts for the four dependent variables of muscle performance

		df	*F*	*p*
Shoulder abduction				
Time	Baseline vs. Post-intvn	1,105	188.719	<.001*
	Post-intvn vs. F-up 4	1,105	948.968	<.001*
	F-up 4 vs. F-up 8	1,105	2.4E+09	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	365.657	<.001*
	Post-intvn vs. F-up 4	2,105	365.662	<.001*
	F-up 4 vs. F-up 8	2,105	1.312	.274
Hip abduction				
Time	Baseline vs. Post-intvn	1,105	76.821	<.001*
	Post-intvn vs. F-up 4	1,105	239.817	<.001*
	F-up 4 vs. F-up 8	1,105	265.266	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	85.559	<.001*
	Post-intvn vs. F-up 4	2,105	80.679	<.001*
	F-up 4 vs. F-up 8	2,105	0.134	.874
Knee flexion				
Time	Baseline vs. Post-intvn	1,105	80.871	<.001*
	Post-intvn vs. F-up 4	1,105	1144.031	<.001*
	F-up 4 vs. F-up 8	1,105	16.071	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	117.389	<.001*
	Post-intvn vs. F-up 4	2,105	100.608	<.001*
	F-up 4 vs. F-up 8	2,105	0.649	.525
Dorsiflexion				
Time	Baseline vs. Post-intvn	1,105	1.804	.182
	Post-intvn vs. F-up 4	1,105	349.700	<.001*
	F-up 4 vs. F-up 8	1,105	39.893	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	99.276	<.001*
	Post-intvn vs. F-up 4	2,105	101.770	<.001*
	F-up 4 vs. F-up 8	2,105	1.168	.315

*p<.01

Table 4.6 Summary results of between groups ANOVA for significant main effects for shoulder abduction muscle performance

	df	*F*	*p*
Baseline	2,107	57.758	.072
Post-intvn	2,107	57.785	<.001*
F-up 4	2,107	2.704	.072
F-up 8	2,107	2.918	.072

*p<.01

shoulder performance at the post-intervention assessment demonstrated by the one-way ANOVA. Post hoc analysis, using the Tukey HSD test, indicated that all groups were significantly different from each other at this assessment ($p<.05$). The mean shoulder abduction performance was 41.0(±3.9), 29.7(±8.4) and 25.7(±5.8) kg for the exercise, social and control groups respectively.

The exercise subjects then decreased in performance between the post-intervention assessment and the follow-up 4 month assessment (the four month period after cessation of the intervention). This interaction was also significant. There was no significant interaction between follow-up assessments at 4 and 8 months as all three groups showed a similar slight decline. No group difference was demonstrated by ANOVA at either follow-up assessment.

These results indicated that the exercise intervention program resulted in improved shoulder abduction performance and that cessation of the program resulted in loss of the exercise-induced gains. The social intervention program did not affect shoulder abduction performance as there was no difference between performance of the social and control groups over time.

A similar result from tests of within-subjects contrasts was demonstrated for hip abduction performance. The interaction was significant between baseline and post-intervention assessments and also between the post-intervention and follow-up at 4 months, but not between follow-up assessments at 4 and 8 months. Results are summarised in Table 4.6. Figure 4.2 illustrates group performance over time.

At the baseline assessment, the ANOVA result indicated no significant group effect. Between the baseline and post-intervention assessments the exercise subjects demonstrated an increase in muscle performance, whereas over this same period, the social and control groups did not show any change. At the post-intervention assessment, there was a significant group difference that was further analysed by the post hoc Tukey HSD test. Results indicated a significant group difference between the exercise group and the social group and the exercise group and the control group, but not between the social and control group. Hip abduction muscle performance values recorded at the post-intervention assessment were 23.4(±2.4), 17.7(±5.8) and 18.4(±5.2) kg for the exercise, social and control groups respectively.

Between the post-intervention and follow-up assessment at 4 months, the exercise group demonstrated a decline in performance, so that at the follow-up 4 month assessment there was again no difference between groups. All groups showed a similar and small decline between the follow-up assessments at 4 and 8 months. At the final assessment there was no group difference in performance of hip abduction.

These results confirm the impact of the exercise intervention in improving hip abduction muscle performance. Following cessation of the exercise program, exercise gains were lost and no longer evident four months later. The social intervention program did not affect hip performance, as there was no difference between performance of the social and control groups over time.

The significant interaction for knee flexion is illustrated in Figure 4.3. The results of within-subjects tests of contrast indicated a result similar to those for shoulder and hip abduction, described above. Results of contrasts are summarised in Table 4.6. There were no group differences evident at baseline. The interaction between baseline and post-intervention assessments was significant. The exercise group demonstrated improved knee flexion performance over this period. The significant ANOVA group result at the post-intervention assessment was further analysed using the Tukey HSD, which indicated that the exercise group was significantly different from both the other two groups. Recorded values for knee flexion performance were 20.0(±3.4), 15.6(±4.9) and 14.2(±4.8) kg for the exercise, social and control groups respectively.

The interaction between post-intervention and follow-up at 4 months was also significant. The interaction was a result of the different response over time of the exercise group. Exercise group subjects declined over this period. There was no group effect at this assessment evident from ANOVA. The interaction between follow-up assessments at 4 and 8 months was not significant and neither was the group effect at the final assessment.

These results indicated that the exercise intervention program resulted in improved knee flexion performance and that cessation of the program resulted in loss of the exercise-induced gains. The social intervention program did not affect knee flexion performance, as there was no difference between performance of the social and control groups over time. A significant interaction was also evident from the 3x4 ANOVA for dorsiflexion and is illustrated in Figure 4.4. Further evaluation was performed using within-subjects contrasts and results are summarised in Table 4.4. There was a significant interaction between baseline and post-intervention assessments and also between the post-intervention and follow-up at 4 months. There was no interaction between follow-up assessments at 4 and 8 months. Significant group differences were evident only at the post-intervention assessment and the exercise group differed from the other two groups. Data for dorsiflexion indicated post-intervention values of 21.0(±4.1), 14.8(±4.8) and 14.6(±4.5) kg for the exercise, social and control groups respectively.

Again, this result echoes those of the other three variables related to muscle performance and confirms the effectiveness of the exercise intervention program in improving dorsiflexion performance. This improvement was not, however, maintained following cessation of the intervention and a detraining effect was observed. The social program did not affect dorsiflexion performance.

Further inspection of the ANOVA result, summarised in Table 4.5, indicated a main effect for time for each variable of muscle performance and for group for shoulder abduction performance. Within-subjects contrasts confirmed significant changes over time for each variable. However, it is often not possible to interpret significant main effects in a 2-way ANOVA when the interaction is significant. These main effects may be due to the pattern observed at the post-intervention assessment and are also overridden by the significant interactions demonstrated for each dependent variable of muscle performance, which have been discussed in detail in this section. Therefore, the main effects are of little interest.

Summary

The exercise intervention program was successful in improving muscle performance of shoulder abduction, hip abduction, knee flexion and dorsiflexion, evident from the significant interactions between baseline and post-intervention assessments and by significant group differences in performance at the post-intervention assessment for all muscle performance variables. The intervention gains were lost following cessation of the intervention and significant interactions were evident for all variables between post-intervention and the first follow-up assessment at 4 months, indicating the different performance (i.e. loss of exercise induced gains) of exercise group subjects over this period. There were no further significant interactions or group differences in the final phase of the study. The social intervention program did not affect muscle performance.

The first hypothesis stated that participation in the exercise intervention program would result in improved muscle performance and can be accepted for all measures of muscle performance. The third hypothesis proposed that participation in the social intervention program would not influence muscle performance. The third hypothesis can also be accepted for all variables of muscle performance.

This result indicates that gains in muscle performance were not maintained following cessation of the exercise intervention program. Significant detraining effects were noted in the post-intervention period. Subjects who completed, then ceased, the exercise intervention program did not demonstrate any difference at follow-up assessments 4 and 8 months later when compared with subjects who had not participated in exercise. Exercise intervention provided significant muscle performance benefits only during participation with no long term benefits following cessation of the program.

4.1.2.2 Balance Performance

The domain of balance performance consisted of data from three dependent variables; single limb balance with eyes open (SLBEO), single limb balance with eyes closed (SLBEC) and Functional Reach. Figures 4.5-4.7 illustrate group performance for each variable over time. Descriptive data for balance performance are presented in Table 4.7.

The MANOVA result demonstrated a significant interaction between time and group, a significant main effect for group and a significant effect for time. The significant interaction indicated that the groups responded differently from one another over time. Results of the MANOVA are summarised in Table 4.8.

An examination of each of the three dependent variables of balance, SLBEO, SLBEC and Functional Reach demonstrated a significant time by group interaction and a significant main effect for time for each dependent variable and a significant main effect for group on SLBEC. ANOVA results are summarised in Table 4.9. The significant interaction of time by group for each balance variable was further examined using within-subjects tests of contrasts. For SLBEO, the interaction was significant between baseline and post-intervention assessments, but not between post-intervention and follow-up at 4 months or between follow-up assessments at 4 and 8 months. The results are summarised in Table 4.10.

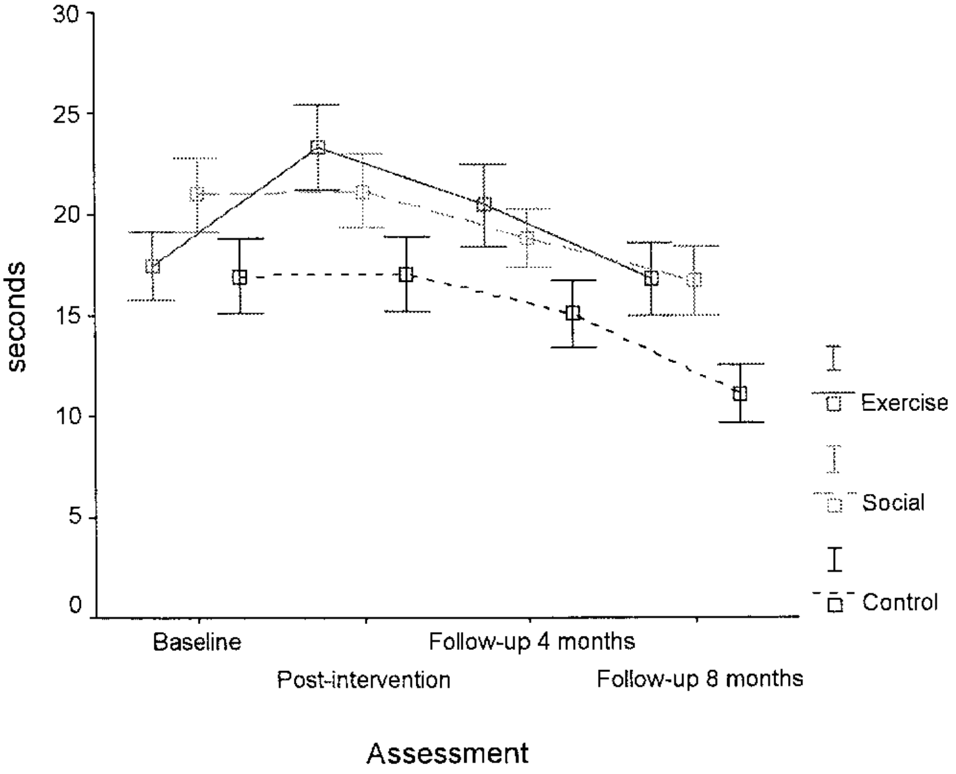

Figure 4.5 Single limb balance with eyes open (SLBEO) performance (mean±SEM) by group throughout the study period

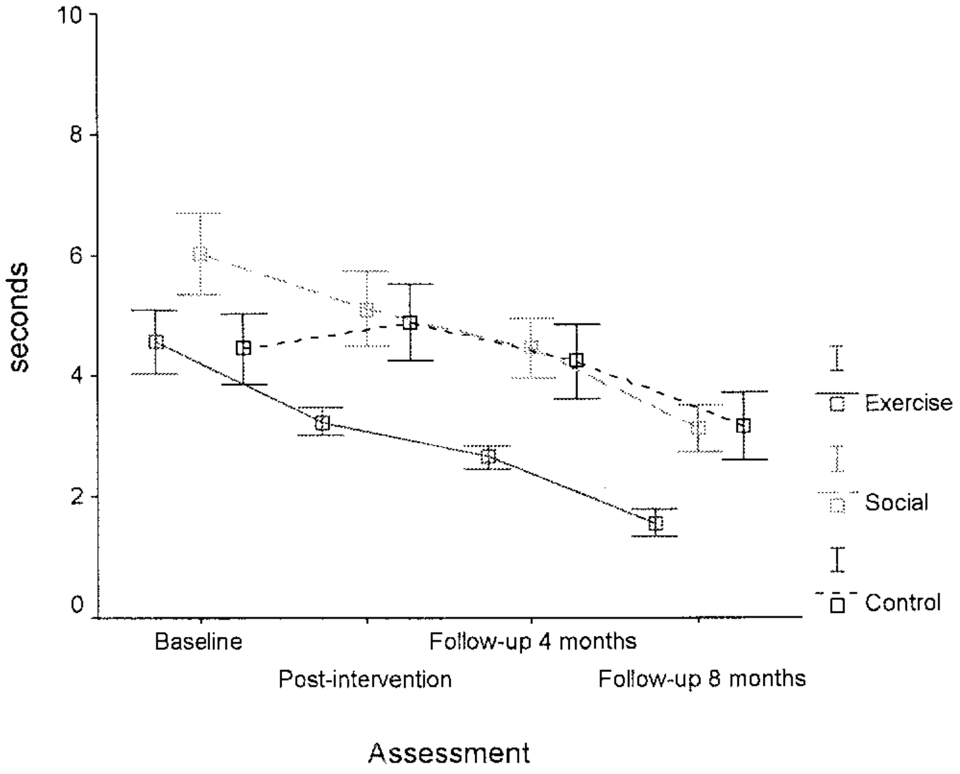

Figure 4.6 Single limb balance with eyes closed (SLBEC) performance (mean±SEM) by group throughout the study period

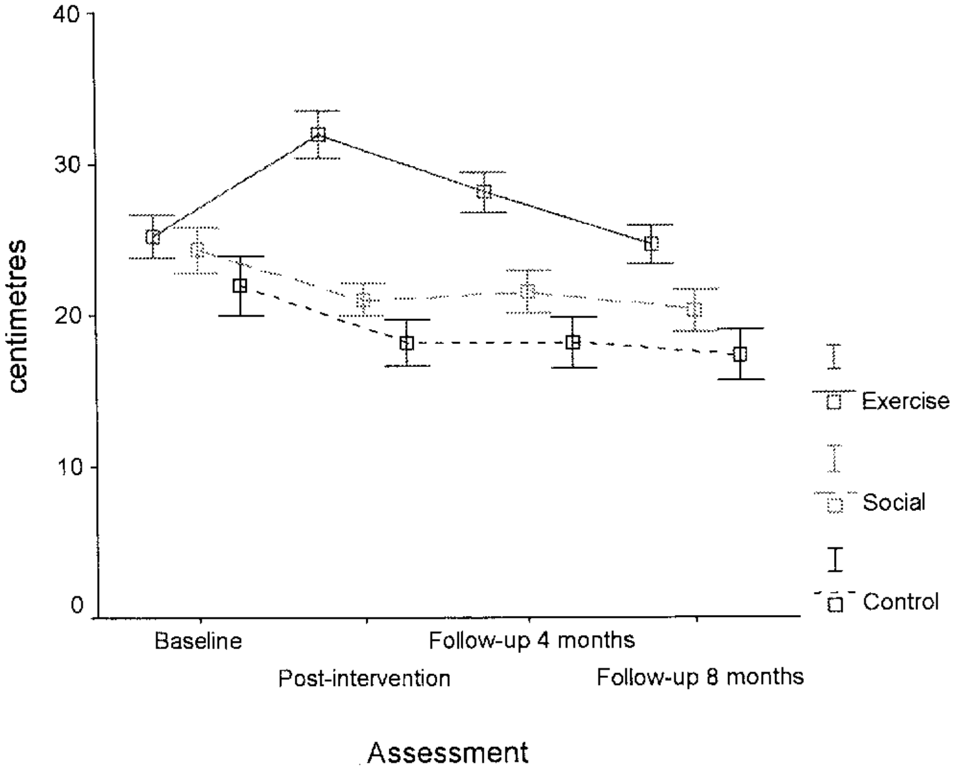

Figure 4.7 Functional Reach performance by group (mean±SEM) throughout the study period

Table 4.7 Descriptive data (mean, standard deviation, 95% CI) for balance performance

	Exercise Mean (sd)	**Group** 95% CI	**Social** Mean (sd)	**Group** 95% CI	**Control** Mean (sd)	**Group** 95% CI
SLBEO (seconds)						
Baseline	17.4 (10.4)	14.0-20.8	22.1 (10.8)	18.5-25.7	20.6 (9.4)	17.3-24.0
Post-intvn	23.4 (13.2)	19.1-27.7	22.3 (10.8)	18.7-25.9	20.8 (9.0)	17.5-24.0
F-up 4	20.5 (13.0)	16.2-24.7	19.8 (8.1)	17.1-22.5	18.3 (8.4)	15.3-21.4
F-up 8	16.8 (11.0)	13.2-20.4	17.6 (9.8)	14.3-20.9	13.6 (7.8)	10.8-16.4
SLBEC (seconds)						
Baseline	4.6 (3.4)	3.5-5.7	6.3 (4.1)	5.0-7.7	5.4 (3.4)	4.2-6.6
Post-intvn	3.3 (1.5)	2.8-3.7	5.4 (3.7)	4.2-6.6	6.0 (3.6)	4.7-7.3
F-up 4	2.7 (1.2)	2.3-3.1	4.7 (3.0)	3.7-5.7	5.2 (3.5)	3.9-6.4
F-up 8	1.5 (1.4)	1.1-2.0	3.3 (2.3)	2.5-4.1	3.8 (3.5)	2.6-5.1
Functional Reach (cm)						
Baseline	25.2 (8.4)	22.5-27.9	25.6 (7.4)	23.2-28.1	26.8 (7.1)	24.2-29.4
Post-intvn	32.0 (9.7)	28.9-35.2	22.2 (4.4)	20.6-23.6	22.2 (4.8)	20.4-23.9
F-up 4	28.1 (8.3)	25.5-30.8	22.6 (7.4)	20.2-25.1	22.2 (7.2)	19.6-24.8
F-up 8	24.6 (8.2)	22.0-27.3	21.4 (7.6)	18.9-24.0	21.1 (7.1)	18.5-23.6

Table 4.8 Summary result of MANOVA for balance performance

	df	*F*	*p*
Time	9,945	27.797	<.001*
Group	6,208	3.484	.003*
Time*Group	18,945	15.297	<.001*

*p<.01

Table 4.9 Summary results of ANOVA for the three dependent variables of balance performance

	df	*F*	*p*
SLBEO			
Time	2.00,210.26	26.416	<.001*
Group	2,105	0.442	.644
Time*Group	4.00,210.26	4.002	.004*
SLBEC			
Time	2.14,225.26	64.032	<.001*
Group	2,105	6.785	.002*
Time*Group	4.29,225.26	3.614	.006*
Functional Reach			
Time	1.092,114.68	76.209	<.001*
Group	2,105	4.690	.011
Time*Group	2.18,114.68	76.430	<.001*

*p<.01

Table 4.10 Summary results of tests of within-subjects contrasts for the three dependent variables of balance performance

		df	*F*	*p*
SLBEO				
Time	Baseline vs. Post-intvn	1,105	6.743	.011
	Post-intvn vs. F-up 4	1,105	22.206	<.001*
	F-up 4 vs. F-up 8	1,105	52.416	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	6.083	.003*
	Post-intvn vs. F-up 4	2,105	0.082	.922
	F-up 4 vs. F-up 8	2,105	2.162	.120
SLBEC				
Time	Baseline vs. Post-intvn	1,105	6.016	.016
	Post-intvn vs. F-up 4	1,105	33.128	<.001*
	F-up 4 vs. F-up 8	1,105	94.543	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	5.463	.006*
	Post-intvn vs. F-up 4	2,105	0.251	.779
	F-up 4 vs. F-up 8	2,105	0.413	.663
Functional Reach				
Time	Baseline vs. Post-intvn	1,105	1.584	.211
	Post-intvn vs. F-up 4	1,105	10.185	.002*
	F-up 4 vs. F-up 8	1,105	1442.958	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	114.628	<.001*
	Post-intvn vs. F-up 4	2,105	16.474	<.001*
	F-up 4 vs. F-up 8	2,105	253.402	<.001*

$^*p<.01$

Table 4.11 Summary results of between groups ANOVA for significant main effects for SLBEC performance

	df	*F*	*p*
SLBEC			
Baseline	2,107	2.256	.110
Post-intvn	2,107	8.104	.001*
F-up 4	2,107	8.985	<.001*
F-up 8	2,107	8.825	<.001*

$^*p<.01$

Figure 4.5 illustrates the time by group interaction for SLBEO performance. ANOVA results indicated no group differences at baseline. The interaction between the baseline and post-intervention assessment was significant. During this time the exercise subjects demonstrated improved SLBEO performance while the other two groups showed little change. However, the group effect for SLBEO performance demonstrated by the ANOVA for data collected at the post-intervention assessment was not significant. Figure 4.5 illustrates that during the intervention period the mean SLBEO performance of exercise group subjects increased while the other two groups showed little change. This improvement was not reflected in significantly different SLBEO scores among groups at either the baseline or post-intervention assessment.

There were no further significant interactions i.e. between the post-intervention and follow-up assessment at 4 months or between follow-up at 4 months and follow-up at 8 months. All three groups showed similar declines in SLBEO performance following the post-intervention assessment. No significant group effects were demonstrated by the ANOVA for SLBEO at any assessment. These results indicate that the intervention programs had no significant effect on SLBEO performance over the study period.

The within-subjects contrast results for SLBEC indicated a similar result with a significant interaction evident between the post-intervention assessment and the follow-up assessment at 4 months. There was a significant interaction for time by group on SLBEC performance between baseline and post-intervention assessments, but not between post-intervention and follow-up at 4 months, nor between follow-up at 4 and 8 months. Table 4.10 summarises the results.

Figure 4.6 illustrates group performance of SLBEC over the study period. There was no main effect for group evident from ANOVA at the baseline assessment indicating no differences among group performance. Between the baseline and post-intervention assessment (the intervention period), the exercise group demonstrated a decline in performance of SLBEC similar to that demonstrated by the social group, whereas the control group exhibited a slight improvement over this period. This interaction was significant. The ANOVA indicated a significant main effect for group at the post-intervention assessment, which was further analysed using the Tukey HSD test. The exercise group was significantly different from the other two groups at this assessment. Exercise group subjects performed significantly more poorly on SLBEC at the post-intervention assessment than subjects from either of the other two groups. The exercise group performance was 3.3(±1.5) seconds compared with 5.4(±3.7) and 6.0(±3.6) seconds for the social and control groups respectively.

There were no further significant interactions for SLBEC performance. All groups demonstrated similar declines between the post-intervention and follow-up 4 month assessment and again between the follow-up assessments at 4 months and 8 months. The ANOVA result however indicated a significant main effect for group at both of the follow-up assessments. Post hoc testing indicated that the exercise group subjects continued to be significantly different from the other two groups and at each assessment performed more poorly on SLBEC than subjects from either the social or control groups. At the assessment held 4 months post-intervention, exercise subjects demonstrated a mean SLBEC performance of 2.7(±1.2) seconds compared 4.7(±3.0) seconds and 5.2 (±3.5) seconds demonstrated by the social and control groups respectively. At the final assessment, eight months following completion of the intervention programs, the mean values for each group were 1.5(±1.4), 3.3(±2.3) and 3.8(±3.5) seconds respectively.

These results indicate that the exercise and social intervention programs were not effective in improving performance on SLBEC. In fact, results indicate that participation compared with no intervention had a detrimental effect on SLBEC performance during the intervention period. Performance of SLBEC declined similarly among groups following cessation of the intervention programs, although exercise subjects performed significantly more poorly on SLBEC than other subjects at each assessment following completion of the intervention program.

Within-subjects contrasts for Functional Reach data indicated that the group by time interaction was significant between all assessments i.e. between baseline and post-intervention assessments, between post-intervention and follow-up 4-month assessments and between follow-up assessment at 4 and 8 months. Table 4.10 presents the results of the analysis.

Figure 4.7 illustrates the interaction. There was no difference in Functional Reach performance between groups at the baseline assessment. Between the baseline and post-intervention assessments (the intervention period), the exercise group demonstrated an improvement in Functional Reach performance. Over this same period, the social and control groups showed a similar pattern of slight decline. This interaction was significant. There was a significant group effect at post-intervention demonstrated by ANOVA that was further analysed using the Tukey HSD test as post hoc analysis. The exercise group was significantly different from the other two groups. The data for the exercise group indicated a mean of 32.0(±9.7) cm compared with 22.2(±4.4) and 22.2(±4.8) cm for the social and control groups respectively.

Between the post-intervention and follow-up assessment at 4 months, the exercise group demonstrated a decline in performance. The social and control groups demonstrated a slight, but similar decline over this period. This interaction was significant as was the group effect at the follow-up 4 month assessment. The exercise group was again significantly different from the other two groups with values of 28.1(±8.3), 22.6(±7.4) and 22.2(±7.2) cm respectively. Similarly, between the follow-up assessments at 4 and 8 months, the exercise group continued to show deterioration in performance of Functional Reach whereas the social and control groups demonstrated similar and slight declines over the period. This interaction was also significant. There was no significant group effect at the final follow-up assessment.

The results of the ANOVA, summarised in Table 4.9, also indicated a significant main effect for time for each of the three balance variables and a significant main effect for group on SLBEC. Significant changes over time were further indicated by the results of tests of within-subject contrasts for each variable. As previously outlined, in the face of significant interactions for each variable, such interpretations are of little interest.

Summary

The intervention programs did not have a consistent effect on balance performance. Although balance performance measured by SLBEO demonstrated some improvement during the intervention period for exercise group subjects, no significant difference between groups was demonstrated. Similarly, no detraining effect was observed. No group differences in SLBEO were demonstrated throughout the study period. In contrast, performance on the SLBEC test deteriorated after participation in the exercise intervention program and this effect lasted for eight months following cessation of the intervention program. The social program had no significant effect on SLBEO or SLBEC performance. Functional Reach performance did, however, improve as a result of the exercise intervention program and this improvement was maintained for a further 4 months, as it was evident at the first follow-up assessment. The social program did not influence Functional Reach performance.

The first hypothesis cannot be accepted for the entire domain of balance performance in this study. Participation in the exercise intervention resulted in improved dynamic balance performance but not in improved static balance performance. The social intervention program did not affect balance performance and this hypothesis can be accepted.

4.1.2.3 Walk Performance

Walk performance involved the dependent variables of usual gait speed, maximal gait speed and circuit. Figures 4.8-4.10 illustrate group performance throughout the study for each variable. Descriptive data for walk performance are presented in Table 4.12. The results of the MANOVA are summarised in Table 4.13. The MANOVA result demonstrated a significant interaction between time and group, a significant main effect for group and a significant effect for time. The significant interaction indicated that the groups responded differently from one another over time.

ANOVA results indicated a significant main effect for time for each variable, a significant main effect for group for maximal speed and circuit and a significant interaction of time by group for maximal walk and circuit. Table 4.14 summarises the results of each ANOVA.

The ANOVA result indicated a significant main effect for time for usual gait speed but no interactions were evident and demonstrated that group performance over time was not different. Within-subjects contrasts were performed to determine the extent of the time effects. Results indicated no significant time periods for usual walk performance. Figure 4.8 illustrates usual gait speed performance by group over the study period. Results at each assessment analysed by ANOVA did not reveal any group differences in usual gait speed. Neither the exercise nor social intervention programs influenced usual gait speed. Subjects from these two groups did not perform differently from control group subjects.

The significant interaction for maximal gait speed was further examined using within-subjects contrasts. Significant interactions were demonstrated between baseline and post-intervention assessments, between post-intervention and follow-up at 4 months and again between follow-up assessments at 4 and 8 months. Figure 4.9 illustrates these interactions.

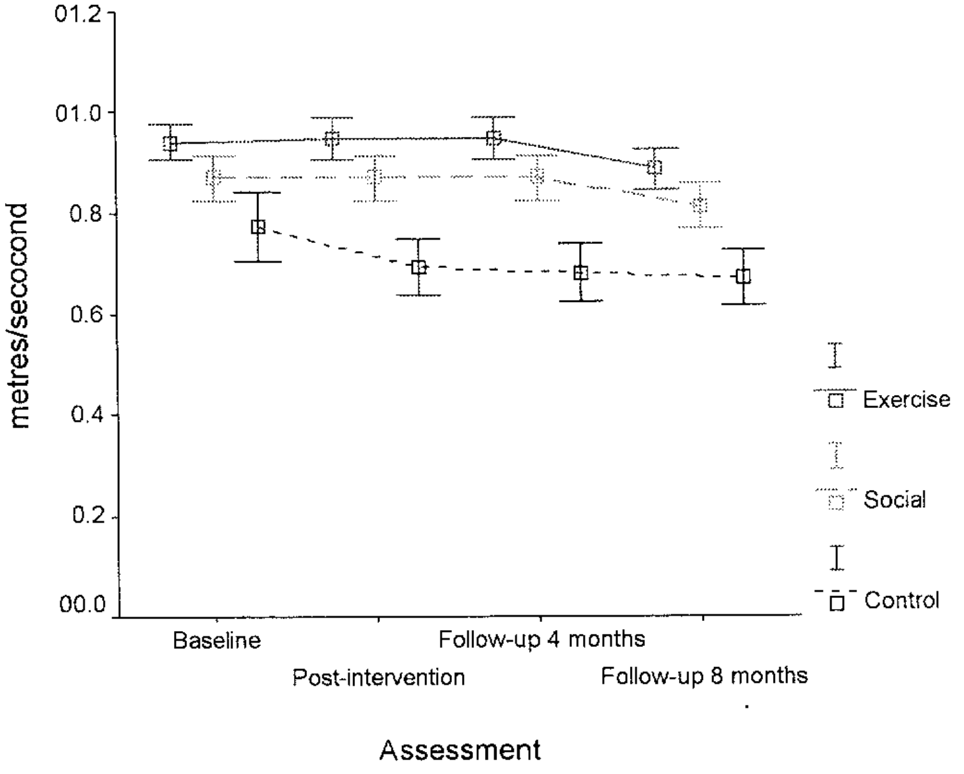

Figure 4.8 Usual gait speed (mean±SEM) by group throughout the study period

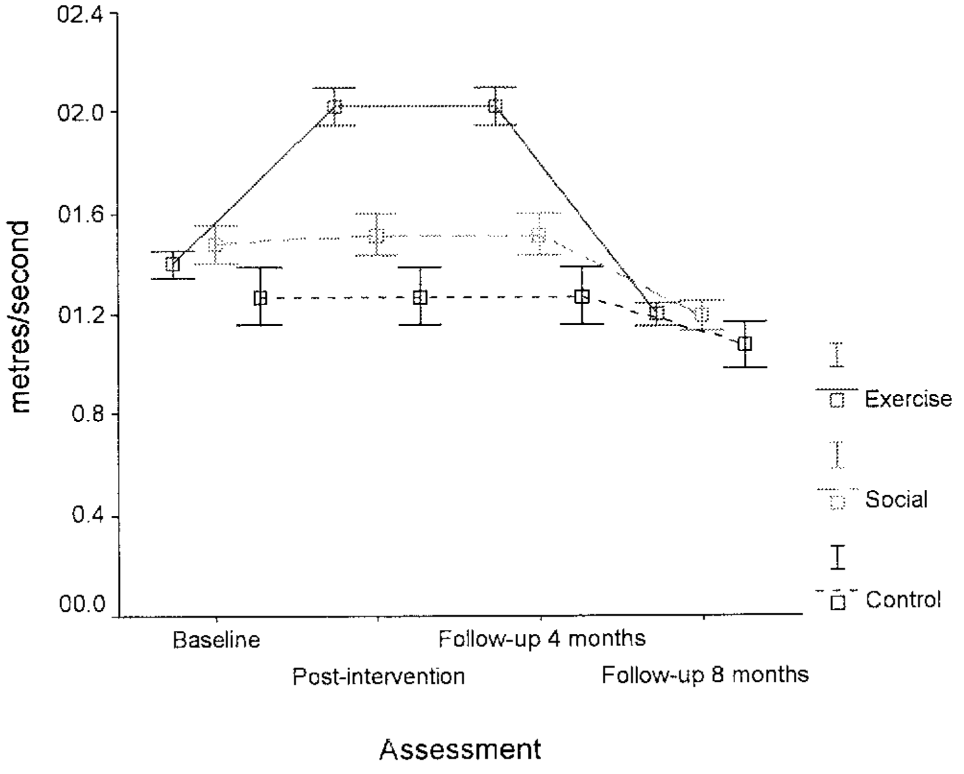

Figure 4.9 Maximal gait speed (mean±SEM) by group throughout the study period

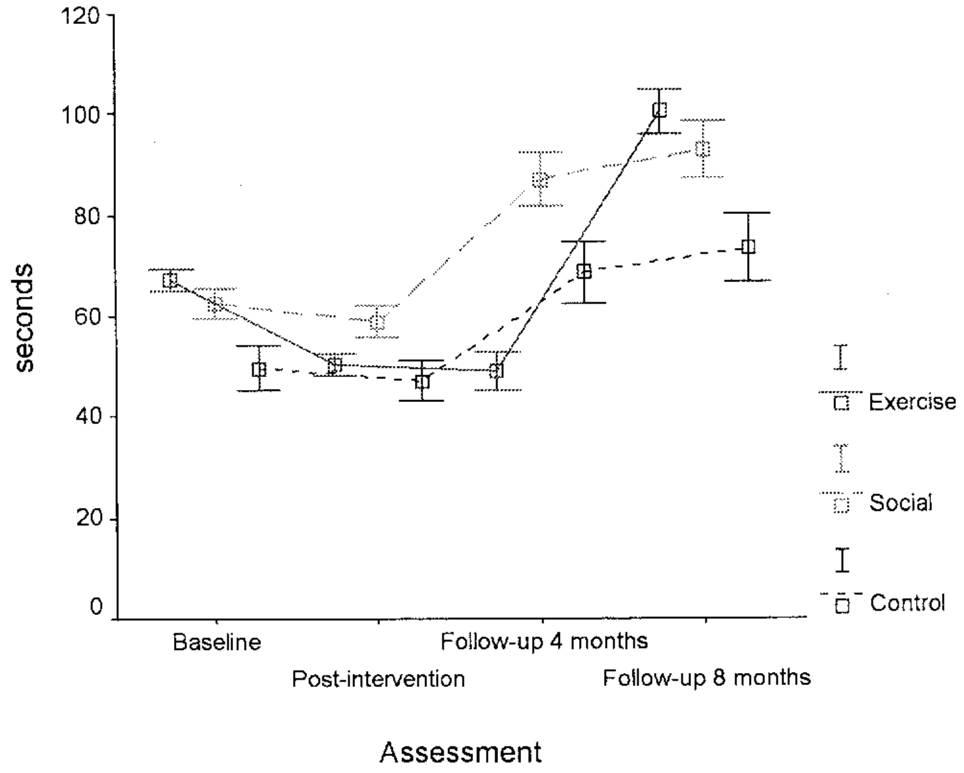

Figure 4.10 Circuit walk performance (mean±SEM) by group throughout the study period

Table 4.12 Descriptive data (mean, standard deviation, 95% CI) for walk performance

	Exercise Group		**Social Group**		**Control Group**	
	Mean (sd)	95% CI	Mean (sd)	95% CI	Mean (sd)	95% CI
Usual speed (metres per second)						
Baseline	0.94(0.22)	0.87-1.01	0.92(0.18)	0.86-0.98	0.94(0.24)	0.86-1.03
Post-intvn	0.95(0.26)	0.86-1.03	0.92(0.20)	0.85-0.98	0.84(0.15)	0.79-0.90
F-up 4	0.94(0.27)	0.86-1.03	0.92(0.20)	0.85-0.98	0.83(0.15)	0.78-0.88
F-up 8	0.89(0.24)	0.81-0.96	0.86(0.20)	0.79-0.92	0.82(0.16)	0.76-0.82
Maximal speed (metres per second)						
Baseline	1.40(0.33)	1.29-1.51	1.56(0.34)	1.45-1.68	1.55(0.43)	1.39-1.70
Post-intvn	2.02(0.47)	1.87-2.18	1.60(0.36)	1.48-1.72	1.55(0.40)	1.40-1.69
F-up 4	1.99(0.52)	1.71-2.11	1.35(0.36)	1.22-1.47	1.34(0.33)	1.22-1.46
F-up 8	1.20(0.29)	1.10-1.29	1.26(0.22)	1.18-1.33	1.21(0.29)	1.10-1.31
Circuit (seconds)						
Baseline	67.2(13.6)	62.8-71.6	65.9(13.1)	61.5-70.2	60.4(14.2)	55.3-65.6
Post-intvn	50.3(13.5)	45.9-54.7	62.1(13.5)	57.6-66.6	57.3(13.8)	52.3-62.3
F-up 4	49.1(23.8)	41.4-56.8	91.9(25.8)	83.3-100.6	83.7(23.1)	75.4-92.1
F-up 8	100.5(27.3)	91.6-109.3	98.0(27.2)	88.9-107.1	89.5(27.6)	79.5-99.4

Table 4.13 Summary result of MANOVA for walk performance

	df	*F*	*p*
Time	9,945	40.189	<.001*
Group	6,208	3.766	.001*
Time*Group	18,945	14.288	<.001*

*$p < .01$

Table 4.14 Summary results of ANOVA for the three dependent variables of walk performance

	df	*F*	*p*
Usual speed			
Time	1.88,197.75	5.273	.007*
Group	2,105	1.482	.232
Time*Group	3.77,197.75	1.370	.248
Maximal speed			
Time	2.35,246.86	97.071	<.001*
Group	2,105	7.083	.001*
Time*Group	4.70,246.86	40.133	<.001*
Circuit			
Time	1.95,204.39	209.433	<.001*
Group	2,105	4.863	.010
Time*Group	3.89,204.39	36.478	<.001*

*$p < .01$

Table 4.15 Summary results of tests of within-subjects contrasts for the three dependent variables of walk performance

		df	*F*	*p*
Usual speed				
Time	Baseline vs. Post-intvn	1,105	2.371	.127
	Post-intvn vs. F-up 4	1,105	4.852	.030
	F-up 4 vs. 8	1,105	4.711	.032
Time*Group	Baseline vs. Post-intvn	2,105	2.732	.070
	Post-intvn vs. F-up 4	2,105	4.585	.012
	F-up 4 vs. 8	2,105	0.572	.566
Maximal speed				
Time	Baseline vs. Post-intvn	1,105	107.726	<.001*
	Post-intvn vs. F-up 4	1,105	49.086	<.001*
	F-up 4 vs. 8	1,105	102.896	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	93.929	<.001*
	Post-intvn vs. F-up 4	2,105	13.245	<.001*
	F-up 4 vs. 8	2,105	51.223	<.001*
Circuit walk				
Time	Baseline vs. Post-intvn	1,105	119.524	<.001*
	Post-intvn vs. F-up 4	1,105	186.386	<.001*
	F-up 4 vs. 8	1,105	156.116	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	39.651	<.001*
	Post-intvn vs. F-up 4	2,105	56.222	<.001*
	F-up 4 vs. 8	2,105	84.380	<.001*

*$p<.01$

Table 4.16 Summary results of between groups ANOVA for significant main effects for maximal speed performance

	df	*F*	*p*
Maximal speed			
Baseline	2,107	2.226	.113
Post-intvn	2,107	14.666	<.001*
F-up 4	2,107	36.430	<.001*
F-up 8	2,107	0.505	.605

*$p<.01$

At the baseline assessment there was no significant group effect evident from ANOVA. The exercise group subjects demonstrated improved maximal walking speed between baseline and post-intervention assessments. This interaction was significant. At the post-intervention assessment, results of the Tukey HSD test indicated that there was a significant difference between the exercise group and the other two groups. Mean maximal speeds recorded were 2.02(±0.47) m/s for the exercise group, 1.60(±0.36) m/s for the social group and 1.55(±0.40) m/s for the control group.

Between the post-intervention and follow-up assessment at 4 months, exercise subjects maintained their improved maximal walking speed while the other groups showed similar declines. This interaction was significant. At the follow-up assessment at 4 months there was a significant main effect for group evident on ANOVA. The Tukey HSD indicated that again the difference was between the exercise group and the other two groups. Exercise subjects had maintained their maximal speed at 1.99(±0.52) m/s in comparison to 1.34(±0.35) and 1.34(±0.33) m/s for the social and control groups respectively. The exercise group subjects showed a considerable decline in performance between the follow-up assessments at 4 and 8 months. The interaction for this period was significant. At the final assessment there was no main effect for group demonstrated by ANOVA.

The exercise intervention was effective in significantly improving maximal walking speed. Subjects maintained these improved speeds for a further 4 months in the absence of continuing intervention. The social intervention did not influence maximal walking speed, as this group's performance over time did not significantly differ from that of the control group. Further analysis was indicated since the result of the ANOVA demonstrated a significant interaction for circuit performance. This was done using within-subjects contrasts. Significant interactions were evident for all phases of the study. Figure 4.10 illustrates circuit performance over the study period.

There was no main effect for group discerned by ANOVA at the baseline assessment. Between the baseline and post-intervention assessments exercise subjects decreased their performance time for the circuit. (Better performance on the circuit is measured by shorter completion times.) The other two groups demonstrated slight and similar declines. The ANOVA demonstrated a significant main effect for group at the post-intervention assessment. Post hoc analysis indicated that the performance of the exercise group was significantly different from the performance of the other two groups. Exercise subjects completed the circuit in 50.3(±13.5) seconds compared with 62.1(±13.5) and 57.3(±13.8) seconds for the social and control groups respectively.

Between the post-intervention and follow-up assessment at 4 months, the exercise group demonstrated a further decline, albeit slight, in circuit time compared with similar but marked increases in performance time for the social and control groups. This interaction was significant. The ANOVA result indicated a significant main effect for group at the follow-up 4 month assessment and post hoc analysis indicated that the exercise group was again significantly different from the social and control groups. Exercise subjects demonstrated a time of 49.1(±23.8) seconds compared with 91.9(±25.8) and 83.7(±23.1) seconds for the social and control groups respectively.

Between the two follow-up assessments, the exercise group showed a sharp increase in performance time whereas the social and control groups showed slight but similar increases. This interaction was significant due to the differing performance of the exercise group. There was no group main effect on ANOVA at the final assessment. Performance on the circuit test improved following participation in the exercise program and these gains were maintained over the follow-up period lasting 4 months. The social program did not influence circuit performance, as the social group did not differ from the control group.

Summary

The exercise intervention was successful in improving performance of maximal gait speed and circuit walk performance. Significant improvements were evident at the post-intervention assessment and these gains were maintained for a further period of at least 4 months but not for 8 months. The social program did not influence maximal gait speed or circuit performance, as this group did not differ from the control group over time. Neither the exercise nor social intervention programs influenced usual gait speed as was highlighted by the lack of a group difference on this variable over time.

As the exercise intervention did not result in improved gait performance overall, the first hypothesis cannot be accepted. Participation led to improved maximal gait speed and circuit walk performance, but not to improved usual gait speed. Participation in the social intervention program did not influence walk performance and the third hypothesis, proposing that the social intervention program would not result in improved physical performance, can be accepted.

4.1.2.4 Step Height Performance

Step height performance was measured by a single dependent variable and performance by group during the study is illustrated in Figure 4.11. Data were normalised by leg length and represented by unit of centimetres (of step height) per centimetre (of leg length). Descriptive data are presented in Table 4.17. Analysis utilised a 3 (group) by 4 (time) ANOVA. Results are summarised in Table 4.18.

The significant interaction demonstrated by ANOVA was further analysed using within-subjects contrasts and results are summarised in Table 4.19. Significant interactions were evident for each phase of the study. Figure 4.11 illustrates these interactions.

At the baseline assessment there was no group effect demonstrated by ANOVA. Between the baseline and post-intervention assessments exercise

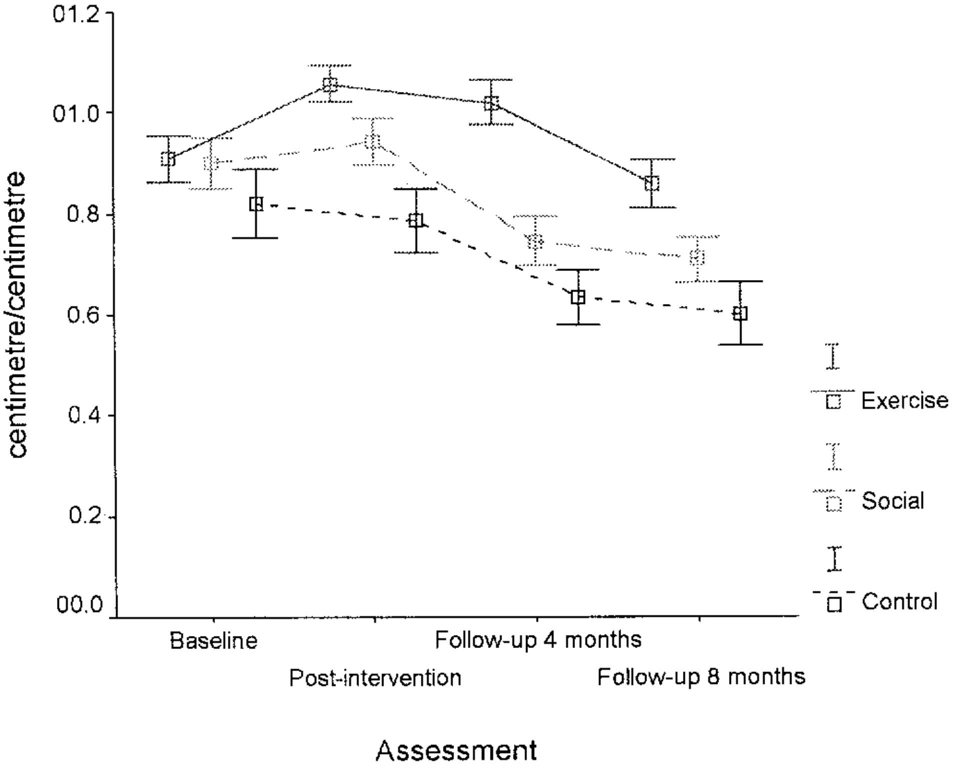

Figure 4.11 Step height performance (mean±SEM) throughout the study period

Table 4.17 Descriptive data (mean, standard deviation, 95% CI) in centimetres in height per centimeter of leg length for step height performance

	Exercise Group		**Social Group**		**Control Group**	
	Mean (sd)	95% CI	Mean (sd)	95% CI	Mean (sd)	95% CI
Baseline	0.91(0.29)	0.81-1.00	0.95(0.24)	0.87-1.02	1.00(0.18)	0.93-1.06
Post-intvn	1.06(0.23)	0.98-1.13	0.99(0.18)	0.93-1.05	0.96(0.16)	0.90-1.01
F-up 4	1.02(0.27)	0.93-1.11	0.78(0.25)	0.70-0.87	0.77(0.18)	0.71-0.84
F-up 8	0.86(0.29)	0.76-0.95	0.75(0.24)	0.67-0.82	0.73(0.30)	0.62-0.84

Table 4.18 Summary results of ANOVA for the dependent variable of step height performance

	df	*F*	*p*
Time	2.60,272.81	63.931	<.001*
Group	2,105	2.411	.095
Time*Group	5.20,272.81	12.420	<.001*

*$p<.01$

Table 4.19 Summary results of tests of within-subjects contrasts for the dependent variable of step height performance

		df	*F*	*p*
Time	Baseline vs. Post-intvn	1,105	8.826	.004*
	Post-intvn vs. F-up 6	1,105	114.693	<.001*
	F-up 4 vs. F-up 8	1,105	30.662	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	9.919	<.001*
	Post-intvn vs. F-up 4	2,105	16.711	<.001*
	F-up 4 vs. F-up 8	2,105	8.149	.001*

*$p<.01$

subjects demonstrated an increase in step height performance. Social subjects demonstrated a smaller improvement in step height performance over this period, whereas control group subjects exhibited a decline in performance. This interaction was significant. At the post-intervention assessment however there was still no group effect demonstrated by ANOVA.

Between post-intervention and follow-up at 4 months, the exercise group declined in step height performance. Both the social and control groups also declined over this period and more markedly than the exercise group. This interaction was significant. ANOVA results indicated a significant main effect for group at the follow-up assessment at 4 months. The Tukey HSD test indicated that the group effect was due to the significantly better performance of the exercise group subjects. The exercise group subjects recorded a mean score of 1.02(±0.27) cm/cm, compared with social subjects who scored 0.78(±0.25) or the control group who scored 0.77(±0.18 cm/cm). Between the follow-up assessments at 4 and 8 months all groups declined in performance with the exercise group showing more marked decline than the other two groups. This interaction was also significant. At the final assessment there was no group effect, indicating that all groups performed similarly.

Summary

Step height performance did not show an immediate improvement as a result of the exercise intervention, however the exercise group demonstrated significantly better performance than the other two groups at the follow-up assessment at 4 months. This improvement had dissipated by the follow-up assessment at 8 months. The social intervention did not influence step height performance.

Both the first and third hypotheses can be accepted for step height performance. Participation in the exercise program resulted in improved, albeit delayed performance, while participation in the social program was not influential on performance.

4.1.2.5 Summary of Physical Performance Measures

The exercise intervention produced the following results on measures of physical performance:

- Muscle performance

  All variables demonstrated a significant effect during participation, immediate detraining and no long-term effect;

- Balance performance

  no effect on SLBEO performance;

  significant negative effect on SLBEC performance which was still present at 8 months post-intervention;

  significant effect on Functional Reach which was present for 4 but not 8 months post-intervention;

- Walk performance

  no effect on usual gait speed;

  significant effect on maximal gait speed and circuit walk performance which lasted for 4 but not 8 months post-intervention;

- Step height performance

  no immediate intervention effect but exercise group significantly better than other groups at 4 but not 8 months post-intervention.

The social intervention did not significantly affect physical performance throughout the study period.

The first hypothesis, proposing that participation in the exercise program would result in improved physical performance, can be accepted for the variables of muscle and step height performance. As the results of intervention were mixed, it cannot be accepted for balance and walk performance. The third hypothesis, prosing that the social intervention program would have no effect on physical performance measures, can be accepted for all parameters.

4.1.3 Functional Ability

The domain of functional ability consisted of the results of the five scales of functional ability that formed the dependent variables – upper limb tiredness (ULT), lower limb tiredness (LLT), mobility tiredness (MT), mobility help (MH) and physical activities of daily living help (PADLH). Figures 4.12-4.16 illustrate functional ability over time by group. Descriptive data for functional ability are presented in Table 4.20. Lower scores on each of the scales are indicative of poorer performance. Although the scores from the functional ability scales represent ordinal data, the data have been treated as continuous data, as explained in the previous chapter. (See Chapter 3.11.2.) Therefore, descriptive data statistics presented included means, standard deviation and 95% confidence intervals.

Two hypotheses proposed a relationship between the intervention programs and functional ability. The second hypothesis suggested that participation in the exercise intervention program would be associated with improved functional ability. The fourth hypothesis proposed that the social intervention program would have no effect on functional ability. The relationship between the intervention programs and the results on each subscale of the QFA, which indicates whether the hypotheses will be accepted or rejected, will be described.

Results of the MANOVA are summarised in 4.21. The MANOVA result demonstrated a significant interaction between time and group, a significant main effect for group and a significant effect for time. The significant interaction indicated that the groups responded differently from one another over time. ANOVA results are summarised in Table 4.22. The significant interaction for each dependent variable was further examined using tests of within-subjects contrasts. Significant interactions were demonstrated for each variable.

4.1.3.1 Upper Limb Tiredness

A significant time by group interaction was evident for ULT between the post-intervention assessment and the follow-up assessment at 4 months. There was no significant interaction evident for ULT between the baseline and post-intervention assessments or between the follow-up assessments at 4 and 8 months.

Figure 4.12 illustrates group performance on ULT over the study period and shows the interactions clearly. There was no difference between groups at baseline. The exercise group showed an increase in ULT scores between the baseline and post-intervention assessments i.e. the intervention period. The social and control groups demonstrated similar and slight declines over the same period, however this interaction was not significant. At the post-intervention assessment, ANOVA demonstrated a significant main effect for group which was further analysed using the Tukey HSD as a post hoc test. The exercise group was significantly different from the other two groups with a mean ULT score of 3.6(±0.6) compared with 2.9(±1.0) and 2.5(±0.7) for the social and control groups respectively.

Between the post-intervention assessment and the follow-up assessment at 4 months, the exercise subjects demonstrated a decline in ULT performance. This interaction was significant, however, there were no differences between groups at this assessment. There was no significant interaction between groups at the follow-up assessment at 4 and 8 months as all groups demonstrated similar performance over this period. Again, there was no difference between groups at the final assessment.

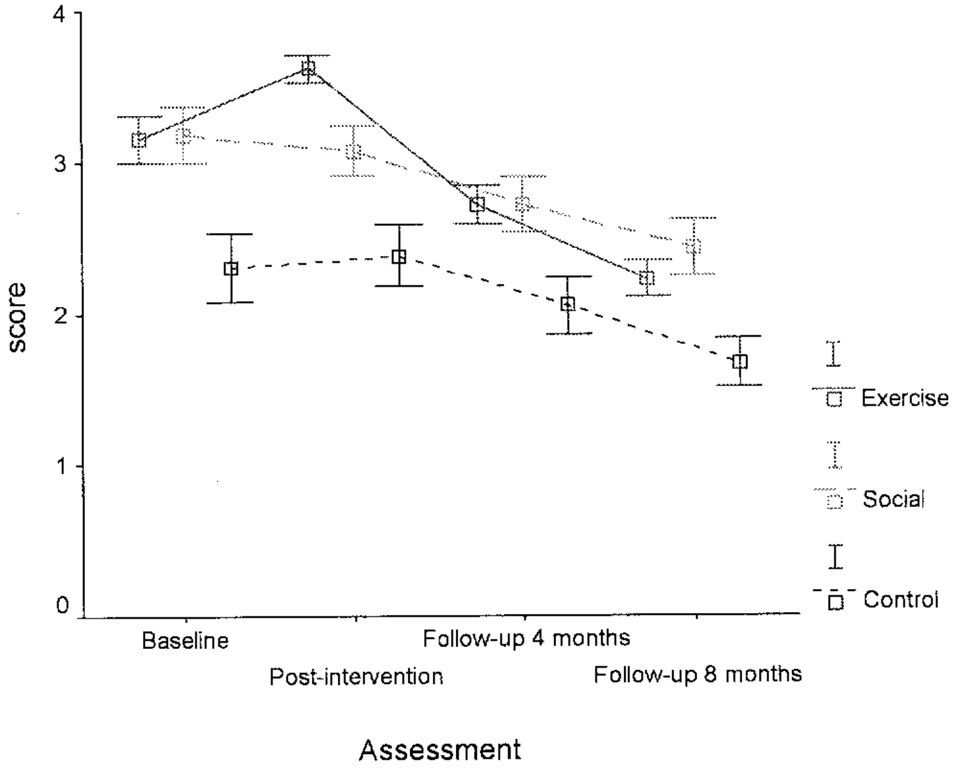

Figure 4.12 Upper Limb Tiredness (ULT) scores (mean±SEM) by group throughout the study period

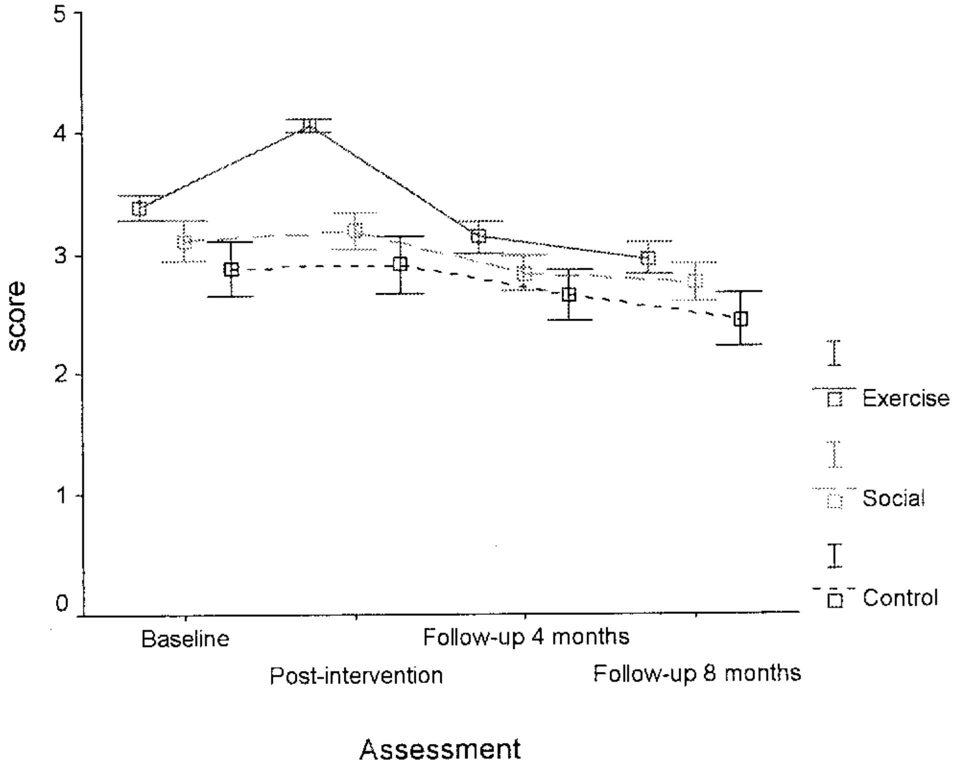

Figure 4.13 Lower Limb Tiredness (LLT) scores (mean±SEM) by group throughout the study period

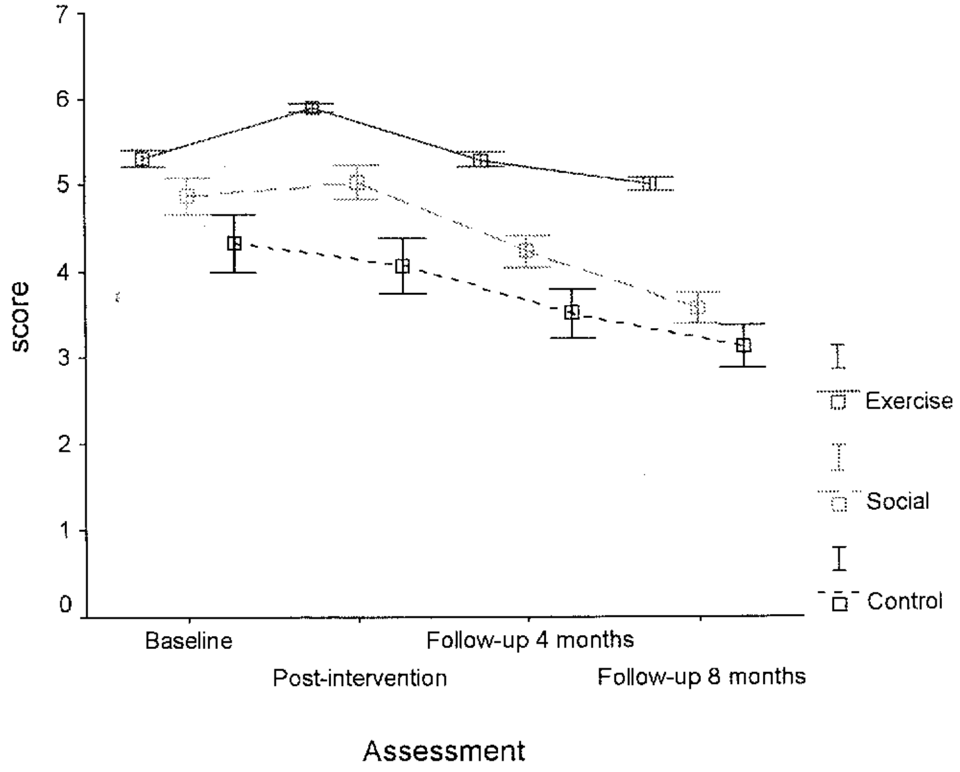

Figure 4.14 Mobility Tiredness (MT) scores (mean±SEM) by group throughout the study period

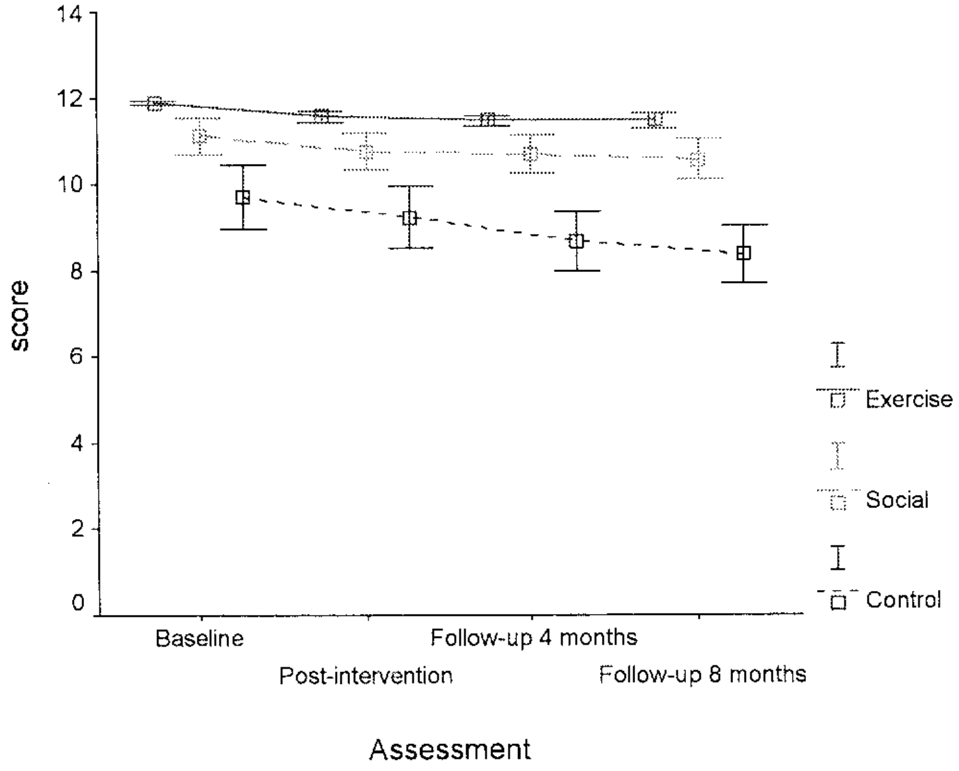

Figure 4.15 Mobility Help (MH) scores (mean±SEM) by group throughout the study period

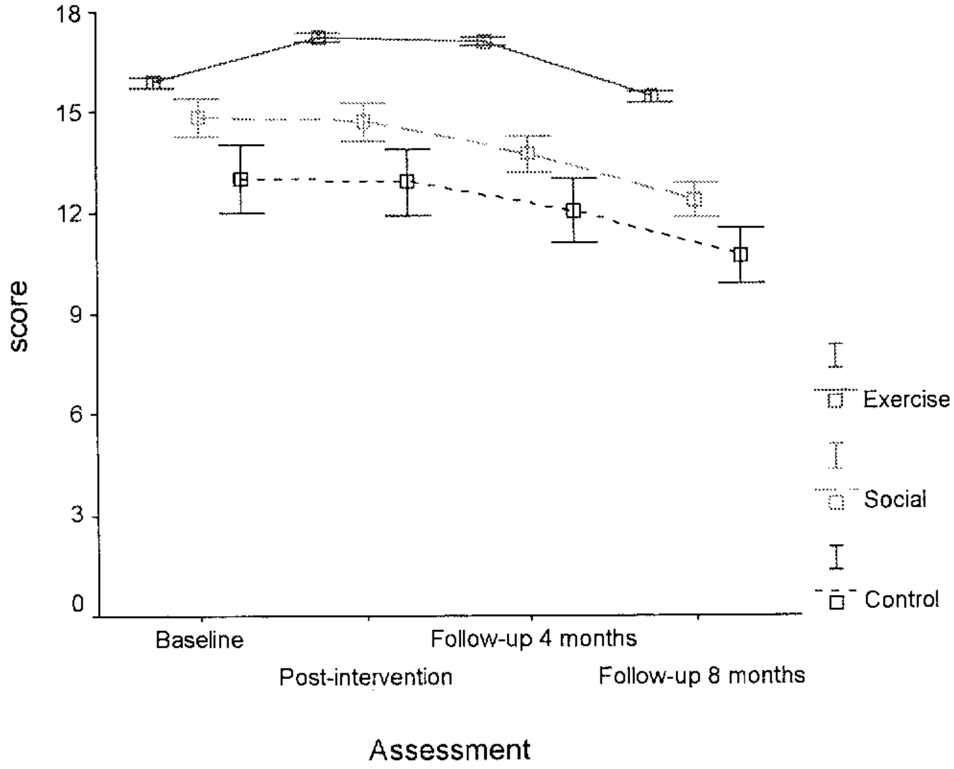

Figure 4.16 Physical Activities of Daily Living Help (PADLH) scores (mean±SEM) by group throughout the study period

Table 4.20 Descriptive data (mean, standard deviation, 95% CI) for functional ability measures

	Exercise Group		**Social Group**		**Control Group**	
	Mean (sd)	95% CI	Mean (sd)	95% CI	Mean (sd)	95% CI
ULT						
Baseline	3.2(1.0)	2.8-3.5	3.4(0.9)	3.1-3.6	2.8(1.0)	2.5-3.2
Post-intvn	3.6(0.6)	3.4-3.8	3.2(0.8)	3.0-3.5	2.9(0.6)	2.7-3.1
F-up 4	2.7(0.8)	2.5-3.0	2.9(1.0)	2.5-3.2	2.5(0.7)	2.2-2.8
F-up 8	2.2(0.7)	2.0-2.5	2.6(1.0)	2.2-2.9	2.0(0.7)	1.8-2.3
LLT						
Baseline	3.4(0.6)	3.2-3.6	3.3(0.7)	3.0-3.5	3.5(0.5)	3.3-3.7
Post-intvn	4.0(0.3)	4.0-4.2	3.4(0.6)	3.2-3.6	3.5(0.6)	3.3-3.7
F-up 4	3.1(0.8)	2.9-3.4	3.0(0.6)	2.8-3.2	3.2(0.5)	3.0-3.4
F-up 8	3.0(0.9)	2.7-3.2	3.0(0.8)	2.6-3.2	3.0(0.8)	2.7-3.3
MT						
Baseline	5.3(0.6)	5.1-5.5	5.1(0.7)	4.9-5.4	5.3(0.5)	5.1-5.5
Post-intvn	5.9(0.3)	5.8-6.0	5.3(0.5)	5.1-5.4	5.0(0.5)	4.8-5.2
F-up 6	5.3(0.5)	5.1-5.4	4.5(0.5)	4.3-4.6	4.3(0.5)	4.1-4.5
F-up 8	5.0(0.5)	4.8-5.2	3.8(0.7)	3.5-4.0	3.8(0.4)	3.7-4.0
MH						
Baseline	11.9(0.3)	11.8-12.0	11.7(0.6)	11.5-11.9	11.8(0.4)	11.7-12.0
Post-intvn	11.6(0.8)	11.3-11.8	11.4(0.8)	11.1-11.6	11.2(1.0)	10.9-11.6
F-up 4	11.5(0.9)	11.2-11.8	11.3(1.0)	10.9-11.6	10.6(1.3)	10.1-11.1
F-up 8	11.5(1.0)	11.1-11.8	11.1(1.4)	10.7-11.6	10.2(1.8)	9.6-10.8
PADLH						
Baseline	15.9(1.0)	15.6-16.2	15.6(0.8)	15.4-15.9	15.8(0.8)	15.5-16.2
Post-intvn	17.2(0.8)	17.0-17.5	15.5(0.8)	15.2-15.8	15.8(0.9)	15.4-16.1
F-up 4	17.1(0.8)	16.9-17.4	14.5(1.1)	14.1-14.8	14.7(1.2)	14.3-15.1
F-up 8	15.4(0.9)	15.2-15.7	13.0(1.0)	12.7-13.4	13.1(1.0)	12.7-13.4

Table 4.21 Summary result of MANOVA for functional ability

	df	*F*	*p*
Time	15,939	38.819	<.001*
Group	10,204	19.887	<.001*
Time*Group	30,1575	11.740	<.001*

*$p<.01$

Table 4.22 Summary results of ANOVA for the five dependent variables of functional ability

	df	*F*	*p*
ULT			
Time	2.20,230.59	85.424	.001*
Group	2,105	3.805	.025
Time*Group	4.39,230.59	4.237	.002*
LLT			
Time	2.41,253.28	69.918	<.001*
Group	2,105	1.949	.148
Time*Group	4.82,253.28	7.701	<.001*
MT			
Time	2.49,261.76	125.667	<.001*
Group	2,105	78.315	<.001*
Time*Group	4.99,261.76	12.164	<.001*
MH			
Time	2.29,240.56	20.819	<.001*
Group	2,105	7.812	.001*
Time*Group	4.53,240.56	4.053	.002*
PADLH			
Time	2.64,277.25	601.390	<.001*
Group	2,105	49.446	<.001*
Time*Group	5.28,277.25	79.393	<.001*

*$p<.01$

Table 4.23 Summary results of tests of within-subjects contrasts for the five dependent variables of functional ability

		df	*F*	*p*
ULT				
Time	Baseline vs. Post-intvn	1,105	3.383	.069
	Post-intvn vs. F-up 4	1,105	70.787	<.001*
	F-up 4 vs. F-up 8	1,105	71.610	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	4.503	.013
	Post-intvn vs. F-up 4	2,105	6.715	.002*
	F-up 4 vs. F-up 8	2,105	1.546	.218
LLT				
Time	Baseline vs. Post-intvn	1,105	33.909	<.001*
	Post-intvn vs. F-up 4	1,105	84.994	<.001*
	F-up 4 vs. F-up 8	1,105	15.910	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	21.745	<.001*
	Post-intvn vs. F-up 4	2,105	11.390	<.001*
	F-up 4 vs. F-up 8	2,105	1.280	.282
MT				
Time	Baseline vs. Post-intvn	1,105	3.814	.053
	Post-intvn vs. F-up 4	1,105	154.418	<.001*
	F-up 4 vs. F-up 8	1,105	83.663	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	11.869	<.001*
	Post-intvn vs. F-up 4	2,105	1.370	.259
	F-up 4 vs. F-up 8	2,105	5.595	.005*
MH				
Time	Baseline vs. Post-intvn	1,105	24.727	<.001*
	Post-intvn vs. F-up 4	1,105	5.602	.020
	F-up 4 vs. F-up 8	1,105	2.511	.116
Time*Group	Baseline vs. Post-intvn	2,105	0.791	.456
	Post-intvn vs. F-up 4	2,105	2.391	.097
	F-up 4 vs. F-up 8	2,105	1.063	.349
PADLH				
Time	Baseline vs. Post-intvn	1,105	69.789	<.001*
	Post-intvn vs. F-up 4	1,105	174.589	<.001*
	F-up 4 vs. F-up 8	1,105	771.679	<.001*
Time*Group	Baseline vs. Post-intvn	2,105	117.331	<.001*
	Post-intvn vs. F-up 4	2,105	33.662	<.001*
	F-up 4 vs. F-up 8	2,105	1.529	.222

*p<.01

Table 4.24 Summary results of between groups ANOVA for significant main effects for functional ability

	df	*F*	*p*
MT			
Baseline	2,107	.859	.426
Post-intvn	2,107	41.304	<.001*
F-up 4	2,107	39.940	<.001*
F-up 8	2,107	61.273	<.001*
MH			
Baseline	2,107	.985	.377
Post-intvn	2,107	1.283	.282
F-up 4	2,107	6.180	.003*
F-up 8	2,107	7.546	.001*
PADLH			
Baseline	2,107	1.012	.367
Post-intvn	2,107	45.046	<.001*
F-up 4	2,107	78.657	<.001*
F-up 8	2,107	81.010	<.001*

*p<.01

As participation in the exercise intervention program resulted in improved ULT scores, the second hypothesis can be accepted. Participation in the social intervention program did not influence ULT results. The fourth hypothesis can also be accepted, as it proposed no improvement in functional ability as a resulting from participation.

These results indicate that the exercise intervention significantly improved ULT performance by the post-intervention assessment. This improvement was not maintained and was not evident four months later. The social intervention did not influence ULT, as there was no difference between the performance of the social and control groups for ULT over time.

4.1.3.2 Lower Limb Tiredness

Within-subjects contrasts for LLT indicated a significant interaction between baseline and post-intervention assessments and between post-intervention and follow-up at 4 months but not between follow-up at 4 and 8 months. Figure 4.13 illustrates these interactions.

At baseline, there was no difference between groups. Between the baseline and post-intervention assessments, the exercise group demonstrated an increase in

LLT scores whereas the social and control groups both demonstrated little change. This interaction was significant. At the post-intervention assessment, there was a significant main effect for group demonstrated by ANOVA. Post hoc tests indicated that the exercise group was significantly different from the other two groups. Exercise subjects reported significantly higher scores for LLT than subjects from either the social or control groups. Exercise subjects scored 4.0(±0.3), social subjects scored 3.4(±0.6) and the control groups averaged 3.5(±0.6).

Between the post-intervention and follow-up at 4 months assessments, the exercise group demonstrated a decline in LLT scores, so that at the latter assessment there was again no difference among groups. This interaction was also significant. There was no interaction between the two follow-up assessments indicating similar performance over time by all groups.

LLT scores were significantly influenced by participation in the exercise intervention program but not by participation in the social intervention program. The second and fourth hypotheses can, therefore, be accepted in relation to the LLT results. Exercise group subjects demonstrated significantly improved scores at the post-intervention assessment but did not maintain these improvements following cessation of the intervention.

4.1.3.3 Mobility Tiredness

MT scores demonstrated significant time by group interactions between the baseline and post-intervention assessments and the follow-up assessments at 4 and 8 months. Figure 4.14 illustrates these interactions. There was no significant interaction between the post-intervention and follow-up at 4 months assessments.

At baseline, there was no difference among groups. Between the baseline and post-intervention assessments the exercise group demonstrated an increase in MT scores whereas the social and control groups demonstrated little change. This interaction was significant. The ANOVA for post-intervention data indicated a significant main effect for group. The Tukey HSD test indicated significant differences among all groups. Exercise subjects demonstrated MT scores of 5.9(±0.3), social subjects scored 5.3(±0.5) and control subjects reported 5.0(±0.5) for MT scores.

There was, however, no interaction between the post-intervention and follow-up at 4 months assessment as all groups demonstrated similar declines. At the follow-up assessment at 4 months, the ANOVA indicated a main effect for group. Post hoc analysis demonstrated a significant difference between the exercise group and the other two groups. The social and control groups were no longer significantly different. Recorded MT scores were 5.3(±0.5) for the exercise group and 4.5(±0.5) and 4.3(±0.5) for the social and control groups respectively. Between the follow-up assessments at 4 and 8 months, the interaction was significant as a result of the slight decline showed by the exercise group in comparison with the greater decline showed by both the social and control groups. At this final assessment, a significant main effect was again indicated by ANOVA. Post hoc tests indicated that the exercise group remained significantly different from the other two groups. MT scores were 5.0(±0.5) for the exercise group and 3.8(±0.7) and 3.8(±0.4) for the social and control groups respectively.

This finding of an interaction between the follow-up assessments at 4 and 8 months was contrary to the pattern exhibited by other dependent variables. No other dependent variable demonstrated significant interaction between the follow-up assessments after a period of no group differences between post-intervention and the first follow-up assessment.

The exercise intervention significantly improved MT performance. The effects of exercise intervention were evident at both follow-up assessments as the exercise group was significantly different from the other two groups. However, there was no significant difference in the rate of change in MT between the post-intervention and follow-up assessment at 4 months among groups, indicating that there was no marked detraining effect for exercise group subjects as a result of cessation of the intervention. The change in MT was significantly different between the two follow-up assessments as the exercise subjects showed less marked decline over time. Exercise subjects reported significantly better MT ability at the follow-up assessments than subjects from the other two groups.

The improved MT scores resulting from participation in the exercise intervention program indicates that the second hypothesis can be accepted. The social intervention program did not influence MT reports and can also be accepted. The exercise intervention was still influencing MT ability eight months following cessation of the intervention.

4.1.3.4 Mobility Help

The ANOVA result for MH scores demonstrated a significant time by group interaction, indicating that performance over time was different between groups. Figure 4.15 illustrates MH performance by group over time. Further analysis using within-subjects contrasts did not demonstrate significance. At the baseline assessment, there was no difference between groups. Between baseline and post-intervention assessments, the interaction was not significant, indicating similar performance over time by all three groups despite the intervention programs. At the post-intervention assessment again no difference between groups was noted. Interactions between the post-intervention and first follow-up assessment and the first and second follow-up assessments were not significant, again indicating no difference among groups over time.

There was however a significant group difference in results obtained at both of the follow-up assessments that were further analysed by the Tukey HSD test. Post hoc analysis indicated that the exercise and social groups were significantly different from the control group at the first follow-up assessment. The exercise group scored 11.5(±0.9), the social group scored 11.3(±1.0) and both were significantly different from the control group score of 10.6(±1.3). At the final assessment, follow-up at 8 months the significant group effect was further examined by the Tukey HSD test. The results indicated that again the exercise and social groups were significantly different from the control group. The exercise group recorded MH of 11.5(±1.0), the social group recorded 11.1(±1.4) compared with the control group scores of 10.2(±1.8).

This result indicates that although the intervention programs did not immediately influence MH performance, there was a significant and protective effect on MH scores 4 and 8 months post-intervention for both intervention groups. This suggests that participation in intervention reduced the later decline in MH performance.

In contrast to the previous variables of functional ability, participation in either of the two intervention programs slowed the usual decline over time in independent mobility. The second hypothesis, indicating that participation in the exercise intervention program would result in improved functional ability, was true when compared with subjects receiving no intervention, and can be accepted. The fourth hypothesis, however, cannot be accepted, as participation in the social intervention program also resulted in improved MH scores in the longer term.

4.1.3.5 Physical Activities of Daily Living

Significant time by group interactions were demonstrated by the results of univariate tests for PADLH. A significant interaction was evident between the baseline and post-intervention assessment and also between post-intervention and the first follow-up assessment at 4 months, but not between the two follow-up assessments at 4 and 8 months. Figure 4.16 illustrates these interactions.

There were no group differences in PADLH scores at the baseline assessment. Between the baseline and post-intervention assessments, i.e. the intervention period, the exercise group demonstrated an increase in PADLH scores. Both the social and control groups exhibited similar declines over this period. This interaction was significant. ANOVA indicated a significant main effect for group and post hoc tests indicated significant differences between the exercise group and the other two groups. Scores recorded for each group were 17.2± (0.8), 15.5(±0.8) and 15.8(±0.9) respectively.

Between the post-intervention and follow-up assessment at 4 months, the exercise group showed little change in PADLH scores, whereas the other two groups demonstrated a similar pattern of decline. This interaction was also significant and demonstrates that cessation of exercise was responsible for little change in PADLH scores in the initial four month post-intervention period. The significant group difference was still evident with the exercise group different from the other two groups with scores of 17.1(±0.8), 14.5(±1.1) and 14.7(±1.2) respectively. Between the follow-up assessments at 4 and 8 months, all groups showed similar declines and no interaction was evident. However, the significant group difference remained. Exercise group scores were significantly different from scores recorded by the other two groups. The exercise group recorded PADLH scores of 15.4(±0.9) compared with the social group's scores of 13.3(±1.0) and control group's scores of 13.1(±1.0).

The exercise intervention resulted in an immediate and significant improvement in PADLH scores and this improvement was maintained for the 8-month follow-up period. The exercise group participants scored significantly higher on PADLH at every assessment following the intervention period. This result indicates that the second hypothesis can be accepted, as participation in the exercise intervention program resulted in improved PADLH scores. Participation in the social intervention program did not influence PADLH results. The fourth hypothesis can be accepted.

Further inspection of the ANOVA result, summarised in Table 4.22, indicated a main effect for time for each variable of functional ability and for group on the scales of MT, MH and PADLH. Within-subjects contrasts confirmed significant changes over time for each variable. However, it is often not possible to interpret significant main effects in a 2-way ANOVA. These main effects may be due to the pattern observed at the post-intervention assessment and are also overridden by the significant interactions demonstrated for each dependent variable of functional ability, which have been discussed in detail above. Therefore, these main effects are of little interest.

4.1.4 Summary of effects of intervention programs

The intervention programs provided either an exercise or social program. Results have shown that the social intervention program did not influence physical performance but did influence the need for assistance with mobility tasks in the longer term, as did the exercise program. The effect of the intervention programs are summarised in Table 4.25.

The first hypothesis, stating that participation in the exercise intervention program would result in improved physical performance, can be accepted for muscle performance, dynamic balance performance, maximal walk and circuit walk performance and step height performance. It cannot be accepted in relation to static balance performance or usual walk speed. The third hypothesis, predicted that participation in the social intervention would not influence physical performance, and was accepted for all parameters.

Two hypotheses envisaged a relationship between participation in the intervention programs and functional ability. The second hypothesis, that participation in the exercise intervention program would result in improved functional ability, can be accepted for all five variables. The fourth hypothesis, indicating no relationship between social intervention and functional ability, cannot be accepted for the domain of mobility dependence (MH scores) but can be accepted for the other four functional ability variables.

Table 4.25 Summary of effects of intervention programs on measures of physical performance and functional ability

Effect	Variables
Exercise Intervention	
Intervention Effects	
significant effect	Muscle performance (all) Functional Reach Maximal gait speed Circuit walk Step height performance Upper Limb Tiredness (ULT) Lower Limb Tiredness (LLT) Mobility Tiredness (MT) Physical ADL Help (PADLH)
no immediate significant effect	Mobility Help (MH)
no significant effect	SLBEO Usual gait speed
significant detrimental effect	SLBEC
Detraining Effects	
no detraining (maintained for 8 months)	Mobility Tiredness (MT) Physical ADL Help (PADLH)
no immediate detraining (maintained for 4 but not 8 months)	Functional Reach Maximal gait speed Circuit walk
immediate detraining (intervention effect lost by 4 months)	Muscle performance Step height performance Upper Limb Tiredness (ULT) Lower Limb Tiredness (LLT)
Exercise and Social Intervention	
Other Effects	
no immediate intervention effect; both groups significantly better than control group at 4 and 8 months post-intervention	Mobility Help (MH)

4.1.5 Intention to Treat Analysis

The primary outcome for the intention to treat analysis was defined as an improvement in functional ability measured at three time periods on each of the five subscales of the Questionnaire of Functional Ability. Each outcome had been measured on four occasions and three steps of data representing change, between baseline and post-intervention assessment, between follow-up 4 month assessment and baseline assessment and between follow-up assessment at 8 months and baseline assessment, were calculated for each subscale. Improvement in functional ability was rated as a favourable outcome while deterioration or no change was recorded as an unfavourable outcome. As the 41 subjects who did not complete the study were not able to record improvement in functional ability over time, each subject was rated as no improvement in functional ability for each subscale and time period. Table 4.26 summarises the results of functional outcomes for 149 subjects who entered the study at baseline over time.

Chi-square analysis was performed to ascertain differences among groups for the number of subjects reporting functional improvement. At a significance level of $p<.01$ (equivalent to previous reports), three functional subscales demonstrated significant results. Performance on LLT between baseline and post-intervention assessments was significant ($\chi^2_{(2,\,n=149)}=44.737, p<.01$). Examination of the data indicated that the difference resulted from the fact that more exercise group subjects reported functional improvement (28) compared with subjects from either the social group (5) or the control group (2) who reported functional improvement. Therefore, the exercise intervention was effective in maximising functional ability, specific to tiredness of the lower limb. Similarly, the result for Mobility Tiredness between baseline and post-intervention assessment was significant ($\chi^2_{(2,\,n=149)}=16.818, p<.01$). Again, the difference was between the exercise group (22 subjects reporting improvement) compared with the social group and control group (12 and 4 subjects reporting improvement respectively). Mobility Tiredness between baseline and follow-up assessment 4 months post-intervention also demonstrated a significant Chi-square result ($\chi^2_{(2,\,n=149)}=9.098, p<.01$).

Table 4.26 Number of subjects per intervention group and time period reporting improvement on functional ability measures (n=149)

QFA subscale	Time period	Exercise (n=50)	Social (n=50)	Control (n=49)
ULT	Baseline - post-intervention change	15	4	10
	Baseline - follow-up 4 month change	0	0	0
	Baseline - follow-up 8 month change	0	0	0
LLT	Baseline - post-intervention change	28	5	2
	Baseline - follow-up 4 month change	0	2	0
	Baseline - follow-up 8 month change	0	0	0
MT	Baseline - post-intervention change	22	12	4
	Baseline - follow-up 4 month change	7	2	0
	Baseline - follow-up 8 month change	5	2	0
MH	Baseline - post-intervention change	5	3	0
	Baseline - follow-up 4 month change	4	1	0
	Baseline - follow-up 8 month change	5	2	0
PADLH	Baseline - post-intervention change	35	0	0
	Baseline - follow-up 4 month change	36	0	0
	Baseline - follow-up 8 month change	1	0	1

Again, the difference was between the exercise group (7 subjects reporting improvement) and the social and control groups (2 and 0 subjects reporting improvement respectively).

Physical ADL Help results showed a similar pattern to Mobility Tiredness results with significant Chi-square results indicating a difference among groups at two time points. Between the baseline and post-intervention period, 35 exercise subjects reported improved functional ability measured on the PADLH subscale, compared with no subjects from either the social or control groups ($\chi^2_{(2, n=149)}=90.576, p<.001$). Similarly, improvement in ability was reported by 35 exercise subjects between baseline and follow-up assessment 4 months post-intervention, compared with no subjects from either of the other two groups ($\chi^2_{(2, n=149)}=92.617, p<.001$). These results from the intention to treat analysis indicate the usefulness of exercise intervention as a strategy to improve and maintain functional ability in older subjects, with regards to tiredness of the lower limbs and during mobility tasks and in the need for assistance with physical ADL tasks. In addition, the exercise intervention exerted a longer term influence by decreasing mobility tiredness and the need for assistance with physical ADL tasks.

4.2 Relationship between physical performance and functional ability

Physical performance and functional ability data collected at each assessment were examined to ascertain the relationships between the two clusters of variables within the domains of physical performance and functional ability. Spearman's rank correlation coefficient results are summarised in Tables 4.27–Table 4.30.

Several significant correlations, at an alpha level of 0.01, were indicated consistently for all assessments between physical performance variables and functional ability results. Shoulder abduction muscle performance was significantly correlated with ULT scores at every assessment (r_s between .72 and .93) indicating a moderate-strong relationship between the muscle performance of shoulder abduction and self-reported upper limb tiredness during functional activities. Similarly, lower limb muscle performance was significantly correlated at a moderate - strong level with LLT. With coefficient values between r_s = .80 - .92 over the four assessments, again indicating a strong relationship between hip abduction muscle performance and self-reported lower limb tiredness during functional activities. Knee flexion and dorsiflexion were also significantly correlated with LLT, although the Spearman's rank correlation coefficient was weaker than for the more proximal hip muscle performance. Knee flexion and dorsiflexion data demonstrated only fair correlation with LLT scores.

Results indicated a further significant correlation over all four assessments for two variables of muscle performance and PADLH. Shoulder abduction performance and PADLH were significantly correlated over all four assessments ranging from r_s = .32 - .65. Hip abduction muscle performance was also significantly correlated with PADLH throughout the study with $r_s =$ .25 and .64. These findings indicate a significant but only fair-moderate correlation between muscle performance of shoulder and hip abduction and the need for assistance with physical ADL. Additionally, a number of variables were also significantly correlated, albeit weakly, at three or less than three assessments, thus, a consistent pattern of correlation was not evident.

The results of this analysis indicate a significant correlation between measures of muscle performance, especially proximally in the lower limb, and reported limb tiredness related to functional ability. Additionally, shoulder and hip abduction muscle performance were fair-moderately correlated with the need for assistance with physical ADL. There was no consistent relationship between the physical performance measures of balance, walk or step and functional ability. Similarly, apart from the influence of proximal muscle performance on limb tiredness and assistance with physical ADL, functional ability was not consistently related to a single aspect or domain of physical performance. Intervention affected muscle performance and limb tiredness with a direct and immediate training effect and an immediate detraining effect on cessation of exercise. As these two variables were correlated throughout the study, they performed similarly in response to the exercise intervention. The effect of the exercise intervention was less well defined on the remaining functional ability scales – MT, MH and PADLH - as there was little or no direct influence of muscle performance on these variables.

The fifth hypothesis proposed for the study was that the relationship between physical performance and functional ability would be significant. While significant results were evident for a number of variables, overall this hypothesis cannot be accepted, as there was not a consistent significant relationship between the two domains.

Table 4.27 Correlation coefficients (Spearman's rho) between measures of muscle performance and Upper or Lower Limb Tiredness scores at each assessment

	Baseline	Post-intvn	F-up 4	F-up 8
		Limb Tiredness		
Shoulder abduction/ULT	.89*	.73*	.93*	.81*
Hip abduction/LLT	.86*	.80*	.84*	.92*
Knee flexion/LLT	.36*	.56*	.32*	.41*
Dorsiflexion/LLT	.31*	.45*	.44*	.37*

*p<0.01(2 tailed)

Table 4.28 Correlation coefficients (Spearman's rho) between physical performance measures and Mobility Tiredness scores at each assessment

	Baseline	Post-intvn	F-up 4	F-up 8
		Mobility Tiredness		
Hip abduction	.16	.39*	-.02	.02
Knee flexion	.04	.40*	.13	.12
Dorsiflexion	.05	.40*	.18	.13
Usual gait speed	.01	.24	.19	.07
Maximal gait speed	-.02	.50*	.35*	-.06
Circuit walk	.08	-.17	-.44*	.07
Step	-.03	.25*	.34*	.35*

*p<0.01(2 tailed)

Table 4.29 Correlation coefficients (Spearman's rho) between physical performance measures and Mobility Help scores at each assessment

	Baseline	Post-intvn	F-up 4	F-up 8
		Mobility Help		
Hip abduction	.14	.20	.01	-.03
Knee flexion	.10	.27*	.30*	.18
Dorsiflexion	.10	.10	-.05	-.14
SLBEO	-.01	-.02	.07	.04
SLBEC	-.15	-.13	-.16	-.23
Functional Reach	.05	.12	.07	-.01
Usual gait speed	.05	-.03	-.03	.32*
Maximal gait speed	-.10	-.04	.06	.11
Circuit walk	.12	.10	-.10	.08
Step	.20	-.03	.13	.11

*p<0.01(2 tailed)

Table 4.30 Correlation coefficients (Spearman's rho) between physical performance measures and Physical Activities of Daily Living Help scores at each assessment

	Baseline	Post-intvn	F-up 4	F-up 8
		Physical ADL Help		
Shoulder abduction	.48*	.65*	.26*	.32*
Hip abduction	.56*	.64*	.26*	.25*
Knee flexion	.18	.49*	.19	.16
Dorsiflexion	.20	.42*	.19	.17
SLBEO	.01	.23	.24	.14
SLBEC	-.22	-.23	-.22	-.28
Functional Reach	.13	.47*	.34*	.25*
Usual gait speed	.03	.10	.16	.24
Maximal gait speed	-.05	.21	.35*	-.10
Circuit walk	.19	-.02	-.47*	.17
Step height	.12	.12	.26*	.17

*$p<0.01$(2 tailed)

4.3 The development of functional limitations and physical performance

The third objective of the study was to investigate the development of limitations in functional ability and to evaluate the relationship with changes in physical performance over time. Derived variables measured the change in scores in physical performance and functional ability measures from the baseline assessment to the final assessment, held eight months following completion of the intervention period. The results obtained from the social and control group were analysed and totalled 69 data sets. Table 4.31 summarises the Spearman's rank correlation coefficient results.

Two significant correlations, at an alpha level of 0.01, were indicated between three variables. All correlations were below $r_s=.50$ and as such represent only fair relationships between the variables (Portney and Watkins, 1993). Correlations were observed between change in the need for assistance with physical ADL tasks and change in usual gait speed ($r_s=.46$) and between change in reported lower limb tiredness (LLT) and hip abduction muscle performance ($r_s=.35$).

Table 4.31 Correlation coefficients (Spearman's rho) between change in physical performance measures and change in functional ability scores (n=69)

	ULT change	LLT change	MT change	MH change	PADLH change
Shoulder abduction change	-.070	-.051	-.152	-.014	-.014
Hip abduction change	-.006	.350*	.071	.016	-.166
Knee flexion change	.081	-.013	.212	.033	.127
Dorsiflexion change	.052	.263	.153	.222	-.081
SLBEO change	-.038	-.083	-.064	-.135	.159
SLBEC change	.128	.094	.001	-.072	.026
Functional Reach change	-.156	-.065	.029	-.081	.184
Usual walk change	.217	.133	-.045	.149	.465*
Maximal walk change	.040	.250	-.154	.066	-.086
Circuit walk change	-.098	-.099	-.018	.050	.049
Step walk change	-.062	.134	-.083	.024	-.058

*$p<0.01$(2 tailed)

Overall, however, there were no significant and strong relationships between the development of limitations in functional ability and changes in physical performance measures, and as a result, the sixth hypothesis proposed for the study, cannot be accepted. One possible explanation for this finding relates to the lack of precision in measuring change of the outcome instruments used in the study. Additionally, this finding may suggest that other factors, not measured in the present study, relate more strongly to the development of functional limitations in older people.

4.4 Self-reports of Falls

The final objective of the study was to record self-reported falls in the study sample. Table 4.32 summarises the group distributions of subjects reporting falls at the first and the final assessments. This classification was based on the falls history reported by subjects at each formal assessment or notified on the monthly report of health completed by each subject for each month during the study. It should be noted that self-report of falls has been found to be an inaccurate measure of true falling behaviour (Cummings et al., 1988).

Within the exercise group, 48% of subjects reported one or more falls in the 12 months prior to the baseline assessment. At the final assessment, these reports

Table 4.32 Cross tabulation of self-reported falls at baseline and final assessment by intervention group

Assessment	GROUP			
	Exercise	Social	Control	Total
Baseline				
Falls history	19	14	14	47
No falls history	20	23	18	61
Total	39	37	32	108
Follow-up 8 months				
Falls history	20	24	21	65
No falls history	19	13	11	43
Total	39	37	32	108

had increased to 51%. Reports from the social group indicated that 38% of subjects at baseline and 65% at the final assessment reported falling. The control group reports indicated 44% and 68% of subjects fell respectively.

The final hypothesis for the study proposed that the falls rate for subjects would be similar to rates reported for similar age groups in the literature. While methodological issues plague the accurate reporting of falls in this age group, the rates reported by subjects involved in this study are similar to those reported by Blake et al., (1988) (one third of those aged 75+ years); Hill et al., (1999) (50% of active 70+ year old women) and Tinetti et al., (1988) (the majority of those 75+ years). The final hypothesis for the study can, therefore, be accepted, as falls rates in this study varied between 44% and 68%.

4.5 Summary

The effect of the intervention programs was examined using multivariate and univariate analyses for the dependent variables of physical performance and functional ability. The social intervention program did not significantly influence physical performance. The exercise intervention demonstrated significant influence on muscle performance, Functional Reach and maximal walk performance in the immediate post-intervention period and longer-term influence over Functional Reach and step height performance. The exercise intervention also demonstrated significant positive effects on all aspects of functional ability. ULT, LLT, MT and PADLH demonstrated immediate improvements, while MT and PADLH demonstrated longer-term benefits from exercise intervention. Results on the MH subscale did not immediately improve as a result of intervention, but participants of both the exercise and the social intervention were significantly better at assessments in the follow-up period than control subjects. The exercise program demonstrated significant immediate and longer-term benefits on aspects of physical performance and functional ability.

Correlational analyses indicated several significant associations between physical performance and functional ability. Moderate – strong associations were evident between shoulder muscle performance and ULT, and hip and lower limb muscle performance with LLT. Weak associations were evident between shoulder and hip abduction muscle performance and PADLH. These results indicate the significant relationship between proximal muscle performance and limb tiredness as well as dependence in physical ADL. The lack of clear associations between measures of physical performance and functional ability indicates the multidimensional nature of functional ability.

The relationship between change in physical performance and change in functional ability demonstrated weak associations. Changes in gait speed and ADL dependence and hip muscle performance and LLT demonstrated significance. These findings indicate that change over time was related to a host of factors, including physical performance measures, and again confirmed the multidimensional nature of functional ability in the elderly subjects. Falls reported throughout the study varied among groups at the baseline assessment (44%-48%) and the final assessment (51%-66%).

The elderly subjects in this study who participated in the exercise intervention benefited in both physical performance and functional ability, with mobility and ADL abilities still showing positive intervention effects 8 months following completion of the program.

CHAPTER FIVE

DISCUSSION

The study was designed to evaluate intervention effects on aspects of physical performance and functional ability in elderly subjects. Specifically, the study aimed to determine the effect of two intervention programs on physical performance and functional ability. One of the interventions was based on increased levels of exercise and the other based on increased social activity. In addition, the relationships between physical performance and functional ability and between changes in physical performance and the development of functional limitation were evaluated. Finally, self-reported falls in an elderly community-living population were recorded.

Data were collected at four points during the study. A baseline assessment was performed prior to the intervention phase, a post-intervention assessment performed immediately following completion of the 16-week intervention programs and two follow-up assessments, the first at four months and the second at eight months, following completion of the interventions. At each assessment, data were collected on aspects of physical performance (muscle, balance, gait speed and step height performance) and functional ability (Questionnaire of Functional Ability). In addition, falls reported each month by subjects were recorded.

Data related to subject loss and physical activity levels will be discussed initially, followed by physical performance and functional ability results. The relationship between measures of physical performance and functional ability will be highlighted prior to discussion of the development of limitations in functional ability and the relationship with changes in physical performance over time. Finally, falls data will be reviewed.

5.1 Subject Loss

The present study offered an initial period of intervention followed by an eight-month period of follow-up assessment.. The overall time of involvement for subjects in this study was 14 to 15 months. An initial cohort of 149 subjects was recruited and these subjects completed the baseline assessment. By the completion of the study, 14 or so months later, 108 subjects remained involved in the study. Forty-one subjects were lost during the study. Reasons for loss included hospitalisation (n=6), ill health (n=10), recuperation from surgery (n=2), move from community to care facility (n=5), move away from the Perth metropolitan area (n=2), unable to be contacted (n=6), deceased (n=7) and withdrawal from study by subject request (n=3).

Subject loss did not differ among groups. Subjects were not lost in significantly greater numbers from the exercise group (n=11), the social intervention group (n=13) or the control group (n=17). Further, results indicated that there were no significant differences between subjects who completed the study and those who did not complete the study on a range of variables including demographic, physical performance and functional ability data collected at the initial assessment.

Thus, while subject loss was expected and occurred throughout the study, analyses indicated that neither group assignment nor subject characteristics differed between those who completed the study and those who did not. Therefore, exclusion of data sets with missing data was an appropriate approach to statistical analysis for this study. The approach enabled the true physical and functional effects of the intervention programs to be demonstrated.

It should be noted, however, that subjects volunteered for participation in the study. Despite being recruited from the community-living cohort of older people, it must be acknowledged that the subjects who volunteered for this study may well have differed from those who did not volunteer. Volunteers have been reported to vary from non-volunteers on a range of variables including sex, age, socio-economic status, education and other less well defined correlates of health (McMurdo and Bennett, 1991). While not negating the validity of the results, the ability to generalise the results of this study to the overall community-living population aged 75 years and over may, therefore, be affected. Specific strategies were employed to minimise the effects of some of these variables by aiming recruitment efforts at both males and females separately and by offering transport to venues (to encourage participation of subjects who no longer drive or take public transport).

With this in mind, a further approach to analyses was taken. An intention to treat analysis was performed to ascertain the true population effects of the intervention program. The result of this analysis will be discussed following the discussion of the results of the initial analyses, performed with complete data.

5.2 Physical Activity Questionnaire

The basic assumptions related to physical activity levels during the study were two-fold. Firstly, that the exercise intervention would significantly increase physical activity levels among participants, while the social intervention program would not affect physical activity levels. Secondly, that in the absence of continuing exercise post-intervention, exercise group subjects would return to former physical activity levels. Thus, differences among groups were expected at the post-intervention assessment, but not at either of the follow-up assessments, at four and eight months later. Data collected from the Physical Activity Questionnaire (PAQ) were examined to ascertain physical activity levels of all participants throughout the study.

Results indicated that groups differed on PAQ results only at the post-intervention assessment and that exercise subjects reported significantly higher levels of physical activity at this assessment than subjects from the other two groups. There was no difference among groups at the baseline or either of the two follow-up assessments. These results confirm the effectiveness of the exercise intervention in significantly increasing physical activity levels in subjects during the intervention period. They also confirm that these higher levels of physical activity were not maintained following cessation of the exercise intervention. Thus, the validity of the follow-up assessments measuring post-intervention and potential detraining effects in physical performance and functional ability was established. Therefore, it was demonstrated that the physical activity levels of the exercise subjects were increased by the exercise intervention and decreased following cessation of the intervention. Data obtained at the follow-up assessment at 4 and 8 months can be confidently assumed to represent physical performance and functional ability performance in the absence of continued exercise among exercise intervention subjects.

It should be noted that levels of social activity post-intervention were not monitored and this lack of discrete information is a limitation of the study.

5.3 Intervention Programs

The intervention programs provided up to either 16 weeks (32 hours) of an exercise intervention program, based on increased levels of physical activity, or 13 weeks (26 hours) of a social intervention program, based on increased levels of social activity.

5.3.1 Physical Performance

Aspects of physical performance measured at each assessment were grouped into four domains. Muscle performance of both upper and lower limb muscle groups was assessed by hand-held dynamometry. Balance performance included static and dynamic tests. Gait speed variables involved usual and maximal gait speeds as well as performance on a novel test incorporating maximal speed and changes in direction. Step height performance measured maximal independent step height at specific heights of 10, 20, 30, 40 and 50cm.

Results of the study will be discussed in relation to each group of measures, rather than individual measures, where intervention effects were similar across the domain of measures. Where differences within a domain were demonstrated, results will be discussed in relation to individual variables.

5.3.1.1 Muscle Performance

The assessment of muscle performance involved four muscle groups – shoulder abduction, hip abduction, knee flexion and dorsiflexion. Isometric force of selected upper and lower limb muscle groups was measured using a hand-held dynamometer. The instrument used was a Nicholas Manual Muscle Tester[3], a hand held dynamometer. At each test, a 'break' assessment was used in which the assessor overcame the subject's maximal force.

This protocol was appropriate for the majority of subjects involved in the study. For several subjects with marked bony prominences, additional padding to the base of the manual muscle tester unit was required in order to both ensure subject comfort and to maintain skin integrity during testing. With additional padding in situ, these subjects were able to complete the testing protocol. A further testing problem was encountered with three stronger subjects when testing knee flexion, as the assessing physiotherapist was not able to overcome the muscle force exerted by the knee flexor muscle group. Additional stabilisation and assistance was provided but the accuracy of these data is questionable. The testing protocol may not have been sufficient to ascertain true measures in strong individuals. However, for the vast majority of subjects, the muscle performance testing protocol and the measuring device were appropriate.

---

[3] Model 01160, Lafayette Instrument Company, PO Box 5729,, 3700 Sagmore Parkway North, Lafayette, Indiana, USA 47903

As the results of each of the four muscle groups over time were similar, muscle performance will be discussed as a single variable. There were no differences among groups at the baseline assessment. A significant interaction, indicating that the exercise group experienced gains in muscle performance during the intervention phase, was evident, as was a significant group difference for exercise subjects at the post-intervention assessment. Following the completion of the intervention assessment, there was a further significant interaction, this time indicating that the exercise subjects were losing the intervention gains in muscle performance. At each of the follow-up assessments there were no differences among groups for muscle performance.

Clearly, the exercise intervention was effective at improving the muscle performance of participants. The magnitude of the increases in muscle performance was specific to each muscle group with shoulder abduction increasing by approximately 38%, hip abduction by approximately 24%, knee flexion by 20% and dorsiflexion by approximately 17%. However, these improvements did not extend past the completion of the intervention program, and detraining was evident four months later. There were no extended benefits following cessation of the exercise program. The social intervention had no effect on muscle performance.

Baseline muscle performance values obtained in this study exceed values previously reported (Andrews et al., 1996) for shoulder abduction but generally agree with values reported for hip abduction, knee flexion and dorsiflexion. Andrews et al., (1996) reported gender specific values in a group aged 70-79 years. Gender comparisons of muscle performance values were not a focus of the current study. The higher values of shoulder abduction in the present study population, mainly female, are in direct contrast to the earlier reported values and are more than double the results quoted for the females of this age group. Both this study and results reported by Andrews et al., (1996) were collected from approximately 150 elderly subjects. It is unclear how well matched these two populations may be in terms of living arrangements, physical independence and physical activity levels. The data collected for this present study offer additional normative data for the group aged 75 years and over.

The distinct training and detraining effect of the exercise intervention on muscle performance noted in this study is not a surprising finding. Designed along specific guidelines as a program to increase muscle performance (Mazzeo et al., 1998; Pollock et al., 1998), each participant performed resisted muscle exercises according to their baseline muscle performance data. In addition, the amount of resistance used was frequently upgraded (not less than every two weeks) in response to increased performance. Muscle performance, particularly strength and endurance, are known to develop by progressive overload (Pollock et al., 1998). Greater resistance than usual, which is individualised and progressive, during muscle work, results in improvement in muscle performance at all ages, and particularly in individuals whose muscles work at low thresholds of resistance during everyday activities (Twomey and Taylor, 1984).

The significant results for muscle performance in the present study indicate that the resistance exercises offered to exercise participants provided enough resistance to overload the muscle and result in improved muscle performance. Based on the known physiological and physical effects of resistance muscle training (Pollock et al., 1998), these results were expected to be significant at the post-intervention assessment. Similarly, in the absence of continuing exercise, loss of these muscle gains was expected to occur. Again, as is suggested by the known physiological and physical effects of cessation of resistive muscle exercise, exercise gains were lost. This pattern of training and detraining was expected in this study and provides the basis for determination of the longer-term effects of exercise on functional ability.

Muscle strengthening programs are perhaps the most common of all of exercise programs prescribed for older people. Gains in muscle strength are widely acknowledged to result from appropriately designed and progressed resistance exercise programs. Muscle strength is also a frequently investigated outcome for exercise intervention studies. Randomised controlled exercise studies, designed to minimise the impact of impairments (of which muscle performance is one) and/or functional limitations, in older people have frequently included muscle strengthening as a component of the intervention program (Ades et al., 1996; Buchner, Cress and De Lateur, 1997; Cress et al., 1999; Jette et al., 1996; Jette et al., 1999; Judge et al., 1994; King et al., 2000; Lord et al., 1995; Lord et al., 1996; McMurdo and Bennett, 1991; Rooks et al., 1997; Rubenstein et al., 2000; Sharpe et al., 1997; Skelton et al., 1995; Wolfson et al., 1996).

Varying protocols have been reported for muscle strengthening programs for older participants. Studies using "low tech" equipment, such as sand bags, bodyweight resistance and elastic tubing, (Skelton et al., 1995; Jette et al., 1999; King et al., 2000; Lord et al., 1996; Rooks et al., 1997; Rubenstein et al., 2000; Sharpe et al., 1997) demonstrate results similar to studies using isokinetic training devices and resistive machines, (Ades et al., 1996; Buchner et al., 1997; Cress et al., 1999) as long as the prescribed weight is significantly greater than the usual resistance under which the muscle group operates in everyday activities.

The length of exercise intervention is one variable of importance when designing programs aimed at improving muscle performance. While programs of 12 months' duration have shown significant muscle performance gains (King et al., 2000; Lord et al., 1995; Sharpe et al., 1997) so have programs of approximately 22 weeks in duration (Cress et al., 1999; Buchner et al., 1997; Jette et al., 1999; Lord et al., 1996; Rooks et al., 1997) and those of 12 weeks in duration (Ades et al., 1996; Rubenstein et al., 2000; Jette et al., 1996; Judge et al., 1994; Skelton et al., 1995). The current study utilised a 16-week intervention phase to ensure that physiological adaptation to resistance had occurred in elderly subjects. Interestingly, the results cited by Lord et al., (1995) indicated that by the end of the 12 month intervention not all muscle strength improvement had plateaued and that for hip flexion particularly, further improvement may well have been possible. It appears that lengthy interventions with older subjects may well offer continuing muscle performance improvements if the program continues past the point where physiological adaptation to the exercise program has occurred (Lord et al., 1995). However, the results of this study indicate that significant muscle performance gains can be achieved in 16 weeks of appropriate intervention.

There is scant literature describing detraining effects on muscle performance in elderly individuals. In the present study, immediate detraining occurred in every tested muscle group within four months, with performance values returning to baseline and no significant differences evident among groups. One of the FISCIT trials (Wolfson et al., 1996) investigated the influence of a maintenance program of Tai-Chi following an intervention program focussed on strength and balance outcomes. This novel intervention was able to maintain the gains from the exercise program. The design of the present study was such that continued physical activity was not encouraged in exercise participants past the end of the formal intervention program and, within four months, exercise subjects were no more or less active than other subjects. Observation of the effects of the cessation of exercise on muscle performance, as well as a range of other variable, has been unique to the present study.

5.3.1.2 Balance Performance

Balance performance was assessed on three measures. The maintenance of a static position with a reduced base of support was assessed by single limb balance tests. Two visual conditions were included. The first test involved single limb balance using vision and the second test removed vision as a sensory input. The third balance test, Functional Reach, tests the limits of stability in an anterior direction by placing the subject in maximal forward reach on a fixed base of support. All three tests proved suitable for use with the community living population aged 75 years and older.

Both single limb balance tests were time limited. When eyes were open, a cut-off time of 30 seconds was used and when eyes were closed, a cut-off time of 10 seconds was used. Both of these limits proved appropriate. No subjects were able to exceed these limits at any assessment. For the population aged 75 years and over, limits of 30 seconds and 10 seconds respectively seem appropriate for the clinical setting. Specific guidelines describing end points for the tests (beyond the inability to continue standing on one leg) such as excessive body sway or use of arms to maintain balance, would be useful to ensure the reliability and validity of single limb tests. However, the single limb, eyes closed test was difficult to perform for subjects with moderate balance impairment and was associated with anxiety in a subgroup of the sample. This finding proved useful in the present study as it provided a clear indicator of impaired balance ability. The Functional Reach test also proved appropriate for use with the study population. Specifically designed for the older population, it was a test easily understood and performed by the majority of subjects. The required position standing next to, but not touching, the wall provided additional 'moral' support for subjects with balance impairment.

Intervention effects on the tests of balance performance were not similar between tests. Therefore, the results of each test will be summarised and discussed in order. However, there were no differences among groups on any measure of balance at the baseline assessment, indicating that balance performance among the study sample was uniformly distributed amongst groups.

The intervention programs were not successful in improving single limb balance performance. While the interaction over time for exercise participants (during the intervention phase) demonstrated significance, indicating improving performance, there was no significant group effect at the post-intervention assessment. In fact, there were no significant group differences evident at any assessment. The social intervention program did not influence SLBEO performance. During the follow-up period, all three groups showed similar declines over time. Therefore, it can be concluded that neither the exercise nor social intervention influenced SLBEO performance, either immediately or in the longer-term.

The SLBEC test places increased reliance on two of the three sensory systems involved in the maintenance of balance. With vision occluded, afferent information is supplied by the somatosensory and proprioceptive systems. Performance of SLBEC did not improve following either exercise or social intervention. The effect of the exercise intervention program negatively influenced SLBEC performance. At the post-intervention assessment, the exercise group demonstrated significantly poorer performance than the other two groups. This group continued to demonstrate significantly poorer performance at each of the post-intervention assessments. At the post-intervention assessment and both follow-up assessments, SLBEC performance did not differ between the social intervention group and the control group. While the social intervention program did not influence performance, the exercise intervention demonstrated a significant immediate and longer-term detrimental effect on SLBEC performance.

The Functional Reach performance data obtained at the baseline assessment did not demonstrate differences among groups. In contrast to the result of the two static balance tests (SLBEO and SLBEC), where intervention did not result in improved performance, exercise group subjects demonstrated significantly improved Functional Reach performance at the post-intervention assessment. Further significant interactions were evident in the first four months following cessation of the exercise program, as the exercise group maintained performance, while both social and control groups demonstrated time related declines. Four months post-intervention, at the first follow-up assessment, the improved Functional Reach performance demonstrated by exercise participants at post-intervention, was still evident. These subjects had significantly better Functional Reach performance than subjects from either of the other two groups. Over the second four months, however, the performance of the exercise group declined and at the final assessment, eight months following completion of the exercise intervention, there was again no difference among groups. The social intervention program did not influence Functional Reach performance at either the post-intervention assessment, or either of the follow-up assessments.

The baseline results for SLBEO were not different among groups and group average times raged from 17.4 – 22.1 seconds. The results from this study however, exceed the values reported in general for this test (Briggs et al., 1989; Bohannon et al., 1984; Frandin et al., 1995; Heitmann et al., 1989; Wolfson et al., 1996). However, little specific information is available about the sample population used in other studies and the usual age ranges reported do not easily translate to the age group involved in the present study. Similar values have been reported from study samples with similar ages and characteristics (Rooks et al., 1997; Furuna et al., 1998).

It is plausible that static balance ability relies more on sensory inputs and automatic adjustments to maintain position. Postural sway in this position may not be affected by improved muscle strength as the effectiveness of adjustments to maintain position relies on automatic mechanisms rather than maximal voluntary contractions. Therefore, an intervention program may not be effective unless the sensory mechanisms and automatic reactions are trained specifically. This theory is supported by Heitmann et al., (1989) who postulates a strong learning effect for single limb balance tests. While the assessment protocol in the present study minimized learning effects during assessment, single limb balance was not specifically trained in the exercise intervention.

Baseline values for SLBEC performance collected in this study indicated group mean scores between 4.6 and 6.3 seconds, which is comparable to results cited by Bohannon et al., (1984) and a little better than the times reported by Briggs et al., (1989) and Rooks et al., (1997). This test has not been commonly used with older subjects, probably because of concerns about balance impairment and the potential for falling and consequent injury. Again, specific guidelines concerning the end points of the test (in addition to the foot touching the ground) would be useful if this test were to be commonly used in the clinical setting. The information gained from comparison of SLBEO and SLBEC results, indicates that individuals rely on the visual system for balance information. As visual changes are very common with advancing age, information about the role of visual problems in balance can be useful in the clinical setting. As a research measure, balance tests with occluded vision allow for some differentiation of each of the three input systems for balance performance.

Results of the Functional Reach test provided group mean data that ranged from 25.2 to 26.8 cm. Comparable values have been reported for similarly aged female subjects (Duncan et al., 1990) and for control subjects (Duncan et al., 1992; Weiner et al., 1993). Some studies have used the Functional Reach test to identify elderly subjects with balance impairments related to falls or high and low levels of physical functioning. Reports of these findings have demonstrated higher values for non-fallers and for higher functioning individuals (Duncan et al., 1992; O' Brien et al., 1996). As falls was not a variable of primary interest in this study, baseline results for Functional Reach were not grouped according to fall history although it was known that the study sample included both those with a history of falls as well as those with no history. The baseline values obtained in the present study are in general agreement with those of Duncan et al., (1990); Duncan et al., (1992), O'Brien et al., (1996) and Weiner et al., (1993).

Improved performance on SLBEC would appear to rely on more efficient sensory mechanisms, especially as the performance of the same test with vision did not improve with exercise intervention. To be effective, intervention would need to improve on the potentially age related changes in the somotosensory and proprioceptive systems. The results of this study indicate that this did not happen as a consequence of the exercise intervention program. There was no positive effect of exercise on SLBEC performance.

Performance deteriorated in exercise subjects and was significantly poorer than for other subjects at each of the three assessments following intervention. Exercise subjects were still significantly worse up to eight months post-intervention. There is no clear explanation for this finding. It is possible that exercise subjects became more reliant on visual input during the intervention phase, especially as many of the exercises and activities were novel and required concentration and visual input for both learning and execution. Thus, reliance on vision may have increased for these subjects in the short term. It may also be possible that subjects participating in the exercise program became more aware of safety as an issue and felt particularly vulnerable when unable to rely on visual input. However, neither of these two theories can account for the significantly poorer performance demonstrated by exercise subjects at both four and eight months following intervention.

Improved performance on Functional Reach by exercise subjects indicates that the intervention was effective in this area. Functional Reach measures the limits of stability, a measure that is more clearly related to functional tasks and everyday activities than the maintenance of static postures. The ability to move effectively and safely within balance limits is important to continued independent function. The exercise intervention was successful in increasing the limits of stability and therefore allowing subjects more excursion in balance. Improved Functional Reach performance as a result of the exercise intervention in the present study was comparable to results reported by Cress et al., (1999) who also reported significant change in performance as a result of combined endurance and strength exercise training over a six month period in subjects aged 70 years and older.

Static balance performance did not improve as a result of the exercise intervention. This was probably largely due to age related deficits in the sensory mechanisms which did not respond to an intervention program. Dynamic balance performance, however, did improve as a result of exercise intervention. Both immediate and longer term benefits (for four months) were evident. Immediate detraining of balance did not occur. This result suggests that an exercise intervention can maximize balance in an older person by increasing their limits of stability.

5.3.1.3 Walk Performance

Three variables, usual speed, maximal speed and performance on a circuit test, were examined in relation to walk performance. Gait speeds were calculated from the time taken to traverse a 10 metre walking course. The circuit test involved the completion of five laps of a 10 metre course walked at maximal pace. As results for usual gait speed are different from those of the other two variables, they will be discussed separately.

All three tests of walking performance used in the study proved to be appropriate to the elderly study population. The two tests related to walking speed were easily understood and performed by subjects. As each related to an individual's choice of walking speed, the tests proved suitable for use with individuals across a broad range of physical ability. The third test, the circuit walk, was a novel test. Specifically designed for this study as a measure combining multiple elements of maximal walking speed, turning around to change direction and the associated deceleration (followed by acceleration), it was proposed that the circuit walking test might prove more useful as a measure of physical performance over time than walking speeds alone. As a novel test, there is no known literature discussing the impact of ageing on performance, such as reports of normative age related data or intervention effects. Discussion of the results will therefore be limited to those demonstrated in the present study.

Neither the exercise nor the social intervention programs influenced usual gait speed. There was no significant difference among groups at any assessment during the study. The exercise intervention program did not result in improved speed when subjects chose their preferred speed. Therefore, it can be concluded that neither increased levels of exercise nor social activity affect usual walking speed.

By contrast, results of both maximal speed and circuit performance improved as a result of the exercise intervention. With no difference among groups at baseline, and a significant group difference noted at the post-intervention assessment for both measures for the exercise group, it can be concluded that the exercise intervention successfully improved performance on both variables. The circuit test consisted of laps walked at maximal speed with additional turns each five metres. It is, therefore, not unexpected that when maximal gait speed increases significantly that there may also be a positive effect on circuit walk results. Improved performance, however, would also be indicative of improved dynamic balance abilities in order that the 180° turns required at the end of each five metre lap could be made efficiently. In addition, the ability to decelerate while approaching turns and accelerate once the turn was completed were required components of execution.

Neither maximal speed nor circuit walk performance demonstrated immediate detraining effects following completion of the exercise program. Rather the enhanced performance demonstrated post-intervention was maintained for a further four months. At the follow-up four-month assessment, both variables demonstrated that the gains made as a result of the exercise intervention were maintained. The performance of the exercise group was again significantly different from the other two groups. However, by the final follow-up assessment, eight months following completion of the intervention program, these differences were no longer evident. The improved performance of maximal speed and circuit test were no longer evident as there was no difference among groups. Therefore, the intervention gains were maintained for a further four, but not eight, months following cessation of the program.

The baseline results obtained in this study for walking speeds in elderly subjects indicated a mean usual walking speed at baseline of 0.92-0.94 m/s. Group mean scores for maximal gait speed were 1.40-1.55 m/s. Reports from Scandinavia indicate a speed of 1.14 m/s is required in order to safely cross roads (Avlund et al., 1995a). Thus, the majority of subjects demonstrated gait speeds comparable with reported requirements for aspects of community living. Walking speeds for subjects aged over 75 years have been reported. Usual gait speeds of 1.08±0.19 m/s and maximal speeds of 1.58±0.28 m/s were noted at baseline in a study designed to evaluate the effect of strength and balance exercises on strength (Judge et al., 1994). An Australian study has reported gait speeds of 1.12 m/s for a group of female subjects with a mean age of 71.1 (±5.2) years (Lord et al., 1996). The current study sample outperformed this group, perhaps because it was a mixed gender group. Most research into gait in older people has, to date, investigated its relationship to falls (Stalenhof et al., 1999) or specific age related aspects of gait, such as obstacle negotiation (Chen et al., 1991) and reactions times related to unanticipated changes of directions (Cao et al., 1997). There is no doubt, however, that age related deterioration in gait speed occurs, reportedly about the age of 62 years (Himann et al., 1987). As the subjects involved in the present study were aged 75 years and older, further deterioration in gait speeds may well have been evident. In subjects older than 62 years, walking speeds in females reportedly declined at a rate of 12.4% per decade compared with a 16.1% per decade loss for males (Himann et al., 1987).

The present study did not demonstrate an improvement in usual gait speeds as a result of the exercise intervention program. Usual gait speed did not respond to improvements in physical performance such as lower limb strength gains and dynamic balance improvements. This suggests that usual gait speed is not directly related to these other aspects of physical performance. A similar result has been reported by Cress et al., (1999) as subjects, with a mean age of 76(±4) years, did not demonstrate usual gait speed changes in response to a six month exercise intervention program. Buchner at al., (1997) also reportedly failed to influence usual gait speed significantly following a 26 week supervised exercise program for elderly subjects. In contrast, Judge et al., (1994) reported significant improvements in usual gait speed in response to resistive exercise, but not balance exercise. However, it should be noted that control subjects also demonstrated improvements in usual gait speed performance. Therefore, this finding must be interpreted with caution. Lord et al., (1996) demonstrated changes in gait speed as a result of intervention, but concluded that subjects with slow speeds were most likely to improve while those with normal speeds were unlikely to improve as a result of exercise. In the face of these conflicting results, the present study did not influence usual gait speeds. The influence of exercise and other factors on usual gait speed warrants further investigation that may elucidate the mechanism by which changes in usual gait speed occur so that specific intervention may be directed toward influencing those mechanisms.

Maximal gait speed demonstrated significant improvement as a result of the exercise intervention. Participation in a 16 week exercise program improved maximal gait speed and these gains remained significant for a further four months. Reports of the effect of exercise based interventions on maximal gait speed are limited. Judge et al., (1994), despite finding that usual gait speed improved following exercise, reported that maximal gait speed was not influenced by the intervention and concluded that gains were possibly only in subjects with marked limitations prior to commencing exercise. Similar to conclusions made by Lord et al., (1996), it may be feasible that exercise gains in muscle and balance performance translate into improved gait speeds for elderly individuals with poor levels of function and not for those unencumbered by disability or disease.

The maintenance of the intervention gains for a further four months post-intervention was a surprising finding. In the absence of continuing exercise, exercise participants maintained maximal gait speeds for four months before significant deterioration occurred. This enhanced performance was maintained in the face of deteriorating muscle performance immediately post-intervention. It may, therefore, be assumed that in this study, improvements in maximal gait speed occurred independently of muscle performance gains. Dynamic balance performance demonstrated post-intervention maintenance of gains in a similar fashion to maximal gait speed. The results of the second follow-up assessment indicated that both dynamic balance and maximal gait speed performance was not maintained for eight months post-intervention. The relationship between balance parameters and maximal gait speed warrants further investigation, especially as high gait speeds are required to maintain community level mobility tasks (Avlund et al., 1995a) and poor balance and gait are major risk factors for falls in elderly people (Tinetti et al., 1988; Nevitt et al., 1989).

The ability to walk at maximal speeds and turn to change directions was evaluated by the circuit walk test. Results indicated a similar pattern of change in response to exercise intervention for the circuit test performance as for maximal gait speed and dynamic balance performance. All measures significantly improved following exercise intervention and maintained this improved performance for four but not eight months. As a new test, the circuit walk test can be recommended as a more functionally oriented test than the calculation of walking speed alone, as it includes aspects of the real life demands often experienced during walking. The exercise intervention successfully improved performance on this test, which is not surprising given that the two main components of the test, dynamic balance performance and maximal gait speed, also improved. Similar patterns of deterioration were also evident. There may well be a relationship between the post-intervention maintenance of dynamic balance and maximal gait speed and the functional demands of gait in everyday living. As dynamic balance improved, exercise subjects may have felt more able, and perhaps more confident, to perform more demanding balance tasks (Vellas et al., 1997a). This is turn allowed for the maintenance of higher gait speeds and circuit walk performance. The influence of increased confidence and its related self-efficacy cannot be ascertained from the results of this study. However, it is a vital area for further investigation that may aid in the provision of successful exercise interventions aimed at improving physical performance for elderly community living people.

5.3.1.4 Step Height Performance

The step height test assesses the maximal height, from 0 – 50 cm, able to be completed safely without additional upper limb or hand support. As a relatively unknown test, the available literature is limited.

The step height test was challenging for most of the elderly subjects involved in the study. As no arm support was allowed, many subjects expressed anxiety when asked to perform at the higher step levels of 40 and 50 cm. Several subjects declined to proceed higher after achieving the 30 cm step height. These subjects consistently reported a fear of falling while completing the task. Therefore, performance of the step height test was occasionally limited by other psychological factors. In general however, the test was safe with supervision offered by a physiotherapist or physiotherapy student, and completed by the majority of subjects at each assessment.

Baseline assessment results indicated that there was no difference amongst groups on initial step height performance. During the intervention period, a significant interaction was demonstrated indicating that exercise group subjects were improving performance, whilst the other two groups remained static. At the post-intervention assessment, there was a significant group difference between the exercise group and the other two groups, with exercise subjects performing significantly better than the other subjects. By the first follow-up assessment at four months, however, the intervention gains had been lost and again there was no difference in performance amongst groups. Thus, the exercise intervention had an immediate and significant effect on step height performance, which was lost on cessation of the intervention program. The social intervention program did not influence step height performance.

The results of step height performance were normalised by lower limb length to control for the obvious advantage of longer lower limbs. As a result, the data obtained in this study differs from that reported by Avlund et al., (1996). These authors reported that about half of women and more than three-quarters of men aged 75 years and over were able to complete the 40 cm step. Review of initial data indicated that these results were similar to those obtained by their study. The small number of men involved in the present study all achieved 30cm or higher with the vast majority achieving 40cm or higher. In contrast, only one-third of the women in the present study achieved 40cm or higher.

The results of this study indicate that the exercise intervention significantly influenced performance of maximal step height, a test involving strength and balance as well as a number of other performance variables. As strength and dynamic balance improved as a result of exercise, so did step height performance. This gain however detrained significantly immediately post-intervention and, by the four month assessment, was lost. Thus, muscle performance may be significantly related to performance of step height. Exercise intervention resulted in both muscle and step height performance improvements. Cessation of exercise intervention resulted in immediate detraining of both domains. Post-intervention improvements in other areas of physical performance, such as dynamic balance and maximal gait speed, did not appear to influence performance on the step height test in the post-intervention period.

5.3.1.5 Summary

The exercise intervention was effective in producing a number of changes in physical performance measures. All muscle performance variables significantly improved, in line with findings in the literature, as program frequency and intensity as well as the design of the resistance program, enabled muscle performance gains to be consolidated. A 16 week program of twice weekly supervised exercise and a home program facilitated these changes.

While static balance abilities were not enhanced by the exercise program (and performance of a single limb balance test with vision occluded deteriorated), dynamic balance ability, measured on the Functional Reach test, improved in response to the intervention and these gains were maintained for a further four months. Few reports have evaluated intervention changes in Functional Reach in community-living elderly people. The baseline values demonstrated by subjects were in general agreement with values reported in the literature for similar populations. The mechanism by which dynamic balance abilities were maintained for four months is unable to be clearly elucidated by the data collected in this study. As a number of other physical performance and functional ability measures demonstrated similar post-intervention maintenance, one mechanism appears to be the translation of improved balance abilities into everyday physical and functional activities. The use of these enhanced abilities may well have provided a suitable threshold to overcome the expected detraining effects usually seen clinically in elderly subjects.

Walk performance also varied throughout the study in relation to the exercise intervention program. Usual walk performance was not affected by exercise. Both maximal gait speed and performance on the circuit walk test were improved following the exercise intervention and remained at this level for a four-month period. This maintenance of the exercise induced gains has not been previously reported. The mechanism by which this occurred appears to be the same as that suggested for maintenance of dynamic balance abilities. This translation into everyday activities maintained performance for a further four, but not eight, months post-intervention.

Maximal step height results suggest that this test relies on lower limb muscle performance. Improvements were evident post-intervention but not maintained in the face of detraining of muscle performance in the post-intervention period. The step height test was also the most challenging test for a number of subjects. This test may well prove to be useful in the clinical setting as an indicator of both muscle performance and confidence in physical abilities.

5.3.2 Functional ability

Functional ability was assessed using the Questionnaire of Functional Ability (QFA). Scores for this instrument were calculated to give results on five subscales, each representing a specific area of functional ability relevant to an older community-living person. The specific scales are Upper Limb Tiredness (ULT), Lower Limb Tiredness (LLT), Mobility Tiredness (MT), Mobility Help (MH) and Physical Activities of Daily Living Help (PADLH). Avlund et al., (1995) reported a significant age related loss in functional ability in relation to scores on all five subscales of the QFA. The results of each subscale will be summarised and discussed individually.

There are no reports of intervention studies using scores on the QFA to measure intervention effects. However, there is some information available that relates functional ability scored on the QFA to physical performance. The present study is the first to discuss the effects of an exercise or social intervention program on levels of functional ability using the QFA subscale scores as an outcome measure. Therefore, discussion of the effects of intervention as described in this study will be limited because of the lack of published information for comparison.

5.3.2.1 Upper Limb Tiredness

The Upper Limb Tiredness subscale of the QFA measures the extent to which tiredness is experienced during functional activities involving the upper limbs (e.g. washing and grooming of the upper part of the body). Tiredness in this regard can only be rated if the activity can be performed independently. Thus, only subjects independent in upper limb activities are able to score on this subscale.

There was no difference among groups on ULT scores at the baseline assessment of this study. During the intervention period, a significant interaction demonstrated that exercise subjects were improving scores, while the other two groups remained unchanged. At the post-intervention assessment, there was a significant group difference between the exercise group and the other two groups, with the exercise subjects reporting less tiredness of the upper limbs during functional activities. Following completion of the intervention phase, there was a further significant interaction, indicating loss of the intervention effects, and at the first follow-up assessment there was no difference among groups. In the absence of continuing exercise, intervention gains were not maintained and ULT scores were again not different among groups. The social intervention program had no effect on ULT scores.

Baseline results indicated group mean scores ranging from 2.8 - 3.4 out of a total possible score of 4, thus indicating some influence of tiredness during functional tasks of the upper limb for most subjects. While the scores of ULT have been proven to be the poorest discriminator of general function in a similar population, reports indicate that 89% of 70 year old people achieve the maximal score for ULT, indicating no effect of tiredness during upper limb functional tasks (Avlund et al., 1995a). At age 75 years, 71% of community-living people reported no tiredness during upper limb activities and scored the maximum score for ULT (Avlund et al., 1996). Deterioration in ULT scores occurred in 24% of women and 13% of men (Avlund et al., 1995a). ULT scores may therefore highlight changes that occur later in old age and serve as markers of impending frailty. Subjects in this study were aged 75 years or more, and likely to be experiencing some declines in their upper limb functional ability.

The ULT results indicate that tiredness of the upper limbs during functional tasks improved as a result of the exercise intervention. Following cessation of the exercise intervention, ULT scores also deteriorated. Many functional activities performed by the upper limbs rely on the proximal stability offered by the shoulder girdle musculature, of which the shoulder abduction group is part. Thus, improvement in regional muscle performance is likely to be associated with improved stability of the shoulder girdle and an increased ability to stabilize the upper limb during functional activities. The results of muscle performance discussed earlier which indicated that shoulder abduction muscle performance increased significantly as a result of intervention, and that the exercise group subjects were significantly better than other subjects at the post-intervention assessment, appear to be the most important. In the post intervention period these gains were lost due to detraining and at the follow-up assessment at four months there was no difference among groups. Thus, scores for ULT and performance of the shoulder abduction muscle group were similar over time and in response to intervention, highlighting a potential relationship between muscle performance and tiredness of the upper limbs during functional activities.

The relationship between ULT scores and muscle strength has been shown to be significant in community-living older people (Avlund et al., 1996). Therefore, as muscle strength changes (for whatever reason), ULT scores are also likely to change. This phenomenon was observed in the present study. As exercise participants experienced increased muscle performance, their ULT scores also improved. Social intervention subjects did not experience any changes in muscle performance. Therefore, their ULT scores did not change during the intervention period. This pattern was also noted in the control group subjects. Significant changes in upper limb muscle performance were associated with significant changes in ULT scores in the present study.

Appropriate exercise, therefore, can be recommended as a strategy to minimise functional limitation related to upper limb activities. Improvements in muscle performance, which were evident within 16 weeks, resulted in improved ULT scores. Cessation of the intervention, which led to significant muscle performance losses, back to near baseline levels, was also associated with loss on the exercise induced gains in ULT. Muscle performance, rather than other aspects of physical performance appears to have been responsible for the ULT changes. Improvements in balance and walk performance were maintained for four months post-intervention but ULT improvements had been lost by this time.

The results of this study, therefore, indicate that upper limb functional activities are frequently affected by tiredness in those aged 75 years and older.

Upper limb tiredness has shown a significant improvement in response to an exercise intervention, while the social intervention has demonstrated no effect. Scores on ULT improved in relation to increased muscle performance and decreased in response to declines in performance. As such, exercise aimed at improving performance of upper limb muscle groups is one strategy that may minimise age related losses in the performance of functional activities involving the upper limbs.

5.3.2.2 Lower Limb Tiredness

The Lower Limb Tiredness (LLT) subscale of the QFA determines the influence of tiredness during functional activities involving the lower limbs, such as putting on and taking off shoes, washing the lower limbs and cutting toenails. Tiredness of the lower limb rates only activities in which the subject can perform independently.

A similar pattern, to that demonstrated for ULT, was evident for LLT. While there was no group difference evident at baseline, exercise participants improved their scores throughout the intervention phase and reported significantly less tiredness at the post-intervention assessment than subjects from the other two groups. By the first follow-up assessment, four months later, there was again no group difference as exercise subjects had lost their improved functional activity in the absence of continuing exercise. The social intervention did not influence scores on LLT. Thus, participation on the exercise program significantly reduced the influence of tiredness of the lower limbs during functional activities, but this improvement was not maintained following cessation of the program.

Baseline results for LLT varied from a group mean score of 3.3 to 3.5. While there are no other data available for comparison, ceiling effects of LLT have been reported. Seventy-seven percent of subjects aged 70 years scored the highest maximum score of 5 on this scale (Avlund et al., 1995a), decreasing to 53% five years later (Avlund et al., 1996). The baseline results reported in the present study indicate that the majority of subjects, aged 75 years and over, were reporting tiredness affecting some functional activities involving the lower limbs.

The results obtained for LLT throughout the present study demonstrates that the exercise intervention significantly decreased the influence of tiredness on lower limb tasks. This effect diminished significantly on cessation of exercise. This result mirrors those reported for upper limb muscle performance. The relationship between LLT scores and muscle performance of the lower limb, was similar to that observed in the upper limb. Performance improved in all three lower limb muscle groups assessed, as a result of intervention, and deteriorated in response to exercise cessation. Improved muscle performance was, therefore, associated with diminished tiredness in lower limb functional tasks.

A relationship between increased muscle strength and improved LLT scores has been reported in community-living older people (Avlund et al., 1994) (Avlund et al., 1996). Subjects with higher strength in lower limb muscles reported significantly less tiredness of the lower limbs. Improved muscle performance, as demonstrated in the present study, may, therefore, be expected to enhance LLT scores, and this was confirmed. Cessation of the exercise intervention was also related to changes in LLT scores. Exercise subjects reported increased tiredness four months post-intervention. Other aspects of physical performance (balance, gait, step) also improved during the intervention period. Many of these changes, were, however, still maintained four months post cessation of exercise and are, therefore, not directly related to the reports of increased tiredness post-intervention.

An individualised exercise program improved LLT and can therefore be recommended as a strategy to minimse lower limb functional limitation in elderly people. The present results demonstrate that functional limitations can be minimised following a 16 week period of exercise intervention. These benefits do not, however, endure following cessation of exercise. Decreased activity is associated with losses of the exercise induced gains.

General exercise should be recommended as an effective approach to minimising increasing tiredness during functional activities of both the upper and lower limb for community-living older people.

5.3.2.3 Mobility Tiredness

The Mobility Tiredness subscale measured the influence of tiredness on mobility tasks such as transfers, walking indoors and outdoors and stairs. Results obtained on this subscale demonstrated a different pattern throughout the study than both limb tiredness scores.

At the baseline assessment there was no difference among groups. A significant interaction during the intervention phase of the study indicated that tiredness was improving for exercise subjects and at the post-intervention assessment, exercise participants reported significantly less tiredness during mobility tasks than subjects from either of the other two groups. At each of the follow-up assessments, four and eight months later, this group difference remained evident. Results indicated no further interactions. Therefore, the exercise induced gains in Mobility Tiredness scores were not lost following cessation of exercise. The exercise intervention improved MT scores and this improvement was maintained for eight months following completion of the exercise program. The social program did not influence tiredness during mobility tasks.

It has been reported that performance of mobility tasks is the most problematic dimension of functional ability in people aged 75 years of age and older (Avlund et al., 1994). Only 47% of 70 year olds attained the highest possible score for MT in a Danish study of 70 year old people (Avlund et al., 1996), which decreased to 33% in the following five years (Avlund et al., 1996). In the present study, group mean MT scores at baseline were 5.1 – 5.3, from a total possible of 7. Thus, many of the subjects were experiencing some tiredness during mobility tasks.

Poor walking ability has been shown to be associated with poorer scores for the MT subscale (Avlund et al., 1994). The performance of mobility relies on a number of factors including muscle performance, balance ability and possibly gait speed. As participation in the exercise intervention resulted in improvements in aspects of all three of these variables, it is likely that the influence of tiredness during mobility tasks might also improve. Muscle performance improvements were lost immediately on cessation of the intervention. However, improvements in Functional Reach performance (a balance measure) and maximal gait speed were maintained in the absence of continuing intervention. The exercise group was significantly better at the initial follow-up assessment (four months post-intervention) on Functional Reach and maximal gait speed measures. These continued performances may well have been the mechanism by which improvement in tiredness during mobility tasks was also maintained for four months post-intervention. The results of this study indicate that muscle performance improvements alone are not associated with improved MT performance since these gains were lost by four months whereas MT gains were maintained for a period of eight months.

There may be a multitude of reasons for tiredness during functional tasks including chronic diseases, coexisting conditions, declines in physiological reserve, psychological factors, physical inactivity or advanced age. A Danish study has identified tiredness during mobility as strongly predictive of disability in the following five years (Avlund et al., 1998a). The ability to remain mobile is fundamental to overall functioning and the maintenance of independence in old age. Poor gait has been identified as a risk factor for falls and hip fracture in the elderly population (Nevitt et al., 1989). Potentially, tiredness during mobility, resulting in poor quality, including poor foot clearance, may well be associated with specific gait risk factors.

Mobility is a higher domain function than ADL and should be assessed in community-based studies (Avlund and Schultz Larsen, 1991). Mobility dysfunction may, therefore, be a significant marker of impending disability. Specific questioning about early and minimal impacts of tiredness during mobility tasks might be a signal of future disability and a trigger for exercise based interventions aimed at stemming the development of further tiredness in mobility tasks in elderly people. As a strategy to minimise disability associated with increasing age, questions about the impact of tiredness during mobility tasks are important for community-living elderly people.

In contrast to previous recommendations, the exercise induced muscle performance does not fully account for MT improvements. Improved balance and walk performance may well have additional and significant influence. Further investigation of the influence of these three variables would be warranted to elucidate the specific contributions of each domain. In order to improve the tiredness experienced during mobility tasks by people aged 75 years and older, the individual contributions of muscle, balance and walk performance will need to be identified to ascertain the most appropriate goals for exercise intervention.

5.3.2.4 Mobility Help

The need for assistance during mobility tasks was measured by the Mobility Help (MH) subscale of the QFA. Dependency is assessed on the same set of items used for the Mobility Tiredness subscale.

At the baseline assessment there was no difference amongst groups on the measure. Similarly, at the post-intervention assessment, there was no group difference evident. Therefore, neither the exercise nor the social intervention immediately influenced dependency reported during mobility tasks. However, both the exercise and the social group subjects reported significantly more independence during mobility tasks than control group subjects at both follow-up assessments. The intervention programs, despite having no significant influence on mobility independence, appear to have offered some longer-term protection against increasing dependence in mobility tasks.

Data collected at the baseline assessment indicated group mean scores of 11.7 – 11.9 from a total possible score of 14. At age 70 years, 96% of Danish subjects scored the highest possible score for MH (Avlund et al., 1995a), compared with 85% five years later (Avlund et al., 1996). The baseline results in this study represent data collected from a group aged 75 years and older, which may account for the increased reports of the need for assistance with mobility tasks. Mobility has been shown to be the functional activity most likely to deteriorate and become problematic in the group aged 75 years and older (Avlund et al., 1995a).

The need for assistance during mobility tasks was the only measure of functional ability to be affected by the social intervention program. This effect was similar to the effect of the exercise program. Participation in the exercise intervention for 16 weeks did not offer additional benefits in relation to the need for assistance during mobility tasks. This observation is based on two distinct characteristics. The first is that as no group difference was evident at the post-intervention assessment, there was no immediate benefit offered by the exercise intervention program. The second observation was that while the significant difference in MH performance was noted at the follow-up assessments at 4 and 8 months, this improved performance was also noted in the social group. The factors modifying the need for assistance with mobility tasks were most likely to be common between the exercise and the social intervention programs. Thus, intervention alone, whether based on physical or social activity, appeared to proffer no immediate effect but rather to diminish the usual increase over time in the assistance needed for the completion of mobility tasks.

While increased levels of activity did not provide immediate and significant reductions in assistance needed during the performance of mobility tasks, the effects of either an exercise or social intervention were associated with improved independence that was evident for eight months post-intervention. Therefore, increased levels of activity, whether physical or social, should be encouraged in elderly people as a strategy for minimising increasing mobility dependence over time.

5.3.2.5 Physical Activities of Daily Living

Dependency during activities of daily living was also assessed on a subscale of the QFA. The Physical Activities of Daily Living Help scale (PADLH) measures the need for assistance during tasks including washing and grooming of both upper and lower body segments.

Again, there was no difference among groups at the baseline assessment. The exercise intervention improved performance so that at the post-intervention assessment, exercise participants were significantly more independent than subjects from either of the other two groups. The cessation of exercise was not associated with loss of the previous gains and at the follow-up assessments four and eight months later the exercise group demonstrated significantly greater independence than subjects from the other two groups. The social intervention program did not affect PADLH scores. Therefore, the exercise program was effective in maximising independence in ADL and withdrawal of exercise did not result in loss of these gains over the next eight months.

At the baseline assessment, group mean scores for PADLH ranged between 15.6 and 15.9 from a total possible score of 18, indicating that most subjects reported some need for assistance with ADL. Independence in ADL was evident for 89% of 70 year olds (Avlund et al., 1995a) compared with 64% at age 75 years (Avlund et al., 1996). Thus, the need for assistance during ADL increases with advancing age.

The exercise intervention provided immediate and long-term benefits by increasing independence during physical ADL tasks. Many of the tasks were those used to rate tiredness in the upper and lower limbs. However, investigation of the validity demonstrated that dependence in ADL was not specific to either upper or lower limb and the items combined for dependence ratings (Avlund et al., 1993a). While immediate benefits occurred as a result of increased physical activity, longer-term benefits were also demonstrated. Thus, in the post intervention period, despite initial losses of muscle performance and later losses (at four months) of balance and walk performance gains, increased independence in ADL persisted.

The immediate benefit of the exercise program on PADLH scores may reflect the interrelated contributions of improved performance in muscle, balance, gait and step measures. Overall, increased levels of physical function were reflected in increased independence in ADL tasks. Muscle performance, however, appears not to be the most significant contributor, as the post-intervention losses did not result in similar losses in PADLH scores. Continued improved performance for balance and gait lasted for four months post-intervention before deteriorating, however, better PADLH scores were maintained by exercise subjects for eight months post-intervention, a further four months longer than balance and gait benefits. Avlund et al., (1994) demonstrated that physically activities subjects reported better levels of functional ability. In the present study, however, improved function, specific to the need for assistance with ADL, was maintained as physical activity levels of the exercise subjects decreased post-intervention. These subjects did not maintain higher levels of physical activity than other subjects but did maintain better PADLH performance.

One of the dimensions not examined specifically by this study was that of self-efficacy. Self-efficacy theory proposes that an individual's beliefs about their performance is directly associated with their ultimate level of performance (Bandura, 1977). Measures of self-efficacy and confidence were not included in the present study's examination of intervention effects. It is possible that one of the nonphysical effects of the exercise intervention was to improve self efficacy as it related to functional ability and that the subjects consolidated their beliefs about their functional ability. If this is so, the effect on self-efficacy lasted for eight months post-intervention. It is unclear whether this is the mechanism by which PADLH performance may be explained. The data collected in this study cannot support or disprove self-efficacy changes. However, this would be a dimension for further investigation.

The results of this study demonstrated the influence of an exercise intervention on independence when performing ADL as significant both at the conclusion of a 16 week program and in the ensuing eight months. The mechanisms by which the longer-term benefits occur are not able to be identified based on the data collected and are worthy of further investigation. However, the influence of exercise on PADLH performance is significant and increased levels of physical activity should be highly recommended to elderly people interested in remaining physical independent in everyday tasks.

5.3.2.6 Summary

A discussion of the results of the intervention programs highlighted by the present study is limited as there is scant literature reporting the relationship between interventions and functional ability, particularly in the area of general exercise training and social, non-health based interventions. Most literature in this area has investigated the predictive ability of measures of functional limitation to provide information about subsequent disability or mortality. For example, an American study has identified functional limitations as highly predicative of subsequent disability within four years in the community-living elderly population (Guralnik et al., 1995). Indeed, the QFA was designed to measure functional ability such that risk factors for subsequent disability could be identified. The present study is the first to use the QFA as an outcome measure for an intervention study and the first to investigate intervention effects on functional ability measured by the QFA.

The only randomised controlled intervention study using similarly aged subjects to have reported a positive effect of exercise on physical disability, a construct similar, but not identical, to that of functional limitation, utilised the Sickness Impact Profile 68 as an outcome measure (Jette et al., 1999). This measure identified change across multiple dimensions including basic and instrumental ADL as well a psychological disability. Following participation in a home based program of exercise, intervention subjects demonstrated improvements in physical disability (ADL and IADL) but not psychological disability. Jette etal., (1999) suggest that the key to psychological change as a result of exercise intervention is that of group contact. Again, these authors did not collect appropriate data that could prove or disprove this hypothesis.

Several other studies failed to demonstrate a significant effect of exercise intervention on physical disability (Buchner et al., 1997); (Cress et al., 1999); (Jette et al., 1996); (King et al., 2000); (Rubenstein et al., 2000) and many have failed to propose that measurement of disability would be a relevant outcome (Ades et al., 1996); (Judge et al., 1994); (Wolfson et al., 1996); (Lord et al., 1995); (Lord et al., 1996); (Rooks et al., 1997); (Sharpe et al., 1997) and

(Skelton et al., 1995). Of those measuring physical disability but reporting no change, most exercise interventions were specifically directed at impairment level outcomes, such as muscle strength, flexibility and aerobic conditioning. Few studies offered multifaceted training programs of strength, balance and other types of training and then measured intervention effects on functional limitations or physical disability.

5.4 Intention to treat analysis

Intention to treat analysis includes the data collected from all subjects, regardless of their compliance with the study protocol. In the present study, of 149 subjects enrolled initially, 41 subjects failed to complete the study intervention phase and assessments. Noncompliance with the intervention program of this study may mean that the intention to treat analysis underestimates the real benefit of treatment (Steiner and Geddes, 2001). However, results indicate the true effect of the intervention for a clinical population. The previously described analyses were based on complete data sets i.e. the 108 subjects who completed the study protocol completely. This approach isolates the effect of intervention, physiological, physical and functional, as only those who completed the study protocol in full are included. In contrast, the intention to treat analysis includes all data from all subjects regardless of whether the study protocol was completed. The primary outcome for the intention to treat analysis was defined as an improvement in functional ability measured at three time periods on each of the five subscales of the Questionnaire of Functional Ability.

Results indicated significant findings for specific time periods. Scores on LLT demonstrated significant improvement for exercise subjects between baseline and post-intervention assessments. Scores on MT and PADLH demonstrated two periods of significant change – between baseline and post-intervention assessments and between baseline and follow-up assessment at four months. In all cases, changes in scores indicated functional improvement.

These results confirm the effect of the exercise intervention on LLT, MT and PADLH scores between baseline and post-intervention assessments. Despite subject losses over time and whether or not exercise subjects completed the intervention or the assessments, subjects assigned to the exercise group demonstrated significant improvement in the impact of tiredness during functional activities of the lower limbs. As this finding was highlighted in the previous multivariate analyses of complete data, readers are directed to review the comments in Section 5.3.3.2 in this chapter.

A further significant result was evident for subjects allocated to the exercise group for scores indicating tiredness during mobility tasks. Between baseline and post-intervention assessments, there was a significant improvement in MT scores indicating that the exercise intervention was effect in minimising reported mobility related tiredness. Additionally, MT scores were significantly different between baseline and the first follow-up assessment at four months, indicating that the exercise induced gains were not lost when the intervention ceased but were maintained for a further four month period. This result was also noted in previous analyses and was discussed in Section 5.3.3 of this chapter.

A similar result was evident for PADLH scores. The increased independence in ADL as a result of the exercise intervention was significant between the baseline and post-intervention assessments. It was also significant between baseline and the four month follow-up assessment. This result indicates that the intervention program was successful in increasing ADL independence immediately and also for a further four month period. As this result has been previously discussed in Section 5.3.2.5 it will not be repeated here.

A significant result highlighted by the initial analyses included an exercise intervention effect for ULT, and both exercise and social intervention effects for MH. These results did not demonstrate significance following the intention to treat analysis. This indicates that while a physiological, physical and/or functional effect resulted from the intervention, the effect was either small or that subject dropout and other loss masked the clinical effect of the program.

For example, subjects who dropped out may well have been those for whom intervention may not have resulted in significant gains. With these subjects no longer in the study, the population effect of intervention may well be magnified. While there is no doubt that the intervention programs did affect ULT and MH scores, the results of the intention to treat analysis demonstrate that these changes were not significant when all original subjects were included in the analysis.

5.5 Relationship between physical performance and functional ability

The relationship between physical performance measures and functional ability scores was examined. Several significant relationships were identified. In order to be reported as consistent, significant correlations were required to be evident at three or more assessments throughout the study period.

Significant moderate – strong correlations were evident between shoulder abduction muscle performance and ULT scores at each of the four assessments. Thus, the relationship between shoulder abduction and ULT was significant. As shoulder abduction muscle performance improved through the intervention period, so did ULT scores, and as muscle performance detrained, ULT scores diminished. The post-intervention changes in muscle performance were significantly associated with ULT scores at each of the follow-up assessments.

Similar significant moderate – strong correlations were evident between performance of hip abductor muscle and reports of tiredness during lower limb activities. Weaker correlations were evident between knee flexion and LLT scores and dorsiflexion and LLT scores. As lower limb muscle performance improved as a result of intervention, so did LLT scores. Following completion of the intervention programs, the decreasing muscle performance was associated with increasing tiredness of the lower limbs during functional activities. These results indicate the importance of proximal muscle performance for functional activities and the relatively less important role of more distal muscle groups.

As previously discussed, the relationship between ULT and LLT scores and muscle strength has been shown to be significant in community-living older people (Avlund et al., 1996). For this group, increasing muscle weakness is associated with the emergence of tiredness during functional activities. As age related changes might serve to diminish muscle performance, tiredness during functional activities may also be prevalent as an age related change in functional abilities. Changes in limb tiredness may be the first indicator of the impacts of physiological and physical ageing noticed by an older person. In this respect, tiredness of limbs during functional activities may serve as a marker of the increasing impacts of age related changes.

There were no consistent and significant correlations noted at three or more assessments for either of the mobility subscales. This result indicates that no one single physical performance measure is strongly associated with mobility tiredness or dependence. Rather, mobility, as measured by the QFA, is a more complex construct. It is more likely that mobility performance relies on a number of aspects of physical performance, rather than one significant aspect. Mobility is a high level functional ability (Avlund et al., 1995a) and may well rely on inputs from muscle strength, balance performance as well as sensory inputs, including proprioceptive and visual inputs. The investigation of these complex relationships was, however, outside of the scope of this study.

Dependence in ADL was significantly and consistently correlated with both shoulder abduction and hip abduction muscle performance. Although these correlations were fair – moderate, they indicate the significant association between performance of ADL and muscle performance. As both upper and lower limb muscle groups were involved, a reasonable conclusion would be that both upper and lower limbs contribute to independence in ADL. The lack of association between PADLH scores and more distal lower limb muscle groups (knee flexors and dorsiflexors) may well indicate that more distal muscle groups are less involved with ADL than proximal groups. Strategies to improve independence in ADL in community-living older people should, therefore, concentrate on improving muscle performance of proximal groups in both upper and lower limbs.

5.6 Development of functional limitations

One of the hypotheses of the present study anticipated that the development of functional limitation would be associated with declines in physical performance. Therefore, as physical performance decreased, similar decreases in functional performance would be evident. Despite gross observations that this was sometimes true, based on graphical representation of the data (for muscle performance and limb tiredness scores), correlational analyses indicated only two significant relationships between derived variables representing change over time in physical performance and functional ability.

Change in hip abduction muscle performance and change in LLT scores were significantly, but only fairly, correlated. In addition, change in usual gait speed and change in PADLH were significantly associated. The results of the present study suggest that changes in physical performance in a community living population are not strongly associated with the development of functional limitations. Although suggested by Tinetti (1995) as potentially useful, the relationship between declining physical performance and functional limitation was not demonstrated as strong. A small number of studies have shown that physical performance is related to concurrent ADL (Gill et al., 1995a; Gill et al., 1997b), however as the patterns of functional decline among elderly people are highly diverse (Rudberg et al., 1996), it may well be too simplistic to expect a strong relationship between only two important parameters without taking into account the broader psychosocial aspects affecting health and function in old age. Such factors might include socio-economic status, cognitive state, depression and social factors. The results of this study do not confirm a strong relationship between changes in physical performance and the development of functional limitations in elderly people.

5.7 Prevalence of falls

Exercise programs in isolation, specifically addressing the risk factors for falls of diminished muscle performance, poor balance and gait, have not demonstrated the ability to decrease falls in elderly people (Gillespie et al., 2001). With the addition of education programs, exercise has an increased effectiveness on reducing falls. However, as falls are substantially and widely underreported (Cummings et al., 1988), the true frequency of falls within the study population may well be underestimated. Every effort was applied to ascertain true reports of falls, including monthly report sheets with follow-up telephone calls when appropriate. These data were checked at each assessment with subjects being asked a second time to report incidents of falls.

5.8 Summary

This randomised controlled trial of two forms of intervention, exercise and social intervention, for elderly subjects involved an initial intervention phase, followed by an eight month period of follow-up. Overall, the minimum time commitment for subjects to complete the study was 14 months. Subject loss over this period totalled 41. Subject loss, however, was not different among groups. Subjects who did not complete the study were not significantly different on a range of measures at baseline than subjects who complete the study.

The study was designed such that the exercise intervention would increase physical activity levels, while the social intervention would not. The Physical Activity Questionnaire was used to evaluate changes in physical activity levels among subjects during the study. The exercise intervention was successful at providing a program that significantly increased physical activity levels during the intervention phase. Subjects were not encouraged to continue with higher levels of exercise post-intervention. As many subjects were not able to drive or access formal exercise programs for elderly people, deterioration in physical activity levels occurred naturally. The social intervention did not increased physical activity levels. Therefore, the validity of the exercise intervention in providing significant physical activity above usual levels for the intervention phase only was confirmed.

The physical performance parameters of muscle performance, dynamic balance performance, maximal gait speed, circuit test performance and step height performance responded positively to the exercise intervention. While muscle strength gains are widely reported, this study is the first to demonstrate some of these changes. Improvements in dynamic balance and maximal gait speed in particular survived the usual detraining following cessation of exercise. This is a new and important finding. The mechanism by which these gains were preserved for four months cannot be clearly described at this stage and warrants further attention.

Limb tiredness during functional activities appears to be strongly associated with muscle performance. The two mobility domains, however, demonstrated more complex relationships over time and were not clearly associated with muscle performance. Improvements in dynamic ability may account for the changes in the longer term in functional ability. Independence in physical ADL was positively influenced by exercise over the following eight months. Again, this is the first time the longer term effect of exercise on functional ability has been reported. The ability of exercise to maintain independence in the longer term is an area important for further research. Perhaps short bursts of suitable exercise may enhance functional abilities in the longer term.

Overall, the study demonstrated that exercise has significant longer term benefits in areas of physical performance and functional ability for community-living elderly people. However, the extent of the association of physical performance and functional ability was unable to be fully described. In the face of an increasingly ageing population, these results indicate the important contribution of exercise in continuing functional independence.

CHAPTER SIX

CONCLUSIONS

The results of this moderate randomised controlled trial that offered an exercise intervention program demonstrated functional benefits for older adults wishing to remain functionally independent in later life. The 16 week exercise program was well received by elderly participants and attendance rates were high, as was compliance with the home program. The exercise program was effective in improving physical performance and functional ability. In contrast, a social intervention program of similar duration demonstrated no changes in physical performance and influenced only one parameter of functional ability, namely dependence in mobility tasks.

Participation in the exercise program over 16 weeks proved beneficial in the longer term following completion, especially in the area of functional ability. Following completion of the exercise intervention program, independence and tiredness in mobility tasks and independence in activities of daily living demonstrated significant improvements. The influence of a short term exercise intervention on functional ability in the absence of continuing exercise is a remarkable finding. Functional benefits were evident at four and eight months following completion of the program.

The relationship between exercise and falls in older people has been discussed for some time. These results confirm the positive influence of exercise on falls reduction in older people.

The specific mechanism or mechanisms by which physical performance and functional ability benefits were maintained following cessation of the exercise program remain unclear and cannot be delineated at this time. There may be a specific mechanism by which physical performance improves and a different mechanism responsible for functional benefits. The influence of increased confidence in performance and abilities was not explored by this study and warrants further attention. The influence of enhanced physical performance on functional ability was not confirmed by correlation analysis, nor were changes in physical performance clearly associated with the development of functional limitation in the study population. Therefore, the relationship between physical performance and functional abilities is not clear-cut in the older population. Other influential factors include social and environmental factors that were beyond the scope of the study. However, the results demonstrate that improved functional ability as a result of exercise participation is achievable for elderly people.

Further research will be required to define the complex relationship between enhanced physical performance and improved functional ability due to exercise by elderly people. Constructs worthy of further investigation would include measurement of self-efficacy and confidence in tasks. Inclusion of social and environmental data may allow for the construction of a model delineating the influence of these factors in functional declines in older people. Further, longitudinal study of the process of functional limitation may well highlight factors of importance as yet undescribed.

Therapists working with older people often provide exercise based interventions. The results of this study indicate that significant improvements in functional ability can occur as a result. It is important, therefore, for therapists to include outcome assessments that are able to measure such changes over time. Traditionally, measures of impairment and occasionally measures of physical performance form the bulk of assessment tools used when working with older people. The non-inclusion of outcome measures in the functional limitation domain hinder the ability of therapists to measure such important change. Older participants would most likely be keen to maintain or improve their physical functional performance and this is likely to be a major motivating factor for many, previously sedentary, older people to commence an exercise program. Physiotherapists have unique knowledge of exercise prescription, usual ageing, pathology and the implications of co-morbidities and can assess and design appropriate programs for an individual which may then be offered within a class setting. This knowledge and ability sets physiotherapists apart from other health and exercise professionals. The results of this study indicate that programs led by a physiotherapist can positively influence functional abilities in participants aged 75 years and over.

Many people in the 75 year and older age group no longer drive and may not be able to access public transportation. An important aspect of the intervention provided was the provision of transportation to and from the exercise venues. As participants with decreasing functional ability have the most to gain from such a program, efforts should be directed to provide an exercise program that can be accessed by people with decreasing abilities. Driving is a multifaceted skill and difficulty or inability to continue is often a sign of increasing difficulty with functional tasks. Successful exercise programs for older people should have a specific strategy to overcome the transportation barrier.

This study demonstrated an exercise program of 16 weeks duration and twice weekly frequency, with the addition of a home program, provides functional benefits. The exercise intervention was designed to improve muscle and balance performance, as well as coordination, flexibility and general endurance. A 'low-tech' approach was utilised. Resistive muscle work was performed with elastic tubing of varying resistance and sand or rice bags. Most physiotherapists have access to such materials. The important variable in the muscle performance program was the ongoing increments in resistance provided, both in the exercise session and for home use. The principle of training overload worked effectively. Exercise programs should, therefore, include a continual review and increase exercise parameters appropriately. Occasionally, it may be necessary to decrease resistance or activity for a short time due to individual factors. Participants should be educated and empowered to work at their preferred level of exertion during the sessions.

In addition to muscle exercise, activities completed during the exercise session generally included a number of components of balance, flexibility and coordination. Individual supervision was not available within the class setting. Dynamic balance abilities, rather than static postures, were highlighted during activities. Activities used were adapted from elements of Tai Chi, yoga and other movement philosophies, to provide challenging activities that were safe for older participants to perform in a class setting. Static balance abilities did not improve as a result of the exercise intervention and specific attention may need to be paid to static balance as an area of importance for older particpants. The provision of a safe environment was of utmost importance and all class leaders endeavoured to minimise injuries and falls.

Older Australians are clear in their wish to remain independent in later life. The results of this study suggest that participation in appropriate and well – designed exercise programs will assist this. Further, this study has demonstrated significant functional improvements following the completion of a relatively short program. Importantly, such benefits occurred in the absence of continuing exercise and some continued for an eight month period. A similar program of exercise should be recommended to all older people with a desire for physical independence.

References

Ades, P., Ballor, D., Ashikaga, T., Utton, J. and Nair, K. (1996). Weight training improves walking endurance in healthy elderly persons. Annals of Internal Medicine 124: 568-572.

Andrews, A. W., Thomas, M. W. and Bohannon, R. W. (1996). Normative values for isometric muscle force measurements obtained with hand-held dynamometers. Physical Therapy 76: 248-259.

Aniansson, A., Rundgren, A. and Sperling, L. (1980). Evaluation of functional capacity in activities of daily living in 70-year old men and women. Scandinavian Journal of Rehabilitative Medicine 12: 145-154.

Applegate, W. B., Blass, J. P. and Williams, T. F. (1990). Instruments for the functional assessment of older patients. New England Journal of Medicine 322: 1207-1214.

Ashworth, J. B., Reuben, D. B. and Benton, L. A. (1994). Functional profiles of healthy older persons. Age and Ageing 23: 34-39.

Australian Bureau of Statistics (1999a) Older People, Australia: A Social Report. Commonwealth of Australia. No. 4109.0 Canberra

Australian Bureau of Statistics (1999b) Disability, Ageing and Carers: Summary of Findings. Commonwealth of Australia. No. 4430.0 Canberra

Avlund, K. and Schultz Larsen, K. (1991). What do 70-year-old men and women actually do? And what are they able to do? From the Glostrup survey in 1984. Aging-Milano 3: 39-49.

Avlund, K. and Holstein, B. (1998). Functional ability among elderly people in three service settings: The discriminatory power of a new functional ability scale. European Journal of Epidemiology 14: 783-790.

Avlund, K., Kreiner, S. and Schultz-Larsen, K. (1993a). Construct validation and the Rasch model: Functional ability of healthy elderly people. Scandinavian Journal of Social Medicine 21: 233-245.

Avlund, K., Shultz-Larsen, K. and Kreiner, S. (1993b). The measurement of instrumental ADL: content validity and construct validity. Aging Clinical Experimental Research 5: 371-383.

Avlund, K., Davidsen, M. and Shultz-Larsen, K. (1995a). Changes in functional ability from ages 70 to 75. Journal of Aging and Health 7: 254-282.

Avlund, K., Kreiner, S. and Schultz-Larsen, K. (1996). Functional ability scales for the elderly. A validation study. European Journal of Public Health 6: 35-42.

Avlund, K., Schultz-Larsen, K. and Davidsen, M. (1998a). Tiredness in daily activities at age 70 as a predictor of mortality during the next 10 years. Journal of Clinical Epidemiology 51: 323-333.

Avlund, K., Damsgaard, M. and Holstein, B. (1998b). Social relations and mortality. An eleven year follow-up study of 70-year -old men and women in Denmark. Social Science and Medicine 47: 635-643.

Avlund, K., Thudium, D., Davidsen, M. and Fuglsang-Sorenson, B. (1995b). Are self-ratings of functional ability reliable? Scandinavian Journal of Occupational Therapy 2: 10-16.

Avlund, K., Schroll, M., Davidsen, M., Lovberg, B. and Rantanen, T. (1994). Maximal isometric muscle strength and functional ability in daily activities among 75-year-old men and women. Scandinavian Journal of Medicine and Science in Sports 4: 32-40.

Balogun, J. A., Akindele, K. A., Nihinlola, J. O. and Marzouk, D. K. (1994). Age-related changes in balance performance. Disability and Rehabilitation 16: 58-62.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioural change. Psychological Review 84: 191-215.

Barratt, D., Ismail, S., Louie, J., Tai, P., Talebi, S. and Westall, F. (1996) Normative data for the 10 metre walk test in the 65 years and over age group in Perth, Western Australia. School of Physiotherapy, Curtin University. Perth

Bassey, E. J., Bendall, M. J. and Pearson, M. (1988). Muscle strength in the triceps surae and objectively measured customary walking activity in men and women over 65 years of age. Clinical Science 74: 85-89.

Berg, K. (1989). Balance and its measure in the elderly: A review. Physiotherapy Canada 41: 240-246.

Berg, K., Wood-Dauphinee, S., Williams, J. I. and Gayton, J. (1989). Measuring balance in the elderly: Preliminary development of an instrument. Physiotherapy Canada 41: 304-311.

Berkman, L. and Syme, S. (1979). Social networks, host resistance and mortality: a nine year follow-up study of Alameda County Study. American Journal of Epidemiology 109: 186-204.

Blake, A., Morgan, K. and Bendall, M. (1988). Falls by elderly people at home: prevalence and associated factors. Age and Ageing 17: 365-372.

Blanke, D. J. and Hageman, P. A. (1989). Comparison of gait of young and elderly men. Physical Therapy 69: 144-148.

Blazer, D. (1982). Social support and mortality in an elderly community population. American Journal of Epidemiology 115: 684-694.

Bohannon, R. W. (1994). One-legged balance test times. Perceptual and Motor Skills 78: 801-802.

Bohannon, R. W., Larkin, P., Cook, A., Gear, J. and Singer, J. (1984). Decrease in timed balance test scores with aging. Physical Therapy 64: 1067-1070.

Boult, C., Kane, R. L., Louis, T. A., Boult, L. and Mccaffrey, D. (1994). Chronic conditions that lead to functional limitation in the elderly. Journal of Gerontology 49: M28-36.

Branch, L. and Myers, A. (1987). Assessing physical function in the elderly. Clinics in Geriatric Medicine 3: 29-51.

Briggs, R. C., Gossman, M. R., Bircg, R., Drews, J. E. and Shaddeau, S. A. (1989). Balance performance among noninstitutionalized elderly women. Physical Therapy 69: 748-756.

Buchner, D. M., Cress, E. and De Lateur, B. J. (1997). The effect of strength and endurance training on gait, balance, fall risk and health services use in community-living older adults. Journal of Gerontology 44: M147-157.

Buchner, D. M., Cress, M. E., Wagner, E. H., De Lateur, B. J., Price, R. and Abrass, I. B. (1993). The Seattle FICSIT study/MoveIt study: The effect of exercise on gait and balance in older adults. Journal of the American Geriatrics Society 41: 321-325.

Cao, C., Ashton-Miller, J., Schultz, A. and Alexander, N. (1997). Abilities to turn suddenly while walking: Effects of age, gender, and available response time. Journal of Gerontology 52A: M88-M93.

Carlson, J., Ostir, G., Black, S., Markides, K., Rudkin, L. and Goodwin, J. (1999). Disability in older adults 2: Physical activity as prevention. Behavioral Medicine 24: 157-168.

Cerny, K. (1993). A clinical method of quantitative gait analysis: suggestions from the field. Physical Therapy 63: 1125-1126.

Chandler, J. (2000). Balance and falls in the elderly: Issues in evaluation and treatment. Geriatric Physical Therapy. Guccione, A. St Louis, Mosby Yaer Book: 280-291.

Chandler, J., Duncan, P., Kochersberger, G. and Studenski, S. (1998). Is lower extremity strength gain associated with improvement in physical performance and disability in frail, community-dwelling elders? Archives of Physical Medicine and Rehabilitation 79: 24-30.

Chen, H., Ashton-Miller, J. A., Alexander, N. B. and Schultz, A. B. (1991). Stepping over obstacles: Gait patterns of healthy young and old adults. Journal of Gerontology 46: M196-M203.

Clark, F., Azen, S., Zemke, R., Jackson, J., Carlson, M., Mandel, D., Hay, J., Josephenson, K., Cherry, B., Hessel, C., Palmer, J. and Lipson, L. (1997). Occupational therapy for independent-living older adults - a randomized controlled trial. Journal of the American Medical Association 278: 1321-1327.

Coakes, S. and Steed, L. (1999). SPSS: Analysis without Anguish: versions 7.0, 7.5, 8.0 for Windows. Milton, Queensland, John Wiley and Sons Australia Ltd.

Colleen, F., Wade, D. and Bradshaw, C. (1990). Mobility after stroke: reliability of measures of impairment and disability. International Disability Studies 12: 6-9.

Collson, S., Cicuttuni, F., Mead, V. and Savio, F. (1999). Low level disability in activities of daily living in elderly people living independently: Risk factors and implications. Australasian Journal on Ageing 18: 38-40.

Crawford, S., Jette, A. M. and Tennstedt, S. (1997). Test-retest reliability of self-reported disability measures in older adults. Journal of the American Geriatrics Society 45: 338-341.

Cress, M., Buchner, D., Questad, K., Esselman, P., Delateur, B. and Scharwtz, R. (1999). Exercise: effects on physical functional performance in independent older adults. Journal of Gerontology 54A: M242-M248.

Cummings, S. R., Nevitt, M. C. and Kidd, S. (1988). Forgetting falls: The limited accuracy of recall of falls in the elderly. Journal of the American Geriatrics Society 36: 613-616.

Dolinis, J., Harrison, J. and Andrews, G. (1997). Factors associated with falling in older Adelaide residents. Australian and New Zealand Journal of Public Health 21: 462-468.

Duncan, P. W., Weiner, D. K., Chandler, J. and Studenski, S. (1990). Functional reach: A new clinical measure of balance. Journal of Gerontology 45: M192-M197.

Duncan, P. W., Studenski, S., Chandler, J. and Prescott, B. (1992). Functional reach: Predictive validity in a sample of elderly male veterans. Journal of Gerontology 47: M93-M98.

Ensrud, K. E., Nevitt, M. C., Yunis, C., Cauley, J. A., Seeley, D. G., Fox, K. and Cummings, S. R. (1994). Correlates of impaired function in older women. Journal of the American Geriatrics Society 42: 481-489.

Evans, W. (1999). Exercise training guidelines for the elderly. Medicine and Science in Sports and Exercise 31: 12-17.

Femia, E., Zarit, S. and Johansson, B. (2001). The disablement process in very late life: A study of the oldest-old in Sweden. Journal of Gerontology 56B: P12-P23.

Fenske, N. A. and Lober, C. W. (1990). Skin changes of aging: Pathological Implications. Geriatrics 45: 27-32.

Fiatarone, M. A. and Evans, W. J. (1993). The etiology and reversibility of muscle dysfunction in the aged. Journal of Gerontology 48: 77-83.

Folstein, M., Folstein, S. and Mchugh, P. (1975). Mini-Mental state: A practical method for grading cognitive state of patients for the clinician. Journal of Psychiatric Research 12: 189-198.

Frandin, K., Sonn, U., Svantesson, U. and Grimby, G. (1995). Functional balance tests in 76-year-olds in relation to performance, activities of daily living and platform tests. Scandinavian Journal of Rehabilitation Medicine 27: 231-241.

Fransler, C., Poff, C. and Shepard, K. (1985). Effects of practice on balance in elderly women. Physical Therapy 65: 1332-1338.

Fried, L. and Bush, T. L. (1988). Morbidity as a focus of preventive health care in the elderly. Epidemiological Reviews 10: 48-64.

Fried, L., Herdman, S. J., Kuhn, K. E., Rubin, G. and Turano, K. (1991). Preclinical disability. Hypotheses about the bottom of the iceberg. Journal of Aging and Health 3: 285-300.

Fried, L., Tangen, C., Watson, J., Newman, A., Hirsch, C., Gottdiener, J., Tracy, R., Kop, W., Burke, G. and Mcburnie, M. (2001). Frailty in older adults: Evidence for a phenotype. Journal of Gerontology 56: M146-M156.

Friedman, P., Richmond, D. and Baskett, J. (1988). A prospective trial of serial gait speed as a measure of rehabilitation in the elderly. Age and Ageing 17: 225-235.

Frontera, W. R., Hughes, V. A., Lutz, K. J. and Evans, W. J. (1991). A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. Journal of Applied Physiology 71: 644-650.

Fyfe, P. (1995). Speedy Metric Converter. Sydney, Lansdowne.

Gill, T., Williams, C. and Tinetti, M. E. (1995a). Assessing risk for the onset of functional dependence among older adults: The role of physical performance. Journal of the American Geriatrics Society 43: 603-609.

Gill, T., Richardson, E. and Tinetti, M. E. (1995b). Evaluating the risk of dependence in activities of daily living among community-living older adults with mild to moderate cognitive impairment. Journal of Gerontology 50A: M235-M241.

Gill, T., Robison, J. and Tinetti, M. E. (1997a). Predictors of recovery in activities of daily living among disabled older persons living in the community. Journal of General Internal Medicine: 757-762.

Gill, T., Robison, J. and Tinetti, M. E. (1998). Difficulty and dependence: Two components of the disability continuum among community-living older persons. Annals of Internal Medicine 128: 96-101.

Gill, T., Williams, C., Richardson, E. and Tinetti, M. E. (1996). Impairments in physical performance and cognitive status as predisposing factors for functional dependence among nondisabled older persons. Journal of Gerontology 51A: M283-M288.

Gill, T., Williams, C., Mendes De Leon, C. and Tinetti, M. E. (1997b). The role of change in physical performance in determining risk for dependence in activities of daily living among community-living elderly persons. Journal of Clinical Epidemiology 50: 765-772.

Gillespie, L., Gillespie, W., Robertson, M., Lamb, S., Cumming, R. and Rowe, B. (2001). Interventions for preventing falls in elderly people (Cochrane Review). The Cochrane Library. Oxford, Update Software.

Graafmans, W., Ooms, M., Hosfstee, H., Bezemer, P., Bouter, L. and Lips, P. (1996). Falls in the elderly: A prospective study of risk factors and risk profiles. American Journal of Epidemiology 143: 1129-1136.

Greig, C., Young, A., Skelton, D. A., Pippet, E., Butler, F. and Mahmud, S. (1994). Exercise studies with elderly volunteers. Age and Ageing 23: 185-189.

Guccione, A. A. (1991). Physical therapy diagnosis and the relationship between impairments and function. Physical Therapy 71: 499-504.

Guccione, A. A. and Jette, A. M. (1990). Multidimensional assessment of functional limitation in patients with arthritis. Arthritis Care and Research 3: 44-52.

Guralnik, J. M. and Kaplan, G. A. (1989). Predictors of healthy aging: Prospective evidence from the Alemeda County study. American Journal of Public Health 79: 703-708.

Guralnik, J. M., Branch, L. G., Cummings, S. R. and Curb, J. D. (1989). Physical performance measures in aging research. Journal of Gerontology 44: M141-146.

Guralnik, J. M., Ferruci, L., Simonsick, E., Salive, M. and Wallace, R. (1995). Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. New England Journal of Medicine 332: 556-561.

Hagemen, P. A. and Blanke, D. J. (1986). Comparison of gait of young women and elderly women. Physical Therapy 66: 1382-1387.

Hausdorff, J., Edelberg, H., Mitchell, S., Goldberg, A. and Wei, J. (1997). Increased gait unsteadiness in community-dwelling elderly fallers. Archives of Physical Medicine and Rehabilitation 78: 278-283.

Hawker, M. (1993). Care of the elderly - an overview. Physiotherapy 79: 825.

Heitmann, D. K., Gossman, M. R., Shaddeau, S. A. and Jackson, J. R. (1989). Balance performance and step width in noninstitutionalized, elderly, female fallers and nonfallers. Physical Therapy 69: 923-931.

Hill, K. (1997). Studies of Balance in Older People. School of Physiotherapy, Faculty of Medicine, Dentistry and Health Sciences. Melbourne, The University of Melbourne.

Hill, K., Schwarz, J., Flicker, L. and Carroll, S. (1999). Falls among healthy community dwelling older women: A prospective study of frequency, circumstances, consequences and prediction accuracy. Australian and New Zealand Journal of Public Health 23: 41-48.

Himann, J. E., Cunningham, D. A., Rechnitzer, P. A. and Paterson, D. H. (1987). Age-related changes in speed of walking. Medicine and Science in Sports and Exercise 20: 161-166.

Hoeymans, N., Wouters, E., Feskens, E., Vandenbos, G. and Kromhout, D. (1997). Reproducibility of performance-based and self-reported measures of functional status. Journal of Gerontology 52A: M363-M368.

House, J., Robbins, C. and Metzner, H. (1982). The association of social relationships and activity with mortality: prospective evidence from the Tecumseh Community Health Study. American Journal of Epidemiology 116: 123-140.

Hu, M. and Woolacott, M. H. (1994a). Multisensory training of standing balance in older adults: I. Postural stability and one-leg stance balance. Journal of Gerontology 49: M52-M61.

Hu, M. and Woolacott, M. H. (1994b). Multisensory training of standing balance in older adults: II. Kinematic and electromyographic postural responses. Journal of Gerontology 49: M62-M71.

Hughes, V., Frontera, W., Wood, M., Evans, W., Dallal, G., Roubenoff, R. and Fiartarone Singh, M. (2001). Longitudinal muscle strength changes in older adults: Influence of muscle mass, physical activity and health. Journal of Gerontology 56A: B209-B217.

Hurley, B. F. (1995). Age, gender, and muscular strength. Journal of Gerontology 50A: 41-44.

Hyatt, R. H., Bhat, W. A., Scott, S. and Maxwell, J. D. (1990). Association of muscle strength with functional status of elderly people. Age and Ageing 19: 330-336.

Iverson, B. D., Gossman, M. R., Shaddeau, S. A. and Turner, M. E. (1990). Balance performance, force production and activity levels in noninstitutionlized men 60 to 90 years of age. Physical Therapy 70: 348-355.

Jagger, C., Arthur, A., Spiers, N. and Clarke, M. (2001). Patterns of onset of disability in activities of daily living with age. Journal of the American Geriatrics Society 49: 404-409.

Jeitz, K., Khoo, S., Lee, L., Lim, H. and Low, P. (1997) Concurrent validity of the 10 metre walk test. School of Physiotherapy, Curtin University. Perth

Jette, A. M. (1994). Physical disablement concepts for physical therapy research and practice. Physical Therapy 74: 380-386.

Jette, A. M. (1997). Disablement outcomes in geriatric rehabilitation. Medical Care 35: JS28-JS37.

Jette, A. M., Branch, L. G. and Berlin, J. (1990). Musculoskeletal impairments and physical disablement among the aged. Journal of Gerontology 45: M203- M208.

Jette, A. M., Harris, B. A., Sleeper, L., Lachman, M. E., Heislein, D., Giorgetti, M. and Levenson, C. (1996). A home-based exercise program for nondisabled older adults. Journal of the American Geriatrics Society 44: 644-649.

Jette, A. M., Lachman, M., Giorgetti, M., Assman, S., Harris, B., Levenson, C., Wernick, M. and Krebs, D. (1999). Exercise - It's never too late: The Strong -for-Life program. American Journal of Public Health 89: 66-72.

Judge, J., Whipple, R. H. and Wolfson, L. I. (1994). Effects of resistive and balance exercises on isokinetic strength in older persons. Journal of the American Geriatrics Society 42: 937-946.

Kaplan, G., Seeman, T., Cohen, C., Knudsen, L. and Guranlik, J. (1987). Mortality among the elderly in Alameda County Study: behavioural and demographic risk factors. American Journal of Public Health 77: 307-312.

Katz, S. (1983). Assessing self-maintenance: Activities of daily living, mobility and instrumental activities of daily living. Journal of the American Geriatrics Society 31: 721-727.

Katz, S., Branch, L. G., Branson, M. H., Papsidero, J. A., Beck, J., C. and Greer, D. S. (1983). Active life expectancy. New England Journal of Medicine 309: 1218-1224.

Kellog International Work Group on the Prevention of Falls by the Elderly (1987). The prevention of falls in later life. Danish Medical Bulletin 34 Supp: 1-24.

Kendig, H., Helme, R., Teshuva, K., Osborne, D., Flicker, L. and Browning, B. (1996). Health Status of Older People project: Preliminary findings from a survey of the health and lifestyles of older Australians. Melbourne, Victorian Health Promotion Foundation.

Keysor, J. J. and Jette, A. M. (2001). Have We Oversold the Benefit of Late-Life Exercise? Journal of Gerontology 56: M412-M423.

King, A., Pruitt, L., Phillips, W., Oka, R., Rodenburg, A. and Haskell, W. (2000). Comparative effects of two physical activity programs on measured and perceived physical functioning and other health-related quality of life outcomes in older adults. Journal of Gerontology 55: M74-M83.

Langlois, J., Maggi, S., Harris, T., Simonsick, E., Ferruci, L., Pavan, M., Santori, L. and Enzi, G. (1996). Self-report of difficulty in performing functional activities identifies a broad range of disability in old age. Journal of the American Geriatrics Society 44: 1421-1428.

Law, M. and Letts, L. (1989). A critical review of scales of activities of daily living. American Journal of Occupational Therapy 43: 522-528.

Lawrence, R. and Jette, A. M. (1996). Disentangling the disablement process. Journal of Gerontology 51B: S173-S182.

Lawton, M. and Brody, E. (1982). Assessment of older people: Self-maintaining and instrumental activities of daily living. Journal of Gerontology 37: 91-99.

Lord, S. and Clark, R. (1996). Simple physiological and clinical tests for the accurate prediction of falling in older people. Gerontology 42: 199-203.

Lord, S., Ward, J., Williams, P. and Anstey, K. (1993). An epidemiological study of falls in older community-dwelling women. The Randwick falls and fractures study. Australian Journal of Public Health 17: 204-205.

Lord, S., Ward, J., Williams, P. and Strudwick, M. (1995). The effect of a 12-month exercise trial on strength and falls in older women: a randomized controlled trial. Journal of the American Geriatrics Society 43: 1198-1206.

Lord, S., Lloyd, D., Nirui, M., Raymond, J., Williams, P. and Stewart, R. (1996). The effect of exercise on gait patterns in older women: a randomized controlled trial. Journal of Gerontology 51A: M64-M70.

Maki, B. (1997). Gait changes in older adults: Predictors of falls or indicators of fear? Journal of the American Geriatrics Society 45: 313-320.

Mathers, C., Vos, T. and Stevenson, C. (1999) The Burden of Disease and Injury in Australia. Australian Institute for Health and Welfare. PHE 17 Canberra

Mazzeo, R., Cavanagh, P., Evans, W., Fiatarone, M., Hagberg, J., Mcauley, E. and Startzell, J. (1998). Exercise and physical activity for older adults. Medicine and Science in Sports and Exercise 30: 992-1108.

Mcmurdo, M. and Bennett, L. (1991). Randomized controlled trial of exercise in the elderly. Gerontology 38: 292-298.

Merrill, S., Seeman, T., Kasl, S. and Berkman, L. (1997). Gender differences in the comparison of self-reported disability and performance measures. Journal of Gerontology 52A: M19-M26.

Mor, V., Murphy, J. and Masterson-Allen, S. (1989). Risk of functional decline among well elders. Journal of Clinical Epidemiology 42: 895-904.

Morgan, D. (1988). Age differences in social network participation. Journal of Gerontology 43: S129-S137.

Nagi, S. (1965). Some conceptual issues in disability and rehabilitation. Sociology and Rehabilitation. Sussman, M. Washington DC, American Sociological Association: 100-113.

Nagi, S. (1991). Disability concepts revisited: implications for prevention. Disability in America: Toward a National Agenda for Prevention. Pope, A. and Taylor, a. Washington DC, National Academy Press.

Nashner, L. (1993). Practical biomechanics and physiology of balance. Handbook of Balance Function Testing. St Louis, Mosby Year Book: 261-279.

Nevitt, M. C., Cummings, S. R., Kidd, S. and Black, D. (1989). Risk factors for nonsyncopal falls. Journal of the American Medical Association 261: 2663-2668.

Nicholas, J., Marino, M. and Gleim, G. (1987). Characterization of a strength measurement device. 33rd Annual Meeting, Orthopedic Research Society, San Francisco.

O' Brien, K., Pickles, B. and Culham, E. (1996). Clinical measures of balance in community-dwelling elderly female fallers and non-fallers. Physiotherapy Canada 49: 212-217.

O' Loughlin, J. L., Robitaille, Y., Boivin, J. and Suissa, S. (1993). Incidence and risk factors for falls and injurious falls among the community-dwelling elderly. American Journal of Epidemiology 137: 342-354.

Oakley, A., Dawson, F., Holland, J., Arnold, S., Cryer, C., Doyle, Y., Rice, J., Hodgson, C., Sowden, A., Sheldon, T., Fullerton, D., Glenny, A. and Eastwood, A. (1996). Preventing falls and subsequent injury in older people. Quality in Health Care 5: 243-249.

Ory, M., Schechtman, K. and Miller, J. (1993). Frailty and injuries in later life: The FICSIT trials. Journal of the American Geriatrics Society 41: 283-296.

Patla, A., Frank, J. and Winter, D. (1992). Balance control in the elderly: Implications for clinical assessment and rehabilitation. Canadian Journal of Public Health 83: S29-S33.

Piotrowski, A. and Cole, J. (1994). Clinical measures of balance and functional assessment in elderly persons. Australian Journal of Physiotherapy 40: 183-188.

Podsiadlo, D. and Richardson, S. (1991). The timed "Up and Go": A test of basic functional mobility for frail elderly persons. Journal of the American Geriatrics Society 39: 142-148.

Pollock, W., Gaesser, G., Butcher, J., Despres, J., Dishman, R., Franklin, B. and Garber, C. (1998). The recommended quantity for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in older adults. Medicine and Science in Sports and Exercise 30: 975-991.

Porter, M., Vandervoort, A. and Lexell, J. (1995). Aging of human muscle: structure, function and adaptability. Scandinavian Journal of Medicine and Science in Sports 5: 129-142.

Portney, L. and Watkins, M. (1993). Foundations of Clinical Research. Applications to Practice. Norwalk, Connetticut, Appleton & Lange.

Potvin, A. and Tourellottee, W. (1975). The neurological examination: Advancements in its quantification. Archives of Physical Medicine and Rehabilitation 56: 425-437.

Prince, F., Corriveau, H., Herbert, R. and Winter, D. (1997). Gait in the elderly. Gait and Posture 5: 128-135.

Rantanen, T. and Avela, J. (1997). Leg extension power and walking speed in very old people living independently. Journal of Gerontology 52A: M225-M231.

Reuben, D., Vellas, L., Hays, R. and Siu, A. (1995). Measuring physical function in community-dwelling older persons: A comparison of self-administered, interviewer-administered and performance-based measures. Journal of the American Geriatrics Society 43: 17-23.

Richardson, J., Stratford, P. and Cripps, D. (1998). Assessment of the reliability of the hand-held dynamometer for measuring strength in healthy older adults. Physiotherapy Theory and Practice 14: 49-54.

Ringsberg, K., Gerdhem, P., Johansson, J. and Obrant, K. (1999). Is there a relationship between balance, walk performance and muscular strength in 75-year-old women? Age and Ageing 28: 289-293.

Ringsberg, K., Gardsell, P., Johnell, O., Jonsson, B., Obrant, K. and Serbo, I. (1998). Balance and walk performance in an urban and rural population. Journal of the American Geriatrics Society 46: 65-70.

Rooks, D., Kiel, D., Parsons, C. and Hayes, W. (1997). Self-paced resistance training and walking exercise in community-dwelling older adults: effects of neuromotor performance. Journal of Gerontology 52A: M161-M168.

Rubenstein, L., Josephson, K. and Trueblood, P. (2000). Effects of a group exercise program on strength, mobility and falls among fall-prone elderly men. Journal of Gerontology 55A: M317-M321.

Rudberg, M., Parzen, M., Leonard, L. and Cassel, C. (1996). Functional limitation pathways and transitions in community-dwelling older persons. The Gerontologist 36: 430-440.

Sarkisian, C., Liu, H., Gutierrez, P., Seeley, D., Cummings, S. and Mangione, C. (2000). Modifiable risk factors predict functional decline among older women: A prospective validated clinical prediction tool. Journal of the American Geriatrics Society 48: 170-178.

Schultz-Larsen, K., Avlund, K. and Kreiner, S. (1992). Functional ability of community dwelling elderly: criterion validity of a new measure of functional ability. Journal of Clinical Epidemiology 45: 1315-1326.

Seeman, T., Charpentier, P. and Berkman, L. (1994). Predicting changes in physical performance in a high-functioning elderly cohort: MacArthur studies of successful aging. Journal of Gerontology 49A: M97-M108.

Seidler, R. and Martin, P. (1997). The effects of short term balance training on the postural control of older adults. Gait and Posture 6: 224-236.

Sforzo, G. A., Mcmanis, B. G., Black, D., Luniewski, D. and Scriber, K. C. (1995). Resilience to exercise detraining in healthy older adults. Journal of the American Geriatrics Society 43: 209-215.

Sharpe, P., Jackson, K. and White, C. (1997). Effects of a one-year physical activity intervention for older adults at congregate nutrition sites. Gerontologist 37: 208-215.

Sherrington, C. and Lord, S. (1997). Home exercise to improve strength and walking velocity after hip fracture: a randomised controlled trial. Archives of Physical Medicine and Rehabilitation 78: 208-212.

Shumway-Cook, A., Gruber, W., Baldwin, M. and Liao, S. (1997). The effect of multidimensional exercises on balance, mobility and fall risk in community-dwelling older adults. Physical Therapy 77: 46-57.

Siu, A. L., Reuben, D. B. and Hays, R. D. (1990). Hierarchial measures of physical function in ambulatory geriatrics. Journal of the American Geriatrics Society 38: 1113-1119.

Skelton, D., Greig, C. A., Davies, J. M. and Young, A. (1994). Strength, power and related functional ability of healthy people aged 65-89 years. Age and Ageing 23: 371-377.

Skelton, D., Young, A., Greig, C. and Malbut, K. (1995). Effects of resistance training on strength, power and selected functional abilities of women aged 75 and older. Journal of the American Geriatrics Society 43: 1081-1087.

Smith, L., Branch, L. G., Scherr, P. A., Wetle, T., Evans, D. A., Hebert, L. and Taylor, J. O. (1990). Short-term variability of measures of physical function in older people. Journal of the American Geriatrics Society 38: 993-998.

Sonn, U. (1996). Longitudinal studies of dependence in daily life activities among elderly persons. Scandinavian Journal of Rehabilation in Medicine 34: 1-35.

Stalenhof, P., Diederiks, J., Schiricke, K. and Crebolder, H. (1999). Impact of gait problems and falls on functioning in independent living persons of 55 years and over: a community study. Patient Education and Counselling 36: 23-31.

Steiner, D. and Geddes, J. (2001). Intention to treat analysis in clinical trials when there are missing data. Evidence-Based Mental Health 4: 70-71.

Stuck, A. E., Walthert, J. M., Nikolaus, T., Bula, C. J., Hohmann, C. and Beck, J. C. (1999). Risk factors for functional status decline in community-living elderly people: a systematic literature review. Social Science and Medicine 48: 445-469.

Tabachnick, B. and Fidell, L. (1989). Using Multivariate Statistics. New York, Harper Collins.

Teshuva, K., Stanislavsky, Y. and Kendig, H. (1994). Towards healthy ageing: literature review. Victoria, Australia, Collins Dove.

Thompson, L. (2000). Physiological changes associated with aging. Geriatric Physical Therapy. Guccione, A. St Louis, Mosby. 2nd Edition: 28-55.

Tinetti, M. E. (1986). Performance-oriented assessment of mobility problems in elderly patients. Journal of the American Geriatrics Society 34: 119-126.

Tinetti, M. E. and Williams, C. (1998). The effect of falls and fall injury on functioning in community-dwelling older adults. Journal of Gerontology 53: M112-M119.

Tinetti, M. E., Speechley, M. and Ginter, S. F. (1988). Risk factors for falls among elderly persons living in the community. New England Journal of Medicine 319: 1701-1707.

Tinetti, M. E., Mendes De Leon, C., Doucette, J. and Baker, D. (1994). Fear of falling and fall-related efficacy in relation to functioning among community-living elders. Journal of Gerontology 49: M140-M147.

Tinetti, M. E., Inouye, S., Gill, T. and Doucette, J. (1995). Shared risk factors for falls, incontinence and functional dependence. Unifying the approach to geriatric syndromes. Journal of the American Medical Association 273: 1348-1353.

Twomey, L. T. and Taylor, J. R. (1984). Old age and physical capacity: Use it or lose it. Australian Journal of Physiotherapy 30: 115-120.

U.S. Department of Health and Human Services (1996) Physical Activity and Health: A Report of the Surgeon General. Centres for Disease Control and Prevention, National Centre for Chronic Disease Prevention and Health Promotion. Atlanta

Unger, J., Johnson, C. A. and Marks, G. (1997). Functional decline in the elderly: Evidence for direct and stress-buffering protective effects of social interactions and physical activity. Annals of Behavioral Medicine 19: 152-160.

Vandervoort, A. (1992). Effects of ageing on human neuromuscular function: Implications for exercise. Canadian Journal of Sports Science 17: 178-184.

Vellas, B., Wayne, S., Garry, P. and Baumgertner, R. (1998). A two-year longitudinal study of falls in 482 community-dwelling elderly adults. Journal of Gerontology 53: M264-274.

Vellas, B., Wayne, S., Romero, L., Baumgertner, R. and Garry, P. (1997a). Fear of falling and restriction of mobility in elderly fallers. Age and Ageing 26: 189-193.

Vellas, B., Wayne, S., Romero, L., Baumgartner, R., Rubenstein, L. and Garry, P. (1997b). One-leg balance is an important predictor of injurious falls in older persons. Journal of the American Geriatrics Society 45: 735-738.

Verbrugge, L. M. and Jette, A. M. (1994). The disablement process. Social Science and Medicine 38: 1-14.

Wade, D., Wood, V., Heller, A. and Hewer, R. L. (1987). Walking after stroke. Scandinavian Journal of Rehabilitation Medicine 19: 25-30.

Wagner, E., Lacroix, A. Z. and Grothaus, L. (1994). Preventing falls and disability in older adults: A population based randomised trial. American Journal of Public Health 84: 1800-1806.

Weiner, D. K., Duncan, P. W., Chandler, J. and Studenski, S. A. (1992). Functional reach: A marker of physical frailty. Journal of the American Geriatrics Society 40: 203-207.

Weiner, D. K., Bongiorni, D. R., Studenski, S. A., Duncan, P. W. and Kochersberger, G. G. (1993). Does functional reach improve with rehabilitation? Archives of Physical Medicine and Rehabilitation 74: 796-800.

Wernick-Robinson, M., Krebs, D. and Giorgetti, M. (1999). Functional Reach: Does it really measure dynamic balance? Archives of Physical Medicine and Rehabilitation 80: 262-269.

West, S., Rubin, G., Munoz, B., Abraham, D. and Fried, L. (1997). Assessing functional status: Correlation between performance on tasks conducted in a clinic setting and performance on the same task conducted at home. Journal of Gerontology 52A: M209-M217.

Winter, D. A. (1991). The Biomechanics of Motor Control of Human Gait: Normal, Elderly and Pathological. Waterloo, University of Waterloo.

Winter, D. A., Patla, A. E., Frank, J. S. and Walt, S. E. (1990). Biomechanical walking pattern changes in the fit and healthy elderly. Physical Therapy 70: 340-347.

Wolfson, L., Whipple, R., Derby, C., Judge, J., King, M., Amerman, P., Schmidt, J. and Smyers, D. (1996). Balance and strength training in older adults: intervention gains and Tai Chi maintenance. Journal of the American Geriatrics Society 44: 498-506.

World Health Organisation (1980). International classification of impairments, disabilities and handicaps. Geneva, World Health Organisation.

World Health Organisation (1997) WHO-ICDH Classification Beta version two. World Health Organisation. Geneva

Appendix 1: Subject Information Statement

Title

Functional adaptation to exercise in older subjects
"Ageing and Independence" study
Investigator -Annette Brown, Physiotherapist and PhD student
Telephone: 9266 3650
Supervisor - Professor Joan Cole, School of Physiotherapy, Curtin University of Technology
Telephone: 9266 3618

Purpose of this study

The aim of this study is to measure changes in common everyday physical activities associated with increasing age and to study the effect of exercise on these changes.

Procedures

Having discussed and understood the aims of the study, and consented to participate, the test procedures would involve measuring strength of arm and leg muscles, ability to climb stairs, balance, walking speed, usual activity levels and everyday functional ability. You would be randomly assigned to a group to be involved in a physical activity program, a social activity program or no organised program for a 16 week period.

The assessment would take up to one hour, with adequate time for rest between tests. The assessment procedures would be repeated three times in the next 12 months, at 4 monthly intervals. The tests and groups would be held at the Shenton Park campus of Curtin University and other venues and the groups would be held on a weekly or twice weekly basis over a 4 month period. Transport to all venues can be provided if needed.

You would also be supplied with a set of prepaid postcards to fill in and return to the researcher on a monthly basis. The postcards would record any visits to the doctor or hospital you have made or any falls you may have had during the month.

Possible benefits and risks

The study will provide you with an opportunity to contribute to an original study about the effect of physical exercise on abilities usually affected by the ageing process. There may be a slight risk to you in the form of muscle or joint soreness or fatigue following the tests or exercises. However, the assessments and exercise sessions will ensure that this is minimised. A qualified physiotherapist will attend at all times during the tests and the exercises.

Investigator and participant responsibilities

The investigator will answer any queries which may arise concerning the procedures to be used in the study. Any request to withdraw, either before or during the study, will be respected. If you need to withdraw from the program, please contact the investigator at the earliest opportunity. Anonymity of all data collected during this study will be ensured.

Appendix 2: Consent Document

Title
Functional adaptation to exercise in older subjects
"Ageing and Independence" study
Investigator
Annette Brown, Physiotherapist and PhD student
Telephone: 9266 3650
Supervisor
Professor Joan Cole
School of Physiotherapy, Curtin University of Technology

I, ____

the undersigned PLEASE PRINT

of ____

____

____

____

Postcode Phone

consent to this investigation. I have read the CONSENT DOCUMENT and understand the consequences and risks associated with participation. I agree to have any results from this study used in any report or research paper, on the understanding that anonymity will be preserved. The investigator has answered my questions concerning the procedures to be used in the study. I may withdraw, either before or during the study, without prejudice. If so, I will contact the investigator (Annette Brown on 9266 3650) at the earliest opportunity.

Signature____ Date _______
Subject

Witness ____ Date _______
I have explained the research procedures to which the subject has consented to participate and answered all questions.

Researcher______________________________________ Date _______

Appendix 3: Consent to Photography

Title
Functional adaptation to exercise in older subjects
"Ageing and Independence" study
Investigator
Annette Brown, Physiotherapist and PhD student
Telephone: 9266 3650
Supervisor
Professor Joan Cole
School of Physiotherapy, Curtin University of Technology

Consent

It has explained that photographs are required in order to illustrate various aspects of the study for the thesis and other articles, and for presentation at seminars and conferences.

By giving consent, I authorise Annette Brown and Joan Cole to use any of the photographs taken of me in both printed and visual format.

I understand that photos may be used in publication of the research findings in physiotherapy related media such as journals and in research theses material. I also understand that my name will not be used in relation to any photos.

I have read and understood the contents of this form.

Signature____ Date _______
Subject

Researcher_______________________________________ Date _______

Appendix 4: Mini- Mental State Examination

Reference: Folstein, M., Folstein, S. and McHugh, P. (1975). Mini-Mental state: A practical method for grading cognitive state of patients for the clinician. *Journal of Psychiatric Research* 12: 189-198.

Appendix 5: Health Questionnaire

Adapted from: Ory, M., Schechtman, K. and Miller, J. (1993). Frailty and injuries in later life: The FICSIT trials. *Journal of the American Geriatrics Society* 41: 283-296.

Appendix 6: Questionnaire of Functional Ability

Reference: Avlund, K., Kreiner, S. and Schultz-Larsen, K. (1996) Functional ability scales for the elderly. A validation study. *European Journal of Public Health* 6: 35-42.

Note: For copyright reasons the contents of Appendix 6 has not been reproduced. See the reference noted above.

(Co-ordinator, ADT Project (Retrospective), Curtin University of Technology, 12.4.03)

Appendix 7: Physical Activity Questionnaire

Reference: Avlund, K., Schroll, M., Davidsen, M., Lovberg, B. and Rantanen, T. (1994). Maximal isometric muscle strength and functional ability in daily activities among 75-year-old men and women. *Scandinavian Journal of Medicine and Science in Sports* 4: 32-40.

Note: For copyright reasons the contents of Appendix 7 has not been reproduced. See the reference noted above.

(Co-ordinator, ADT Project (Retrospective), Curtin University of Technology, 12.4.03)

Appendix 8a: Monthly Report Sheet Instructions

AGEING AND INDEPENDENCE
MONTHLY REPORT

Attached are Report Sheets and reply paid envelopes for the next four months (until the next assessment).

Please complete one at the end of every month and post it. The letter is already addressed and does not need a stamp.

The report asks you questions about your general health, visits to the Doctor or hospital and if you have had any falls during the month. There is also space to report anything else that may have happened. Please write anything that you might think is important for the researchers to know. You could write on the back of the page if necessary.

It is important to send in a report every month. If you report is not received, Annette Brown from the School of Physiotherapy, Curtin University or one of her co-researchers will contact you.

You may also contact Annette at any time to talk further on telephone number 9266 3650.

Appendix 8b: Monthly Report Sheet

AGEING AND INDEPENDENCE
MONTHLY REPORT

MONTH: ___________

1) Were you unwell at all this month? YES NO

IF YES, PLEASE DESCRIBE: ______________________________

____

2) Did you visit the doctor this month because you were unwell? YES NO

IF YES, WHAT FOR? ______________________________

____

3) Were you a patient in hospital at all this month? YES NO

IF YES, YOU WILL RECEIVE A FOLLOW-UP TELEPHONE CALL SHORTLY TO DISCUSS THIS FURTHER

4) Did you have any falls or stumbles from which you landed on the floor this month? YES NO

IF YES, YOU WILL RECEIVE A FOLLOW-UP TELEPHONE CALL SHORTLY TO DISCUSS THE FALL FURTHER

5) Was there anything else unusual this month that you feel is important to report? YES NO

IF YES, PLEASE DESCRIBE: ______________________________

____

Please return this report in the envelope provided to Annette Brown. No postage is required. If you have any questions or comments, please contact Annette at Curtin University, School of Physiotherapy on 9266 3650.

Appendix 9: Descriptive data (mean, standard deviation, 95% CI) for Physical Activity Questionnaire (PAQ) scores

Table 5.1 Descriptive data (mean, standard deviation, 95% CI) for Physical Activity Questionnaire (PAQ) scores

	Exercise Group		**Social Group**		**Control Group**	
	Mean (sd)	95% CI	Mean (sd)	95% CI	Mean (sd)	95% CI
Baseline	2.31(0.92)	1.99-2.62	2.44(1.21)	2.04-2.85	2.75(1.11)	2.38-3.12
Post-intvn	3.11(1.06)	2.75-3.47	2.08(1.18)	1.68-2.48	2.50(1.08)	2.13-2.87
F-up 4	2.25(0.91)	1.94-2.56	2.03(1.18)	1.63-2.43	2.42(1.08)	2.05-2.78
F-up 8	2.19(0.75)	1.94-2.45	1.72(1.06)	1.36-2.08	2.17(1.06)	1.81-2.52

Appendix 10: Mean difference and 95% CI for change at post-intervention assessment in raw data for physical performance measures and functional ability scales

Table 5.2 Mean difference and 95% CI for change at post-intervention assessment in raw data for physical performance measures and functional ability scales

Variable	Mean Difference	Lower 95% CI	Upper 95% CI
Muscle Performance			
Shoulder abduction	13.00	11.63	14.37
Hip abduction	5.97	4.73	7.20
Knee flexion	4.10	3.32	4.88
Dorsiflexion	4.72	3.74	5.71
Balance			
SLBEO	5.84	1.11	10.57
SLBEC	-1.85	-3.24	-0.46
Functional Reach	11.45	9.41	13.48
Walk			
Usual Speed	0.01	0.01	0.22
Maximal Speed	0.62	0.50	0.74
Circuit Walk	-13.78	-18.06	-9.51
Step Height	0.19	0.01	0.29
Functional Ability			
ULT	0.37	-0.11	0.84
LLT	0.63	0.37	0.89
MT	1.43	1.16	1.70
PADLH	0.25	-0.23	0.75
MH	0.90	0.46	1.34

Appendix 11: Graphical representation of normalised percentage change in physical performance variables at post-intervention assessment

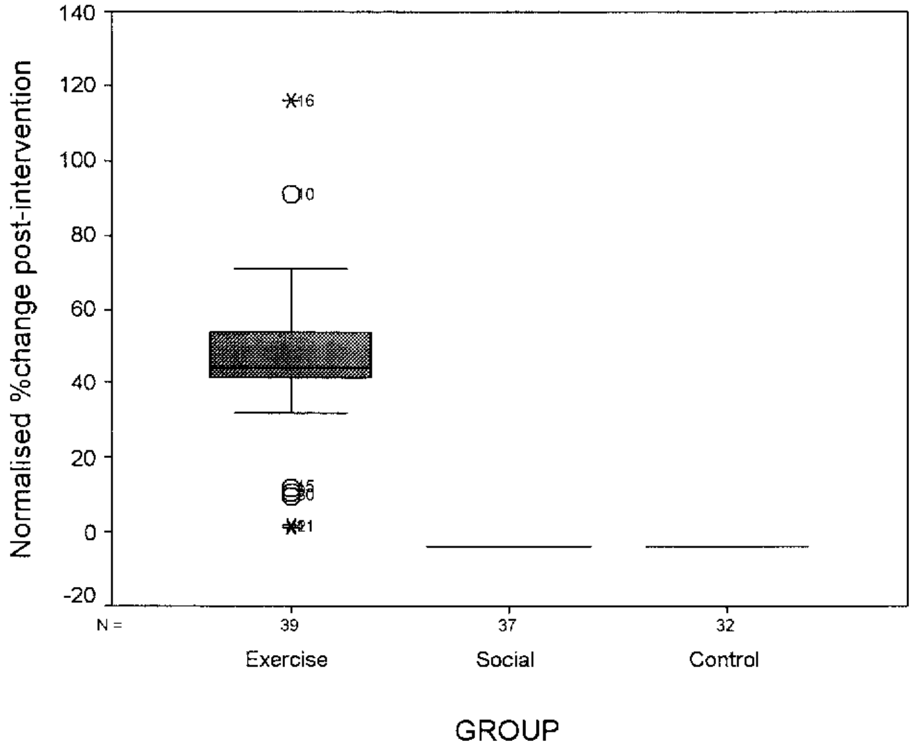

Figure 5.1 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in shoulder abduction performance

Appendix 11: Graphical representation of normalised percentage change in physical performance variables at post-intervention assessment (cont.)

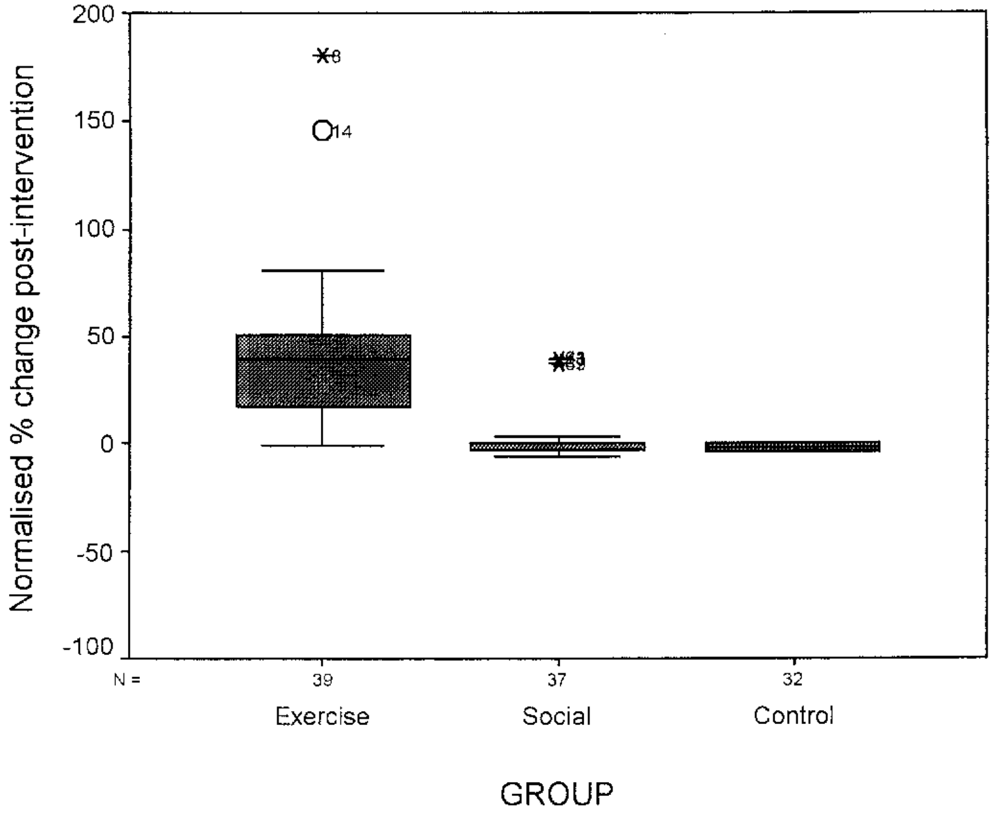

Figure 5.2 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in hip abduction performance

Appendix 11: Graphical representation of normalised percentage change in physical performance variables at post-intervention assessment (cont.)

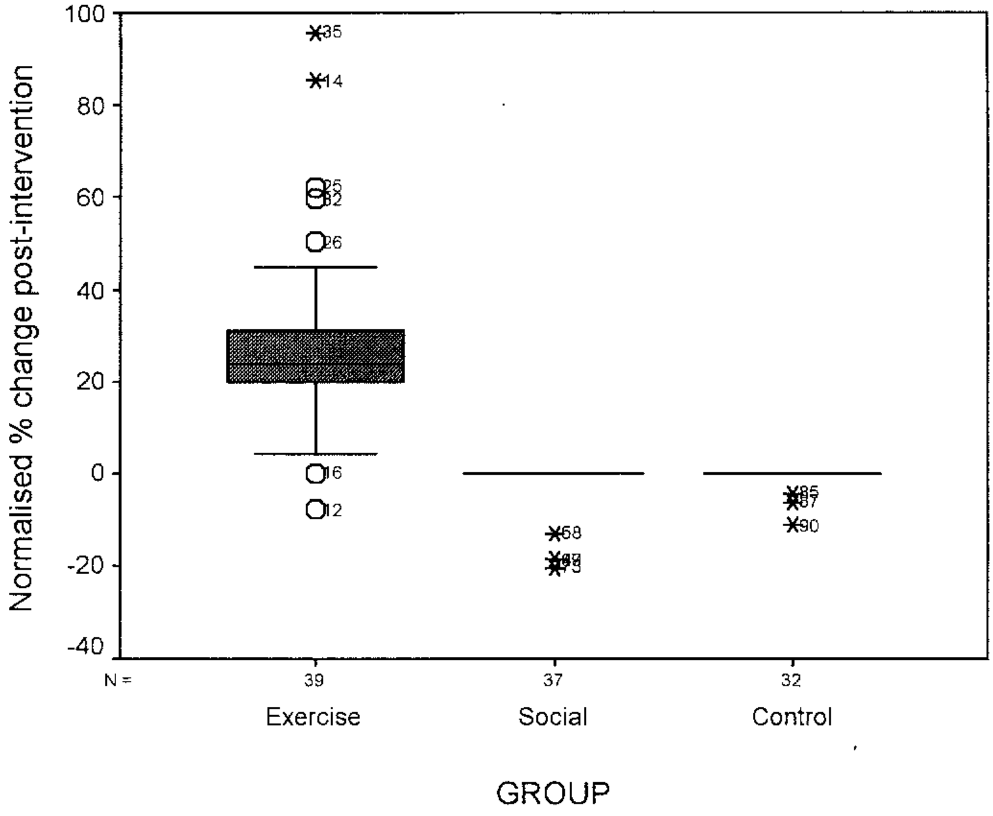

Figure 5.3 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in knee flexion performance

Appendix 11: Graphical representation of normalised percentage change in physical performance variables at post-intervention assessment (cont.)

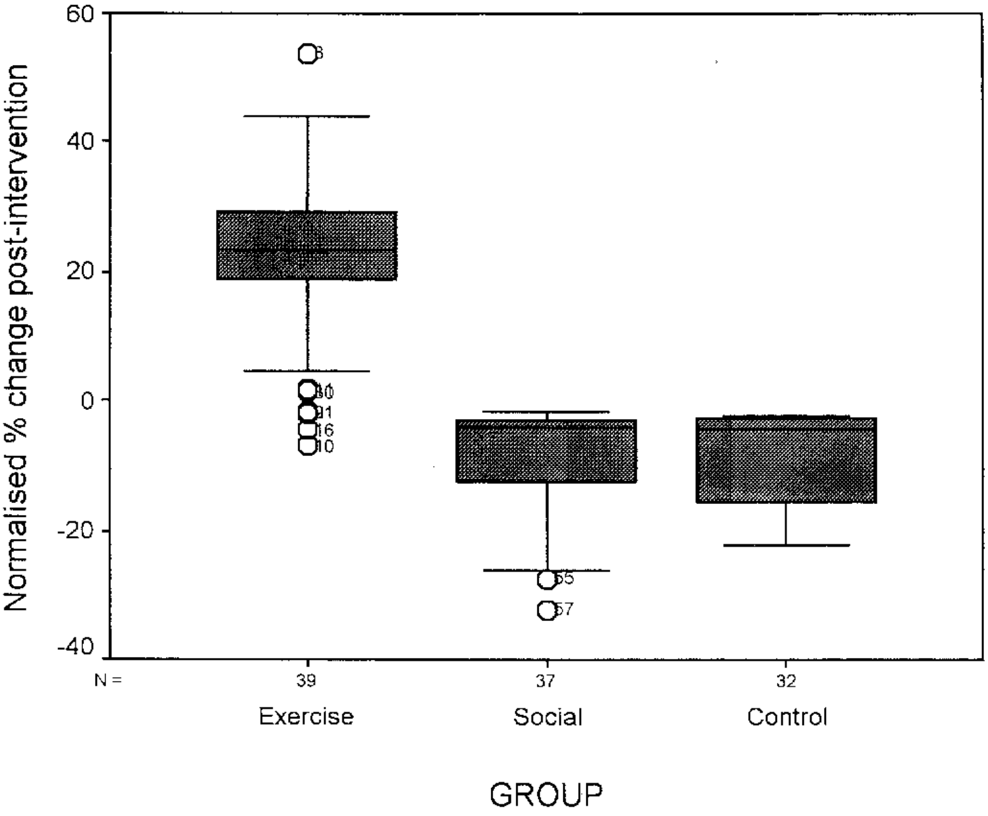

Figure 5.4 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in dorsiflexion performance

Appendix 11: Graphical representation of normalised percentage change in physical performance variables at post-intervention assessment (cont.)

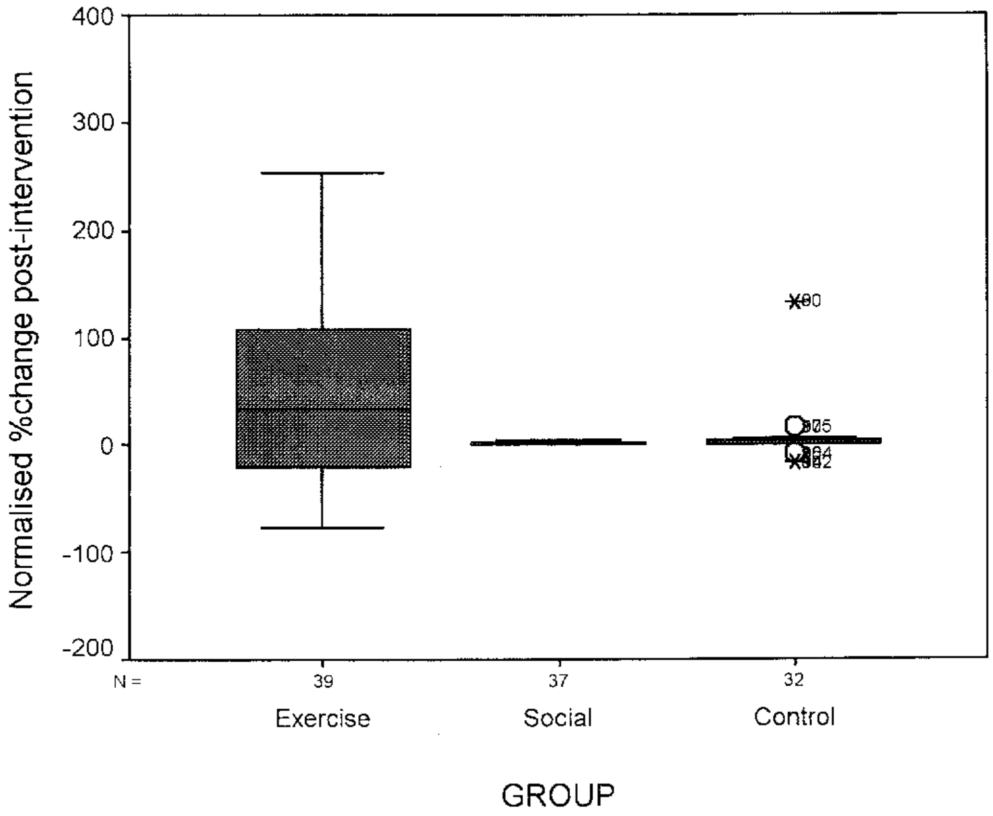

Figure 5.5 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in single limb balance with eyes open performance

Appendix 11: Graphical representation of normalised percentage change in physical performance variables at post-intervention assessment (cont.)

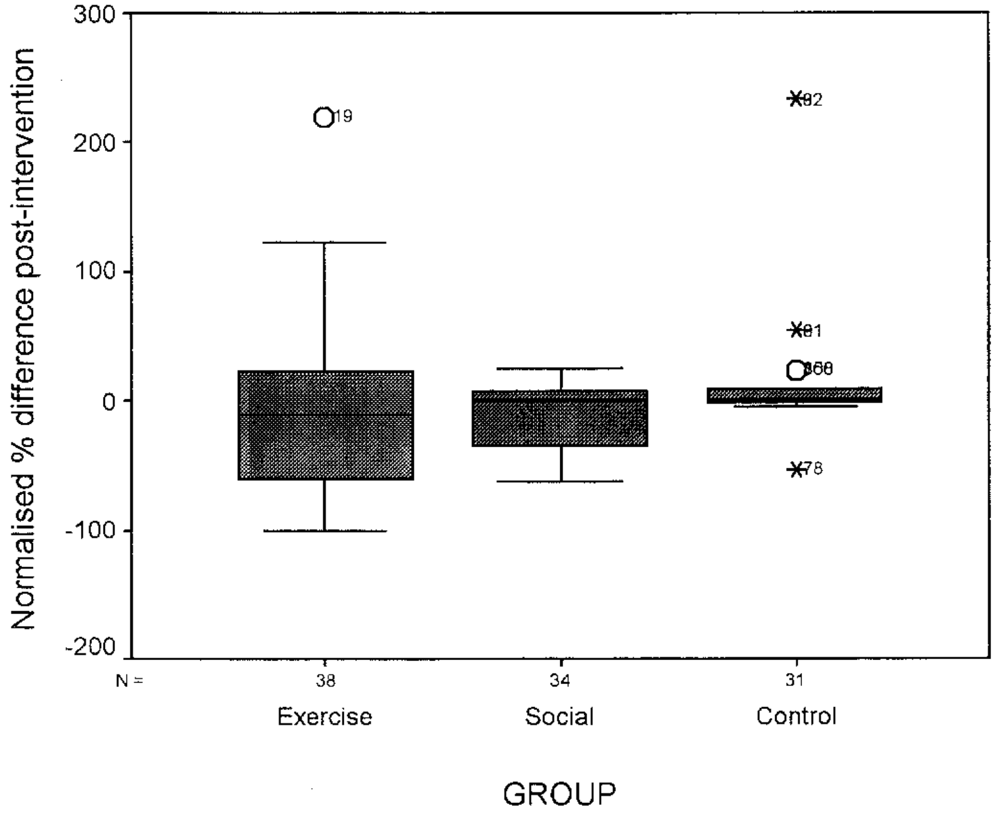

Figure 5.6 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in single limb balance with eyes closed performance

Appendix 11: Graphical representation of normalised percentage change in physical performance variables at post-intervention assessment (cont.)

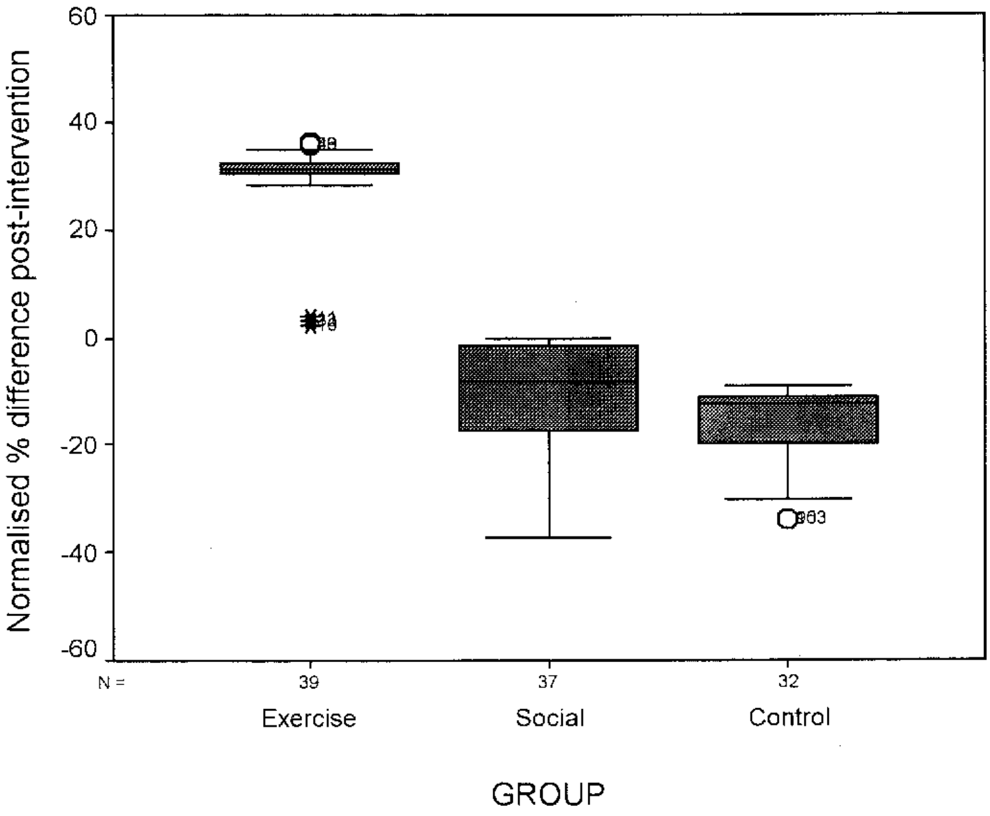

Figure 5.7 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in Functional Reach performance

Appendix 11: Graphical representation of normalised percentage change in physical performance variables at post-intervention assessment (cont.)

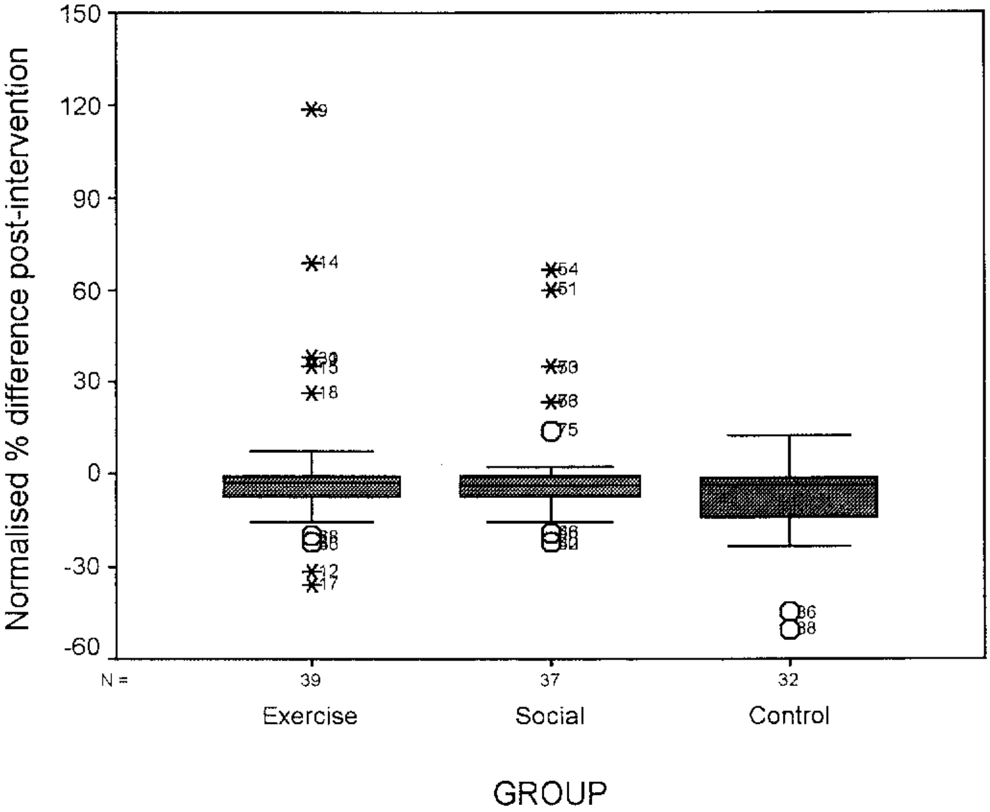

Figure 5.8 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in usual gait speed performance

Appendix 11: Graphical representation of normalised percentage change in physical performance variables at post-intervention assessment (cont.)

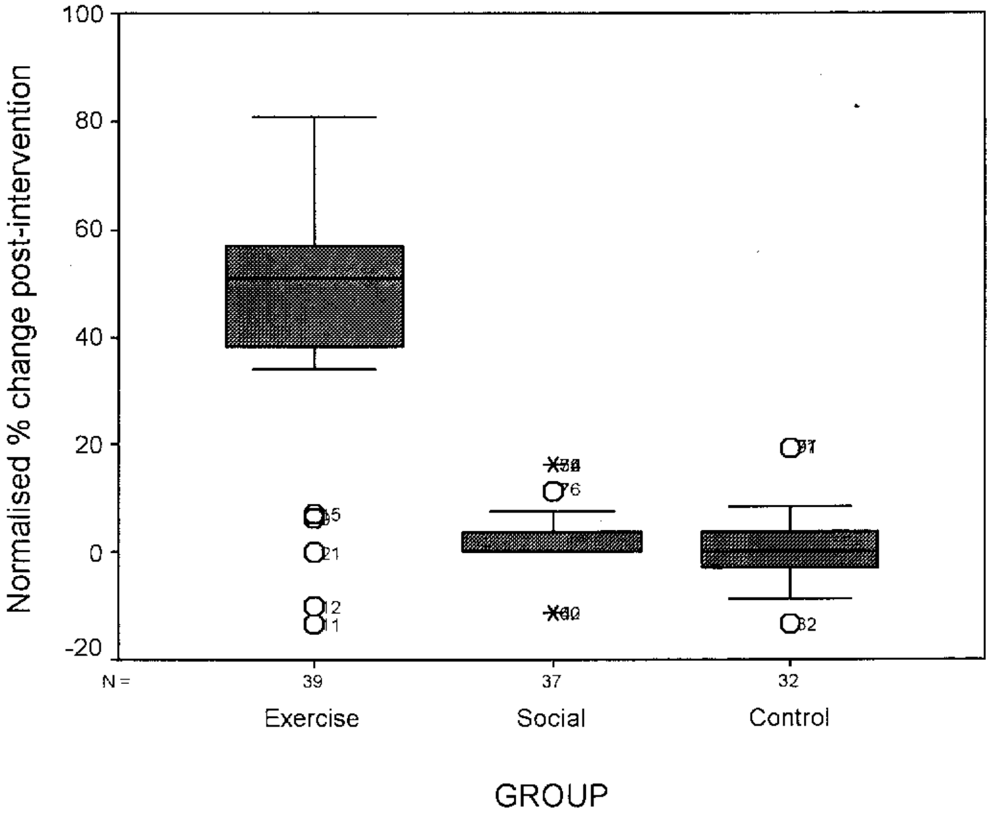

Figure 5.9 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in maximal gait speed performance

Appendix 11: Graphical representation of normalised percentage change in physical performance variables at post-intervention assessment (cont.)

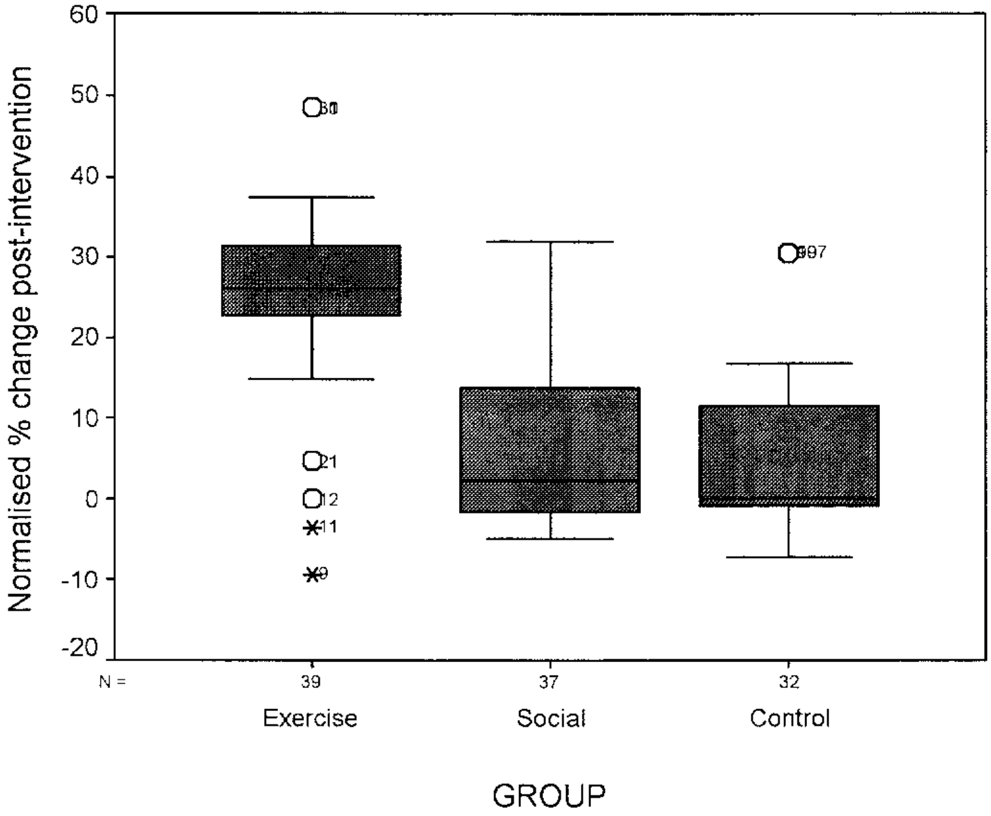

Figure 5.10 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in circuit walk performance

Appendix 11: Graphical representation of normalised percentage change in physical performance variables at post-intervention assessment (cont.)

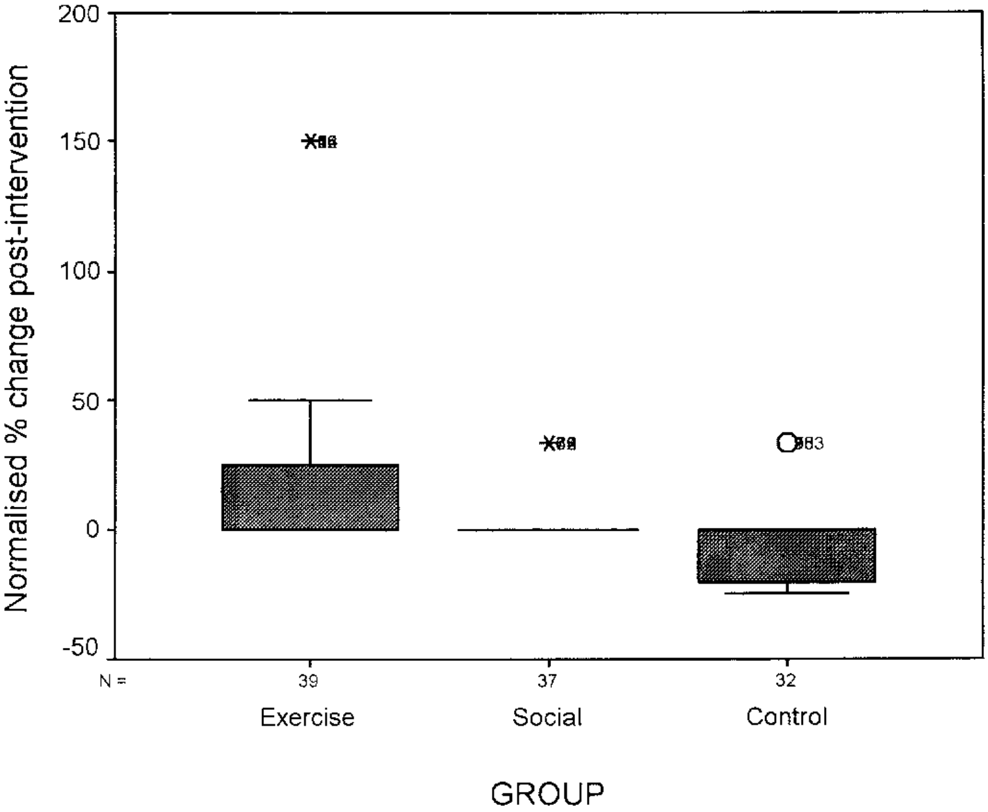

Figure 5.11 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in step height performance

Appendix 12: Graphical representation of normalised percentage change in measures of functional ability at post-intervention assessment

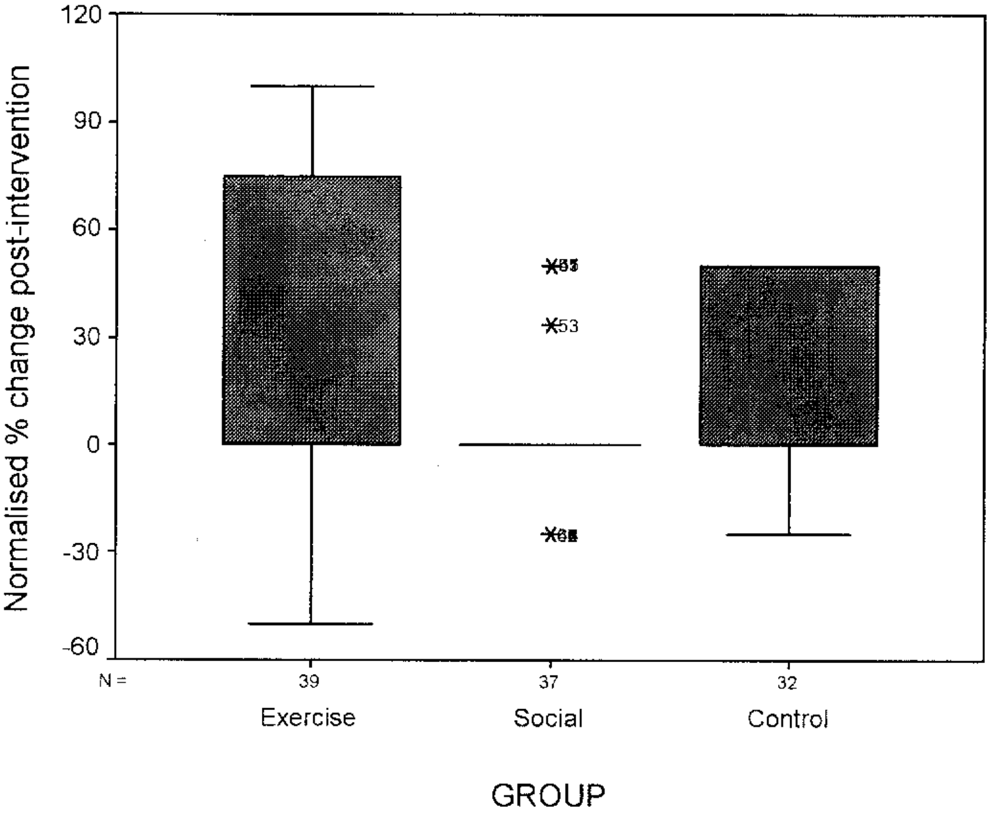

Figure 5.12 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in Upper Limb Tiredness (ULT) scores

Appendix 12: Graphical representation of normalised percentage change in measures of functional ability at post-intervention assessment (cont.)

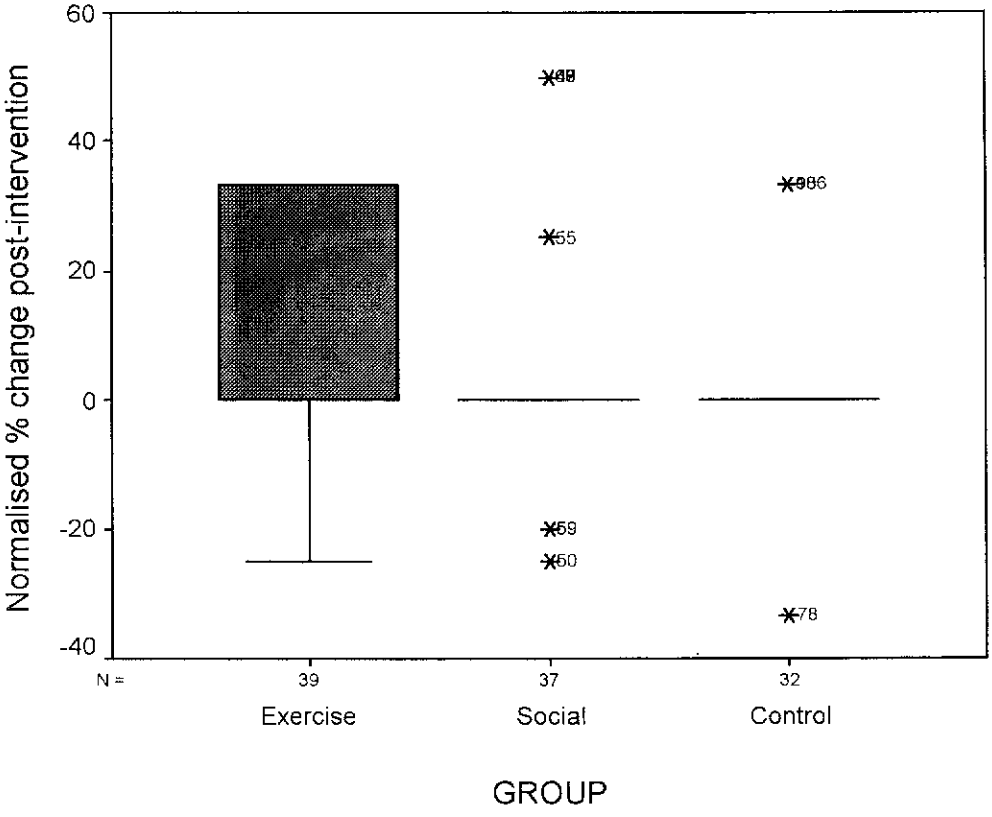

Figure 5.13 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in Lower Limb Tiredness (LLT) scores

Appendix 12: Graphical representation of normalised percentage change in measures of functional ability at post-intervention assessment (cont.)

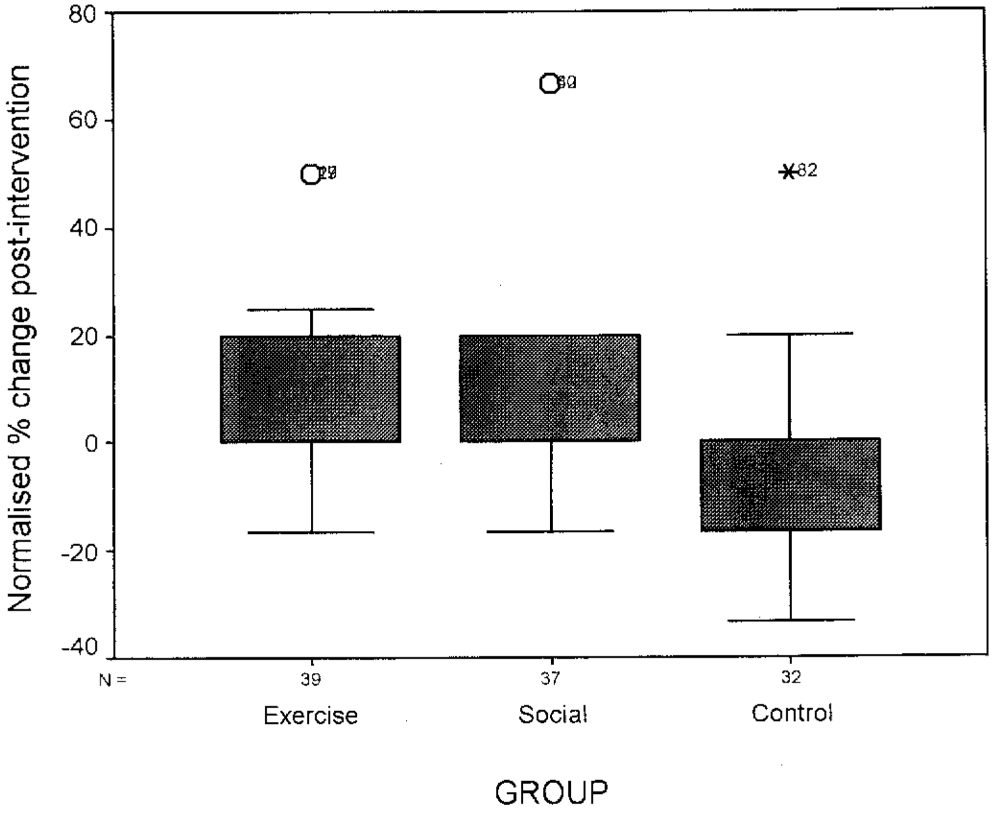

Figure 5.14 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in Mobility Tiredness (MT) scores

Appendix 12: Graphical representation of normalised percentage change in measures of functional ability at post-intervention assessment (cont.)

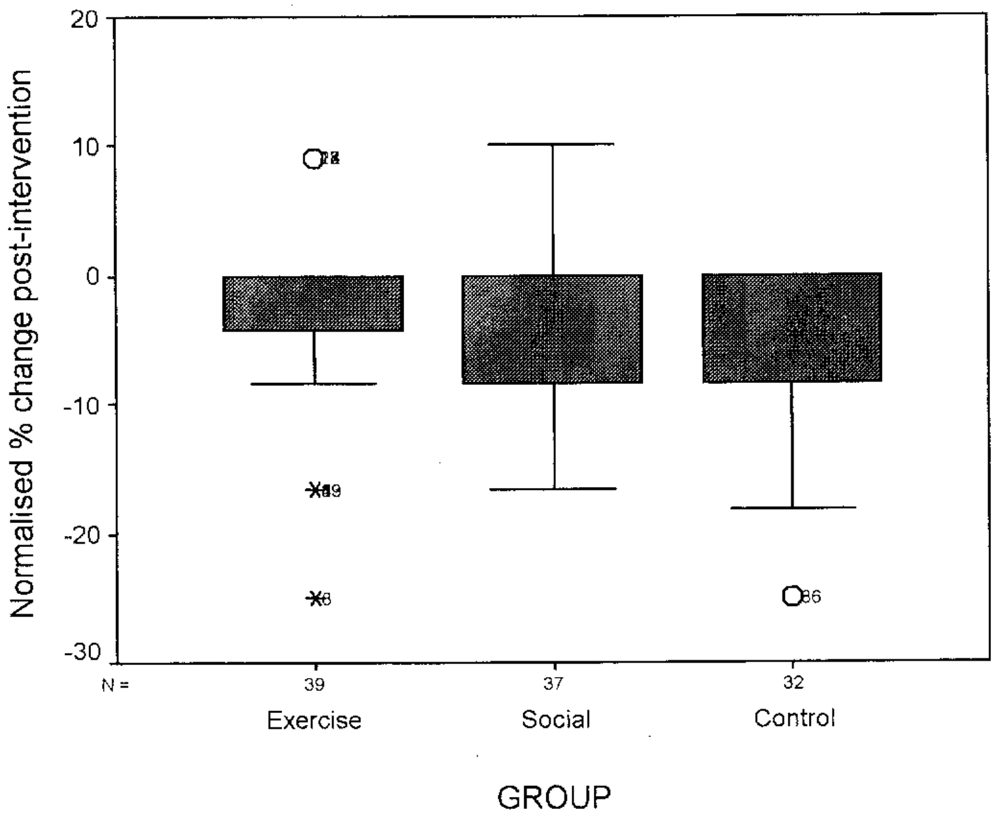

Figure 5.15 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in Mobility Help (MH) scores

Appendix 12: Graphical representation of normalised percentage change in measures of functional ability at post-intervention assessment (cont.)

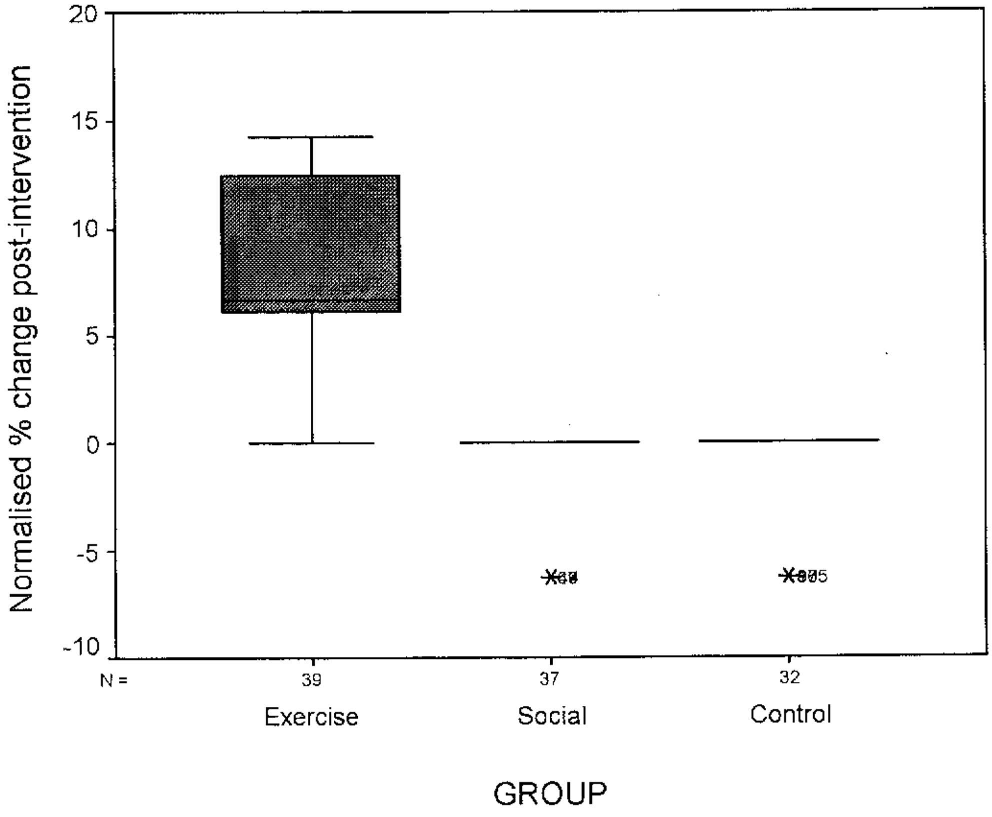

Figure 5.16 Box plot (mean, standard deviation and outlying values) for normalised percentage change at post-intervention assessment in Physical Activities of Daily Living Help (PADLH) score

Appendix 13: Posthoc Sample Size Calculation

Sample size was calculated posthoc to ensure that the study possessed appropriate power to discern differences between groups. Group means and standard deviations, for the exercise (n=39) and control (n=32) groups, were compared at the post-intervention assessment for each subscale of the Questionnaire of Functional Ability (QFA). Alpha was set at < .05. The results indicated that with the exception of the Mobility Help subscale, power was more than sufficient in the study.

Table 5.3 Posthoc sample size and power calculation

QFA subscale	Power of study exercise n=39 control n=32	No.of subjects required for 80% power
ULT	100%	13
LLT	100%	11
MT	100%	5
MH	28%	144
PADLH	100%	7