The Influence of Proprioceptive Training on the Functional Balance of Older Adults

Hanlie Jacoba Gertenbach

Thesis presented for the degree of
M. in Sport Science
University of Stellenbosch

Study Leader: Dr ES Bressan

December, 2002

Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and has not previously, in its entirety or partially, been submitted at any university for the purpose of obtaining a degree.

Signature ______________________ Date ______________

Abstract

Proprioception is generally defined as the sense of position and movement of the limbs. The sense arises through activity in sensory neurons located in skin, muscles and joint tissues. Joint proprioception provides the neurological feedback needed for the control of muscle actions, and serves as protection against excessive strain on passive joints. The rationale for this study was that if proprioception improves, functional balance will improve. Improvements in functional balance will contribute to improvements in functional skills. An improvement in functional skills can decrease dependence on others, which in turn w\could increase quality of life.

The objective of this study was to determine the effectiveness of a proprioceptive training programme, using only low technology apparatus, on the proprioception and functional balance of older adults. Twenty-five older adults (M = 73.1 years) were assigned to either a control (n = 10) or intervention group (n = 15). The Berg Balance Scale was used for assessment of the functional balance of the participants, while the Harrison's Recovery Test was used to assess proprioception. The intervention group was placed on an eight-week proprioceptive training programme consisting of three, twenty-minute sessions a week. Using paired and unpaired t-tests for the statistical analysis, significant improvements were observed in the intervention group for both proprioception and functional balance ($p<0.05$). It was concluded that the proprioception and functional balance of older adults could be significantly improved with a proprioceptive programme using only low technology apparatus.

Opsomming

Propriosepsie kan gedefinieer word as die liggaam se vermoë om die posisie en die beweging van die afsonderlike liggaamsdele waar te neem. Dit vind plaas deur die registrering van die aktiwiteit van sensoriese neurone wat in die vel, spiere en die sagte weefsel van die gewrigte is. Die neurologiese terugvoer wat noodsaaklik is vir die doeltreffende beheer van spieraksies, is afkomstig van die proprioreseptore in die gewrigte. Dit is as gevolg van hierdie neurologiese terugvoer, dat propriosepsie dien as beskermingsmeganisme teen oormatige stremming op die liggaam se gewrigte. Die beginsel van hierdie studie was dat as propriosepsie verbeter, dit sal lei tot verbeteringe in funksionele balans. Verbetering in funksionele balans sal weer lei tot verbeteringe in funksionele vaardighede. Dit is heel moontlik dat verbetering in funksionele vaardighede ‘n persoon minder afhanklik sal maak van ander. Hoe meer onafhanklik ‘n mens van ander is hoe beter is jou lewenskwaliteit, aangesien jy baie meer dinge kan ervaar en doen.

Die doel van hierdie studie was om vas te stel of ‘n propriosepsie inoefenings program, wat slegs van lae tegnologiese apparaat gebruik maak, suksesvol gebruik kan word om die propriosepsie en ook die funksionele balans van ouer volwassenes te verbeter. Vyf-en-twintig ouer volwassenes (M = 73.1 jaar) het deelgeneem aan die studie en was òf deel van die kontrole group (n = 10) òf van die oefen groep (n = 15). Funksionele balans is gemeet deur van die “Berg Balance Scale” gebruik te maak, terwyl die “Harrison’s Recovery Test” gebruik is om propriosepsie te meet. Die oefengroup het deelgeneem aan ‘n propriosepsie oefenprogram wat bestaan het uit drie, oefensessies van twintig minute elk vir ag weke. Gepaarde en ongepaarde t-toetse is gebruik gedurende die statistiese analise. Die resultate was statisties betekenisvol vir beide die propriosepsie en die funksionele balans van die oefen groep ($p<0.05$). Die studie het getoon dat die propriosepsie en funksionele balans van ouer volwassenes statisties betekenisvol verbeter kan word deur middel van ‘n inoefeningsprogram vir die verbetering van propriosepsie waar slegs van lae tegnologiese apparaat gebruik maak word.

ACKNOWLEGEMENTS

My sincere thanks and appreciation are extended to the following people:

- My mom, dad and sisters for continued encouragement, love and support.

- Dr. E.S. Bressan, who supervised this study, putting in a great deal of her time and effort. Her support, guidance, motivation, understanding and continued trust is greatly appreciated.

- Doctor M. Kidd who helped with the statistical analysis the data of this study.

- My appreciation is also extended to Suzanne Stroebel, Willie, and the rest of the Joubert family of the farm *Skilpadvlei* who has always been tolerant and supportive of me. Their love and friendship are greatly appreciated.

- The financial assistance of The National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the researcher and are not necessarily to be attributed to the National Research Foundation.

To my parents, Koos and Jo Gertenbach, for all their love.

Table of Contents

List of Figures

List of Tables

Chapter One

Setting the Problem

"Every man desires to live long… but no man would be old."

(Jonathan Swift, Thoughts on Various Subjects)

Aging is a complex process involving many variables that interact with one another. These variables greatly influence the manner in which we age (Mazzeo et al. 1999). Applied health and social scientists use several controllable factors such as nutrition, general activity level and physical activity to change the shape of the human survival curve so that most individuals can live longer. It is desirable to live a long life with health and physical mobility, yet many people live out their years in a state of morbidity, physical dependence and poor health (Spirduso, 1995).

The elderly are the fastest growing segment of the population in the United States. By the year 2020, about 20% of the American population will be older than 65 years of age (Daley & Spinks, 2000; DeVries & Housh, 1994; Martin & Grabiner, 1999; Mazzeo et al. 1999; McArdle, Katch & Katch, 1996; Spirduso, 1995; Tang & Woollacott, 1996). The most dramatic increases in the number of people over 80 are projected to occur between 1990 and 2000. Predictions of growth for this age group 80+ range from 30.3% to 45.3% for men and 23.7% to 36.4% for women. The period of greatest overall growth for people of both genders 65 and older will be from 2010 to 2020, when the baby boomers reach retirement age (Daley & Spinks, 2000; Martin & Grabiner, 1999; Spirduso, 1995). The life expectancy (the average, statistically predicted, length of life for an individual) for the majority of men in developed countries is about 71.8 years, about 78.6 years for women. Since the mid-19th century, the life expectancy of the US population at birth has nearly doubled from 40 to almost 80 years (Martin & Grabiner, 1999; Robergs & Roberts, 2000; Spirduso, 1995). It is projected that the median age for the United States will be 39 by the year 2010, this means that half of all the people living in the States will be older than 39 years (Robergs & Roberts, 2000). Figure 1 illustrates the population growth for people aged over 65 in Britain as shown by the office of population censuses and statistics. It projects that the number of people aged 65 and over will increase by 60% by 2031 (Laventure, 2000).

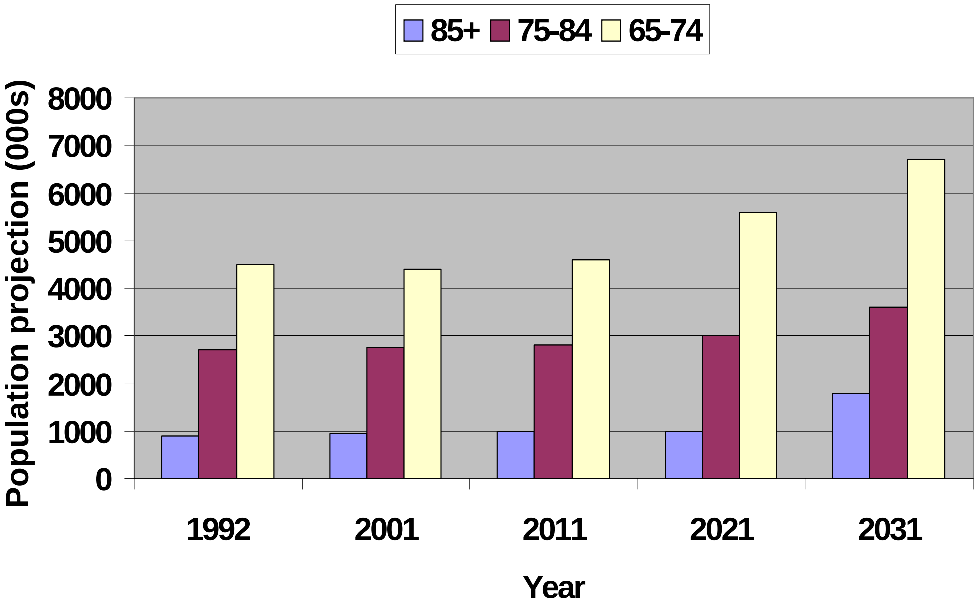

Figure 1

Projected changes in the population of older people (Laventure, 2000).

In the early part of the Twentieth Century, neonatal, infant and maternal deaths decreased, which led to an increase in life expectancy. Deaths from degenerative diseases replaced deaths from infectious diseases, which meant that gains in life expectancy were the effect of reduced mortality due to cardiovascular disease. It is estimated that the life expectancy of males at age 30 could be increased by more than 15 years if major known risk factors, such as smoking, high cholesterol, high blood pressure, and obesity were eliminated (Daley & Spinks, 2000; Mazzeo et al. 1999).

In the United States, falling is the leading cause of fatal injury in people over the age of 70 years. In 1984 death rates from falls per 100 000 persons were 1.5 for those aged younger than 65, and 147 for those 85 years and older. Of those aged over 65 years, 20% experience a serious fall each year and 30% experience a fall of some magnitude (Daley & Spinks, 2000; Kiely, Kiel, Burrows & Lipsitz, 2000; Tang & Woollacott, 1996). The annual incidence of falls in persons 65 years or older in the US is approximately 220 per 1000, resulting in approximately 7 million falls annually (Tang & Woollacott, 1996; Thapa & Ray, 1996). The annual incidence of falling is highest among older people in long-term care institutions (Kiely et al. 2000).

Somatosensation is the primary source of the sensations that trigger automatic postural responses when a standing person experiences sudden horizontal support surface displacements. These responses include the activation of distal leg muscles via short latency followed by activation of more proximal muscles. It is because of the short latency that somatosensation serves as the primary defense mechanism against falling. Visual and vestibular inputs are also critical in helping to prevent falls when a person slips (Tang & Woollacott, 1996; Wolfson et al. 1996).

Muscle weakness, impaired gait and diminished balance have been identified as the most significant risk factors for falling because they diminish the individual's ability to cope with environmental hazards (Daley & Spinks, 2000; Martin & Grabiner, 1999; Perrin, Gauchard, Perrot & Jeandel, 1999; Snow, 1999; Thapa & Ray, 1996; Tinetti et al. 1993). It has been discovered that with older individuals who fall, it may be because their ankle dorsiflexors are the weakest and have the slowest onset latency of all the muscles in the lower extremities (Ringsberg, Gerdhem, Johansson & Obrant, 1999; Snow, 1999; Tang & Woollacott, 1996; Woollacott & Shumway-Cook, 1990).

Other factors that may be associated with an increased risk of falling include vision problems, the presence of environmental hazards, and other diseases (Judge, Lindsey, Underwood & Winsemuis, 1993; Ringsberg et al. 1999; Tang & Woollacott, 1996; Thapa & Ray, 1996). The fear of falling is also a risk factor. Fear of falling contributes to a loss of self-confidence, which contributes to a decrease in physical function and mobility (Daley & Spinks, 2000; Snow, 1999).

There is increased interest in the development of programmes to address the issue of falling among the elderly.

> It is difficult to distinguish effects due to deconditioning, age-related decline, and disease. Aging is inevitable, but both the pace and potential reversibility of this process may be amenable to intervention. (ACSM, 1995: 228-229)

Although the benefits of regular physical activity have been well documented, the majority of adults in developed countries do not exercise (Buchner et al. 1993; Rhodes et al. 1999). Sample surveys conducted in Canada and the US indicated that 40% of the adult population are sedentary and another 40% exercise with a frequency and intensity too low to derive any substantial health benefits. This decrease might have something to do with the deteriorating health that often accompanies the aging process (Rhodes et al. 1999).

Age-related loss of mobility is often an uneven process that can suddenly affect an individual's functional independence and quality of life (Martin & Grabiner, 1999; Perrin et al. 1999). The adoption of a sedentary lifestyle characterized by long-term inactivity is a pitfall facing the majority of older individuals. Too many elderly people are content to believe that their physically active life ceases with increasing age, thereby creating the belief that “old” and “inactivity” are synonymous (Nicholson, 1999; Roubenoff, 2001). The decline in physical activity with advancing age promotes loss of muscle and gain in fat and leads to morbidity and mortality (Roubenoff, 2001). Spontaneous activity levels decline with aging in most individuals, resulting in increased passivity and its accompanying adverse effects. An interesting finding from studies of the effects of physical fitness programmes on elderly persons was that their spontaneous activity levels increased as they gained muscle strength (Christmas & Andersen, 2000). It is clear that regular physical activity is an important component of preventive health strategies (Mazzeo et al. 1999; McArdle et al. 1996; Rhodes et al. 1999; Robergs & Roberts, 2000; Snow, 1999).

Specifically for the elderly population, maintenance of mobility and independence should be an important exercise goal because impaired balance and gait are the two most significant risk factors for limited mobility and falls in the elderly (Daley & Spinks, 2000). There is a strong association between increased number of impairments, increased prevalence of falls, low confidence, and immobility. Therefore, a multifaceted intervention strategy is needed (Tinetti et al. 1993). It has been suggested that the practice of physical and sporting activities efficiently counteracts the age related muscle weakness, diminished balance and impaired gait associated with falling, therefore, reducing the risk of falling significantly (Perrin et al. 1999). Special attention must be given to lower extremity strength, since it is a central factor in balance, gait and the occurrence of falls (Daley & Spinks, 2000; Kirkendall & Garrett, 1998; Snow, 1999).

> Balance is also responsive to training, but the response is less predictable than strength. Unlike strengthening, however, there is no consensus regarding which of the critical elements of motor behavior need to be trained to result in improved balance or what measures of balance validly reflect its complexity and multidimensionality. Very few balance interventions had a predefined frameworks for training (e.g., sensory organization conditioning and vestibular habituation training) or were described in enough detail to be replicable (Wolfson et al. 1996:498)

Exercise interventions aimed at reducing falls in the elderly rest on the assumption that falling in the elderly is related to poor control of balance and that balance can be improved by practice and exercise (Shupert & Horak, 1999). If skeletal muscle strength in the frail elderly could be improved, more functional aspects of their lives would benefit (Kirkendall & Garrett, 1998). Snow (1999) states that exercise programmes promoting physical function should increase confidence and reduce fear of falling. These exercise programmes should include lower extremity strength and power exercises, biomechanical measures of balance, dynamic posturography and functional or mobility measures for example, chair rise and sit to stand. Some researchers found that Tai Chi interventions significantly reduced the risk of falling, but that some of the other exercise interventions they used actually might have increased the risk of falling (Owings, Pavol, Foley, Grabiner & Grabiner, 1999). Important questions remain about the role of exercise in preventing frail health and falling, including whether certain types of exercise produce greater benefits than other types do (Buchner et al. 1993). According to Frank, Winter, and Craik (1996) current training programmes for the elderly focus too much on reducing impairments and too little on helping the person function successfully in complex environments.

Statement of the Problem

Functional dependence is one of the most serious health problems encountered by elderly people. Among non-institutionalized individuals 65 years and older in the US, 12.9% have difficulty with at least one activity of daily living (ADL). Difficulty with walking affects 7.7% of older adults and difficulty with bed and chair transfers affects 5.9%. The rate of difficulty increases progressively after the age of 65 years, rising sharply in the 80s to reach 34.5% in noninstitutionalized people aged over 85 years (Daley & Spinks, 2000).

> For the average adult, about 11 to 14 years is spent with some degree of physical disability. This is not only a costly burden, for the health care system, it is also an unpleasant reality for the individual concerned. Therefore it is important to focus on examining ways to prevent losses in function through early detection of factors supporting mobility and functional independence, and maintain the ability to perform normal everyday activities safely and effectively (Nicholson, 1999:3).

Falling is an increasing problem with age. Falls compromise the health and quality of life of the older adult and increase the cost of health care. Falls are the seventh leading cause of death in the elderly (Frank et al. 1996; Perrin et al. 1999; Rose & Clark, 2000; Wolf & Gregor, 1999). Falling among the elderly is a significant clinical and public health problem that contributes to their functional decline, loss of dependence, increased health care costs, and death (Rose & Clark, 2000; Wolf & Gregor, 1999).

The majority of falls experienced by the elderly occur when walking. While both the young and the old trip and slip, the elderly are just less able to recover from such perturbations and therefore fall more often. The elderly also have a reduced ability to respond in stressful situations (Downton, 1996; Frank et al. 1996; Judge et al. 1993). The elderly have an impaired ability to correct imbalances as their corrective synergistic muscle actions are incomplete and delayed compared to the young (Downton, 1996;

Frank et al. 1996; Tang & Woollacott, 1996; Thapa & Ray, 1996). By the time messages travel from the proprioceptors to the brain and back, it is often too late to perform the movements required to control balance.

The elderly also tend to estimate postural sway less accurately, resulting in over- or under-correction and further loss of balance. Postural sway increases with age due to strength loss of the ankle dorsiflexor muscles and decreased tactile sensitivity, joint position sense, and proprioception. Proprioception and sensory input from the plantar surface of the feet have been reported to be the most important sensorial system for maintaining balance under normal conditions. Several studies indicate that one of the effects of aging is to reduce nervous conduction velocity (Perrin et al. 1999). The major reason for the 35 to 40% increase in falls among individuals over 60 years of age seems to be the delay in motor and sensory nerve conduction in the peripheral nervous system (Daley & Spinks, 2000).

Significance of the Study

> The cost of falling is high both to the individual in terms of physical and psychological trauma, loss of independence, or even death, and to health and allied services in terms of resources and bed occupancy (Close et al. 1999:93).

Providing health care to an ever-increasing elderly population is a serious problem. Total yearly costs for acute care associated with fall-related injuries are extremely high, annual expenditure for fall-related fractures alone are estimated at $10 billion (Perrin et al. 1999; Tang & Woollacott, 1996). Therefore, the ability to identify high-risk fallers and ultimately prevent falls among older persons is of great clinical, social, and economic importance (Kiely et al. 2000). The incidence of fall-related fatalities and deaths increases 40 to 60-fold between ages 25 and 75. In 1985, falls resulted in approximately 2.4 million injuries, 369 000 hospitalizations, 8920 fatalities, and direct costs of $7.8 billion in the US. In addition to their substantial adverse economic effects, falls and fall-related injuries have major medical and social consequences, including loss of ambulation, precipitation of nursing home entry, and excess mortality (Tang & Woollacott, 1996; Thapa & Ray, 1996).

The combination of an increasing population of older adults and escalating health care costs contribute to a major public health problem. In the United States, older adults account for more than one third of health care spending. In 1985, nursing home care for 1.3 million older adult residents cost $31.1 billion. By 2040, as many as 5.9 million older adults will reside in nursing homes at a cost of as much as $139 billion (without adaptations for the increase in the value of the dollar). The number of hip fractures is expected to increase from approximately 220,000 in 1987 to as many as 840,000 by the year 2040. Similarly, the cost of medical care associated with the treatment for hip fractures will rise nearly fourfold, from approximately $1.6 billion in 1987 to as much as $6 billion in 2040 (Daley & Spinks, 2000; Martin & Grabiner, 1999). It is estimated that the proportion of total health expenditure spent on people aged over 65 years in Australia will increase from 34% in 1990 to 52% in 2051. During this same period the total health services is projected to rise from $A28.7 billion to $A126 billion. This represents an increase from 8.4% to 11.1% of the gross domestic product (Daley & Spinks, 2000).

These economic figures indicate the need for preventive measures to promote the health of the elderly (Robergs & Roberts, 2000). One way to address this need is to find ways to reduce the incidences of falling. The serious medical and social impact of falling on the elderly has led researchers to develop numerous methods to explore the extent of balance dysfunction and to improve balance control abilities in older adults (Frank et al. 1996; Tang & Woollacott, 1996). An important objective of exercise programming for older adults is to increase the quality of their lives, and to focus on the extension of functional life span.

> As more individuals live longer, it is imperative to determine the extent and mechanisms by which exercise and physical activity can improve health, functional capacity, quality of life, and independence in this population (Mazzeo et al. 1999:115).

If exercise has the capability to enhance just one dimension of quality of life, even if it does not lead to functional changes in other dimensions, those subjective gains are better than no gains at all (Nicholson, 1999). Physical activities, through the increased usage of proprioceptive stimuli, contribute to more efficient postural control (Perrin et al. 1999). It is suggested that somatosensory inputs can compensate for both eye closure and vestibular deficit when a person maintains balance (Perrin et al. 1999; Riemann & Guskiewicz, 1999). Repeated participation in practice activities that present different task goals and environmental constraints should make it possible for the participant to learn how to select and implement the appropriate movement strategies more effectively (Rose & Clark, 2000).

> Postural stability involves the complex integration of motor and sensory systems, and thus, the decline in postural stability with age is likely due to several factors. Exercise seems to be able to ameliorate some of these changes, which may result in improved balance and fewer falls (Christmas & Andersen, 2000:319).

Williams and Bryan (in Nickall, 1992) indicated a significant increase in the aged population of South Africa. The projection of the population, aged 65 years and older, for the year 2010 is 2 792 200. This increase will have serious implications on the financial resources of the country. Van Rensburg (in Nickall, 1992:13) commented as follows on the situation in South Africa:

> The increase in the percentage of the aged has great economic implications. The situation will then be that an increasing proportion of the population, which is non-productive, will be dependent on a decreasing proportion of the population, which is productive.

When focussing on the South African situation, economic restrictions make it especially important to try and keep the population as healthy and independent as possible for as long as possible. Practical exercise programmes specifically designed for the South African situation could contribute to this effort.

> Training programmes for older adults should be safe, practical, and inexpensive, easily adapted at-home or in-groups, promote independence, and generalize to a wide population of community and institutionalized older adults. This approach would reduce the need for high-cost physical therapy on an individual basis (Snow, 1999:89).

The purpose of the study was to design an exercise programme for older adults that can be implemented in any setting, irrespective of the availability of resources such as finances, apparatus, time, personnel etc. The specific aim of the programme is to provide progressions of activities that promote the development of proprioception and functional balance control in older adults in an effort to improve their functional skills and thereby increasing their independence. It is hoped that improved functional balance control would also contribute to a reduction in the risk for falls.

Research Questions

The study was designed to establish whether it is possible to show improvements in the functional balance of older adults following an eight-week proprioceptive training programme. The following research questions were developed for investigation:

1. Can a proprioceptive training programme consisting of proprioceptive exercises for the upper and lower extremities, as well as the trunk, be effectively used as modality for improving the functional balance of older adults?

2. Can a proprioceptive training programme consisting of proprioceptive exercises for the upper and lower extremities, as well as the trunk, be effectively used as modality for improving the proprioception of older adults?

Methodology

The overall body proprioception and the functional balance of both the intervention as well as the control group were tested. The intervention group then followed an eight-week individualized proprioceptive training programme. Consisting of three 20-minute sessions a week. After the eighth week of training the tests were done again. A control group was pre- and post-tested using the identical protocol, with an eight week period between testing sessions. Both of these groups were asked not to modify their normal activity levels.

Limitations

1. Both the tests used are subjective in nature making it difficult to compare the results of the present study with the results of other studies.

2. The number of subjects used in this study constitutes a limitation in that the data are insufficient to generate conclusive results.

3. The sample used was not chosen at random.

Terminology

Specific terminology has been used in this study according to the following definitions:

Older Adult

There are differences in ways of classifying individuals as elderly. This might be the cause of the discrepancies found in studies examining age-related changes in the physiological systems. Therefore, whenever this study refers to the older adult or the elderly, it refers to anyone who is chronologically over 65 years of age.

Independent Living

Within the context of this study, independent living refers to the ability of persons to do the basics for themselves without assistance. In other words, they do not need help to get dressed, or with personal hygiene etc. It does not mean that they necessarily live on their own.

Functional Skills

For the purpose of this study, functional skills are all the functions that a person needs to have to enable him to go through life independently and safely.

Functional Balance

For the purpose of this study, functional balance describes balancing activities that are required for the performance of functional skills during independent living. For example, uni-pedal standing can be used for improving functional balance, as it is necessary for walking, which is a functional skill.

Chapter Two

Review of Literature

This chapter contains a summary of the literature relevant to this study. It begins with a section on proprioception where several aspects associated with proprioception are explored. Then, the focus moves to the presentation of information about aging and the older adult, with specific reference to the effects of aging on the body as well as the effect that different exercise modalities has on the older adult. The topic of functional balance is also briefly discussed. The chapter concludes with a description of how this study was organized and implemented.

Proprioception

The topics of neuromuscular control and particularly proprioception has drawn increasing attention over the last 20 years. Numerous investigators have documented the importance of the development of proprioception in preventing injury, rehabilitation following injury, and in the modification of disabilities (Lo & Fowler, 2000).

> The proprioceptive system, was first described in 1906 by Sherrington as the afferent information from 'proprio-ceptors' located in the 'proprio-ceptive field' that contributes to conscious sensations ('muscle sense'), total posture (postural equilibrium), and segmental posture (joint stability). He defined the 'proprio-ceptive field' as the 'deep' areas of the body that were not subjected to stimuli arising either in the external environment ('extero-ceptive field') or the 'partially screened' environment of the gastrointestinal tract ("intero-ceptive field"). 'Proprio-ceptors' referred to those located in joints, muscles, and tendons that were 'adapted for excitation consonantly with changes going on in the organism itself' (Lephart, Riemann & Fu, 2000:xxii).

Proprioception is generally defined as the sense of position and movement of the limbs. The sense arises through activity in sensory neurons located in skin, muscles, and joint tissues (Grigg, 1994). Proprioception is the interpretation of those sensations having to do with the physical state of the body, which includes position sensations, tendon and muscle sensations, pressure sensations as well as the sensation of equilibrium (Guyton, 1996). The term proprioception is frequently confused with closely related concepts such as kinesthesia, reflexive muscle splinting, and postural balance (Barrack & Munn, 2000; Lephart et al. 2000; Riemann & Guskiewicz, 2000; Wilkerson & Nitz, 1994).

Proprioception is specifically defined as a specialized variation of the sensory modality of touch that encompasses the sensation of joint movement (kinesthesia) and joint position (joint position sense) (Lephart, Pincivero, Giraldo & Fu, 1997; Barrack & Munn, 2000). Proprioception is the cumulative neural input to the central nervous system (CNS) from the mechanoreceptors in the joint capsules, ligaments, muscles, tendons, and skin (Wilkerson & Nitz, 1994). Proprioception and postural balance work closely together in the postural control system which utilizes sensory information related to movement and posture from peripheral sensory receptors e.g. muscle, joint, and cutaneous receptors. Joint proprioception provides the neurological feedback needed for the control of muscle actions, and serves as protection against excessive strain on passive joints. These are the primary reasons why proprioceptive mechanisms are essential for proper joint function in sports, activities of daily living, and occupational tasks (Borsa, Lephart, Kocher & Lephart, 1994).

Functional Neuroanatomy of Proprioception

Proprioception is a system of cutaneous, muscle, and joint mechanoreceptors (Lephart et al. 1997) that mediate neural feedback to the central nervous system (CNS). The system involves a largely subconscious set of neurological mechanisms that constantly monitor, adjust, anticipate and correct the sequence of musculoskeletal actions. The major components of this system are the cerebellum, basal ganglia, spinal cord, and the immense network of proprioceptive receptors supplying the CNS components with data (Dye, 2000).

The Somatosensory Sub-system

The somatosensory system is critical for balance and motor control and provides information related to body contact and position. The successful control of movement depends on constant and accurate information from the somatosensory system (Spirduso 1995). Joint rotations deform the skin, muscles, tendons, fascia, joint capsule, and ligaments in and around the joint, all of which are innervated by mechanoreceptors (Grigg, 1994). These mechanoreceptors convert the mechanical energy of the physical deformation into electrical energy of a nerve action potential (Barrack, Lund, & Skinner, 1994; Barrack & Munn, 2000; Koralewicz & Engh, 2000; Wilkerson & Nitz, 1994). Full proprioceptive sensitivity depends on combined actions of the muscle receptors, joint receptors, and cutaneous mechanoreceptors (Giraldo, Fink, Vassilev, Warner & Lephart, 2000; Grigg, 1994).

The mechanoreceptors provide position sense (the conscious awareness of the position of the joint in space) and initiate protective reflexes that help to stabilize the joint (Barrack et al. 1994; Barrack, Skinner & Buckley, 1989). Information from the mechanoreceptors is used to initiate preparatory and reactive muscle activation during motor performance (Swanik, Rubash, Barrack & Lephart, 2000). This information also should be adequate to compensate for eye closure and minor vestibular deficits when maintaining balance (Riemann & Guskiewicz, 2000).

Skin Mechanoreceptors: Joint rotation causes skin to be stretched on the one side of the joint, and relaxed or folded on the other. This stretching of the skin signals joint motion and position. This contribution to proprioception via the skin mechanoreceptors is minor (Grigg 1994; Hall & McCloskey, 1983).

Joint Mechanoreceptors: There are three major types of receptors surrounding the joints that provide important information for balance and coordination (see Table 1).

Table 1. Joint mechanoreceptors (Barrack et al. 1989; Brindle, Nyland, Shapiro, Caborn, & Stine, 1999; Grigg, 1994; Irrgang & Neri, 2000; Johansson, Pedersen, Bergenheim & Djupsjöbacka, 2000; Lephart et al. 1997; Newton, 1982; Spirduso 1995).

Receptor Type	Location	Adaptation Rate	Function
Ruffini endings	Joint capsule and ligaments	Slow	Sensing joint position, intra-articular pressure, and the amplitude and velocity of joint rotation.
Pacinian corpuscule	Joint capsule and periarticular connective tissue	Rapid	Sensing high frequency vibration and sudden movements or accelerations and decelerations.
Unmyelinated free nerve endings	Ligaments and related muscles	Slow	Joint pain, e.g. inflammation

Rapidly adapting receptors generate maximal impulses immediately after stimulation and that rate declines quickly despite the continued presence of the stimulus (Barrack et al. 1989; Grigg 1994; Irrgang & Neri, 2000). Slowly adapting receptors sustain impulse rate for a longer period of time in response to continued stimulation (Barrack et al. 1989; Irrgang & Neri, 2000; Johansson et al. 2000).

Muscle Mechanoreceptors: There are two main types of receptors providing complementary information about the state of the muscles (see Table 2). The muscle spindle is located in the fleshy part of the muscle, and is most active when the muscle is stretched. The Golgi tendon organ is located in the junction between the muscle and the tendon, and is most active when the muscle contracts (Irrgang & Neri, 2000; Schmidt & Timothy, 1999). The process of alpha-gamma coactivation (the interaction of afferent and efferent functions of the muscle spindle) enables the body to match the magnitude of the postural response to the magnitude of the perturbation. This process enables afferent information to be returned to the brain in order to provide awareness of the movement of the body parts and their spatial position (Robergs & Roberts, 1997; Shupert & Horak, 1999).

Table 2. Muscular mechanoreceptors (Brindle et al. 1999; Irrgang & Neri, 2000; Lephart et al. 1997; Robergs & Roberts, 1997; Schmidt & Timothy, 1999; Spirduso, 1995).

Receptor Type	Location	Adaptation Rate	Function
Golgi tendon organ	Tendons	Slow	Reflex
Muscle spindle	Muscle	Slow	(stretch) Reflex

Stimulation of the mechanoreceptors in joint structures increase the sensitivity of muscle spindles in those muscles associated with the joint (Fitzgerald, Axe & Snyders-Mackler, 2000). This increased sensitivity of the muscle spindles may result in a higher state of “readiness” of muscles to respond to perturbing forces, which may, in turn, improve joint stability. Of all the classes of receptors responsible for providing proprioceptive signals, the muscle receptors play the biggest part (Beard & Refshauge, 2000; Giraldo et al. 2000; Grigg, 1994; Refshauge, Kilbreath & Raymond, 2000; Wilkerson & Nitz, 1994).

Central Nervous System (CNS)

In the CNS, proprioceptive input is integrated with afferent signals from vision and the vestibular apparatus to monitor the position of the center of gravity (COG) to control balance. Balance control relies on appropriate muscle activation patterns, coordinated by a complex interaction between the signals of the cerebrum, cerebellum, spinal cord, and the peripheral afferents and efferents (Allen, 2000; Wilkerson & Nitz, 1994).

Motor control is carried out at three different levels (Biedert, 2000; Giraldo et al. 2000; Irrgang & Neri, 2000; Lephart et al. 1997; Lephart & Henry, 2000):

- Simple reflexes provide joint stability and occur at spinal level.
- The brain stem provides for the coordination of responses associated with balance and postural activities.
- The cerebral cortex is where conscious sensations of motion and position occur, and it is responsible for controlling complicated responses as well as the learning of new skills.

Spinal Level: At the spinal level, proprioception is a non-conscious process with reflexes initiating movement responses. This provides reflex stabilization of the muscles acting on the joint, and helps maintain muscle stiffness during activity (Irrgang & Neri, 2000; Lephart et al. 1997; Lephart & Henry, 2000). Reflex actions are important for joint stabilization during conditions of abnormal stress, which is why it important to work with these reflexes during rehabilitation (Lephart et al. 1997).

Brain Stem: The brain stem receives afferent input from the joint and muscle receptors as well as the vestibular centers in the ears and the eyes. All this information is used to maintain balance and posture of the body (Lephart et al. 1997; Lephart & Henry, 2000). The brain stem plays an important role in modulating spinal motor circuits. The input from the reticular formation, the vestibulospinal projections and other motor system components are integrated in the brain stem to provide a continuously adapting background of muscle tone and body posture, which facilitates voluntary motor actions (Giraldo et al. 2000).

Cerebral Cortex: The cerebral cortex processes sensory stimuli and supports the voluntary control of movements. It is capable of coordinating the different functions in the spinal cord, brain stem, basal ganglia and cerebellum to produce effective movement patterns (Biedert, 2000). At the level of the cerebral cortex, the conscious awareness of joint motion and position can contribute to proprioception and balance control (Allen, 2000).

The higher level of representation of receptors in the lower limbs in the post central gyrus, accounts for the conscious awareness of the position sense of the extremities, as well as for the importance of proprioceptive input from the lower extremities (Barrack et al. 1994; Barrack & Munn, 2000). The premotor and supplementary motor areas are important for coordinating and planning sequences of movement (Giraldo et al. 2000). Movement patterns that are repetitive in nature are stored as central commands and can be performed without continuous reference to consciousness (Lephart & Henry, 2000).

Proprioceptive Deficits and Functional Instability

Proprioception provides the information needed for dynamic joint stability (Laskowski, Newcomer-Aney & Smith, 1997). Normal proprioceptive input is adequate to protect and stabilize the joints during normal daily functions but it is not enough to protect the joints from the extraordinary circumstance that are encountered in the case of catastrophic accidents. In an injury situation, for example, no level of muscle response/contraction could prevent ligament damage (Barrack & Munn, 2000). The load imposed on the joint is the most important factor of functional joint stability, and the load is just too extreme during some accidents (Johansson et al. 2000).

Patients with generalized joint laxity and functional instability have a weakened sense of proprioception (Allen, 2000). It is suggested that injury precede deficits in proprioception and propagates the cycle of the functional instability paradigm (Allen, 2000; Barrack & Munn, 2000; Borsa, Lephart, Kocher & Lephart, 1994; Irrgang & Neri, 2000; Lephart et al. 1997; Lephart & Henry, 2000).

The functional instability paradigm (See Figure 2) shows the link between proprioceptive deficits and joint pathology in athlete populations, persons with traumatic joint pathology and degenerative joint disease (Borsa et al. 1994). Injury results in altered somatosensory input influencing neuromuscular control. If static and dynamic balance and control are not re-established following injury the athlete will be susceptible to recurrent injury and performance may decline (Borsa et al. 1994; Irrgang, Whitney & Cox, 1994).

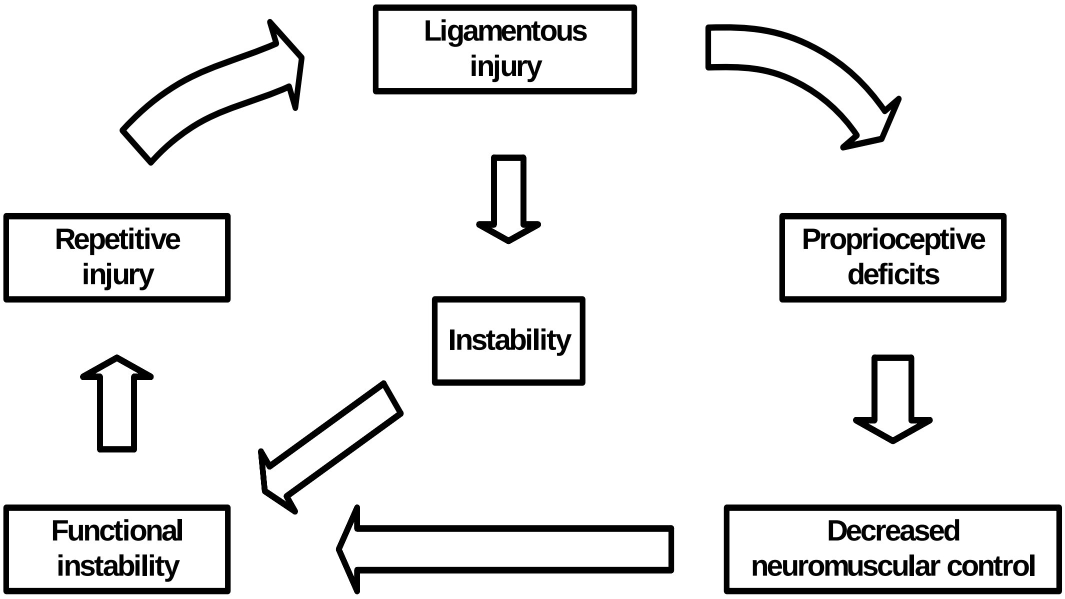

Figure 2
Functional instability paradigm (Lephart & Henry, 2000).

It can be seen in this figure that injury produces proprioceptive deficits and joint instability. Surgery combined with rehabilitation is intended to improve function and prevent the recurrence of these symptoms (Borsa, Lephart, Irrgang, Safran & Fu, 1997; Giraldo et al. 2000). This is one reason why the development of balance and proprioception in the rehabilitation of injured athletes is receiving increasing attention (Borsa et al. 1994).

Proprioceptive Deficits in the Ankle

Impaired postural control demonstrated by the results of performance on a stabilometer (balance platform) is a predictor of future ankle injuries. Factors such as muscle atrophy and impaired postural control contribute to the development of functional instability, and predispose a person to recurrent ankle sprains. Ankle proprioception is widely regarded as an important factor affecting susceptibility to ankle sprains, but the precise mechanisms by which proprioceptive abilities may enhance ankle stability are not well understood (Barrack et al. 1994). Several researchers found improvements in postural sway and reduced subjective complaints of ankle “giving way” after an ankle disk training programme (Gauffin, Tropp & Odenrick, 1987; Hewett, Lindefeld, Riccobene &

Noyes, 1999; Lo & Fowler, 2000; Tropp, Ekstrand & Gillquist, 1984:a). This improved ankle stability might be caused by increased muscle strength or by improved coordination (Gauffin et al. 1987).

Proprioceptive Deficits in the Knee

A lack of reflex stabilization of the knee is associated with a decrease in the sensory feedback mechanisms, which in turn causes latent motor responses of the hamstring muscles (Borsa et al. 1997; Lephart et al. 1997). This leads to abnormal body positioning and an increased probability of re-injury (Lephart et al. 1997). Patients who are fatigued may have changed proprioceptive abilities, which make them more prone to injuries. This might not be due to a deficit in proprioception, but rather to the decreased ability of the muscles to respond to the mechanoreceptor signals (Barrack et al. 1994; Giraldo et al. 2000; Lo & Fowler, 2000). Whether proprioceptive deficits are the cause of the injury or the result of the injury remains controversial (Lo & Fowler, 2000).

There is a clinical proprioceptive deficit in most patients with functional instability after an anterior cruciate ligament (ACL) rupture. This deficit seems to persist to some degree after an ACL reconstruction (Barrack et al. 1994). The most appropriate rehabilitation protocol for ACL rehabilitation would be a programme that includes isometric strengthening of the hamstrings, gastrocnemius and quadriceps as well as dynamic reflex training and functional hamstring co-contraction. This could be achieved by proprioceptive training utilizing unstable boards, visual feedback, and other muscle training techniques combined with closed kinetic chain exercises to promote early return of isometric strength while training hamstring co-contraction (Barrack et al. 1994). Simple muscle strengthening exercises do not have as beneficial an effect as dynamic training programmes. Ihara and Nakayama (1986) found that the use of exercises on an unstable board to stress the ACL and hamstring contraction pattern could restore the efficiency of the reflex arc that contributes to knee stability.

Proprioception and the Lower Back

Persons who have low-back pain demonstrate significantly greater postural sway and are less likely to be able to balance in challenging positions than those who do not have back pain. It is believed that persons who have low-back pain experience an alteration in afferent feedback that may lead to poor control of posture and movement. Dynamic lumbar stabilization exercises are the most popular method of proprioceptive retraining for the low back. This involves the coordinated strengthening of the abdominal, back, and trunk muscles in functional movement planes. The amount of resistance for strength training must be modified according to the person's pain and progress. Position sense may not be the most sensitive measure of proprioception in the lower back, because pain may provide a stimulus and that can actually enhance awareness of body position. Postural sway has been identified as a better measure of proprioception in the lower back, especially for people with lower back pain (Laskowski et al. 1997).

Proprioceptive Deficits and Aging

Proprioceptive sensation thresholds increase with age, which reduces sensitivity to joint position and vibration (Barrack & Munn, 2000; Berg, 1989; Daley & Spinks, 2000; Giraldo et al. 2000; Ishii, Terajima, Terashima & Matsueda, 2000; Kaplan, Nixon, Reitz, Rindfleish & Tucker, 1985; Spirduso, 1995). The ankle joint is one of the primary sites of receptors that provide information for controlling posture. Any loss of proprioceptive sensitivity in the lower limbs will decrease balance control considerably and contribute to gait dysfunction in the elderly (Ashton-Miller, 2000; Barrack et al. 1989; Berg 1989; Borsa et al. 1994; Daley & Spinks, 2000; Ishii et al. 2000; Kaplan et al. 1985). These proprioceptive deficits might be caused by the loosening of joint capsules as a result of the narrowing of joint space, which could result in a reduction in the deformation of mechanoreceptors (Giraldo et al. 2000). Regular physical activity lessens the decline in proprioception with age, suggesting that disuse atrophy is another possible causative factor (Swanik et al. 2000).

The temporal and spatial organization of postural synergies seems to change in older adults. Older adults have difficulty in perceiving moving objects as well as perceiving self-motion with reference to their external environment (Tang & Woollacott, 1996; Woollacott & Shumway-Cook, 1990). It is known that elderly persons take longer time to carry out movements and fail more frequently when adjusting their movements to compensate for errors than young subjects (Kaplan et al. 1985). Elderly subjects with poor visual acuity and contrast sensitivity have increased postural sway only when their proprioception is also reduced. This shows that proprioception is crucial for maintaining balance (Downton, 1996).

Osteoarthritis is associated with decreased proprioception. If a person has arthritis in only one knee, the ability to detect passive motion is impaired in both knees (Borsa et al. 1994; Giraldo et al. 2000; Koralewicz & Engh, 2000; Lephart et al. 1997; Lo & Fowler, 2000). Individuals with chronic proprioceptive impairments will more likely exhibit articular pathology (Ashton-Miller, 2000). The loss of proprioception is independent of the severity of knee arthritis (Koralewicz & Engh, 2000). The hip joint proprioception of patients with hip fractures is not diminished compared to age-matched controls. The maintenance of the femoral head is not necessary for the maintenance of joint proprioception in elderly patients with hip fractures (Ishii et al. 2000). The perception of the position of the neck and head also may become less accurate with aging due to gradual loss of cervical articular mechanoreceptor function (Spirduso, 1995).

Proprioceptive Training

Freeman and Wyke (in Barrack et al. 1994) were the first to suggest that proprioceptive training is an important aspect of the rehabilitation following ligament reconstruction. They found that proprioceptive training through stabilometry (training on an unstable board) significantly reduced episodes of the joint “giving way.” Several other authors found similar results (Gauffin et al. 1987; Hewett et al. 1999; Lo & Fowler, 2000; Tropp, Ekstrand & Gillquist, 1984:b). Regaining dynamic neuromuscular control is very important for an athlete to return to functional activity. Rehabilitation exercises should focus on incorporating joint position sensibility and reflexive-type contractions into the training programme (Lephart et al. 1997).

To improve the proprioceptive system or to restore lost function, the system has to be challenged (Laskowski et al. 1997). Proprioceptive training as part of the rehabilitation of joints in the lower limbs is commonly thought of as single-leg balance exercises. These exercises are performed on multi-axial balance boards to enhance neural mechanisms and restore lost proprioception following injury (Irrgang & Neri, 2000; Wilkerson & Nitz, 1994). The objective of proprioceptive rehabilitation is to enhance the sensation of the joint relative to body position and movement, and to enhance muscular stabilization of the joint in the absence of structural restraints, such as a knee or ankle brace (Borsa et al. 1994; Lephart et al. 1997; Wilkerson & Nitz, 1994). Specific proprioceptive training can help to fine-tune the afferent-efferent arcs.

Reflex control of muscular stabilization and a person’s conscious awareness of joint motion and position are mediated by the proprioception, which is why proprioceptive training is focused on the re-establishment of afferent and efferent pathways (Borsa et al. 1994). Rehabilitation programmes recommended to promote dynamic joint stability should include a proprioceptive component addressing the retraining of reflexes, basic balance and body awareness (brainstem activity) and voluntary movements (cognitive involvement) (Lephart et al. 1997; Lephart & Henry, 2000; Irrgang & Neri, 2000). The objective must be to stimulate the joint and muscle receptors in order to encourage maximum afferent discharge to the respective CNS level (Borsa et al. 1994).

Progressive Neuromuscular Control Programmes

The following progression of activities should be conducted in order to restore proprioception and neuromuscular control following an injury or instability. Such a progression allows the rehabilitation programme to address the integration of spinal reflex, cognitive, and brainstem pathways and focus on stabilization, motion, and neuromuscular control (Lephart et al. 1997; Lephart & Henry, 2000; Irrgang & Neri, 2000).

1. Dynamic Stabilization.

   The objective of dynamic stabilization exercises is to promote co-activation of the receptors that surround the joint and adjacent muscles. This should be the first element to be restored during rehabilitation. Without the muscular stabilization provided by the activation of the force couples, progression to more reactive and functional activities is not plausible (Barrack et al. 1994; Irrgang & Neri, 2000; Lephart et al. 1997; Lephart & Henry, 2000).

   Activities focusing on sudden alterations in joint position re-establishes reflex neuromuscular control and stimulates dynamic joint stabilization originating in the spinal cord (Borsa et al. 1994; Lephart et al. 1997). These exercises can be performed in an open kinetic chain using manual assistance or in a closed kinetic chain using an unstable base. They should stimulate both joint and muscular mechanoreceptors for reflex stabilization. As joint position changes, dynamic stabilization must occur for the participant to control his/her balance (Borsa et al. 1994).

2. Position Sensibility.

   The objective of the exercise to promote position sense is to restore kinesthesia. The activities in this category enhance the ability of the muscles to provide joint stability and to perform precise movement patterns. This phase stimulates cognitive level processing through exercises such as body re-positioning with and without visual input and proprioceptive neuromuscular facilitation patterns performed with manual resistance (Borsa et al. 1994; Lephart et al. 1997; Lephart & Henry, 2000).

Stimulating the conversion from conscious to automatic motor control of body position can be achieved by performing joint positioning activities, especially at joint end ranges (Borsa et al. 1994; Lephart et al. 1997). Passive and active joint repositioning is necessary to accomplish appreciation of joint position. Passive repositioning stimulates articular mechanoreceptors, while active repositioning relies on input from articular- and muscle receptors (Borsa et al. 1994).

3. Reactive Neuromuscular Control.

A proposed mechanism for neuromuscular control of joint stability is that when applying destabilizing forces to the knee during treatment, it may enhance neuromuscular responses to destabilizing forces encountered during function (Borsa et al. 1994; Fitzgerald et al. 2000; Lephart et al. 1997). Another proposed mechanism is the “force-feedback” hypothesis, which states that when a perturbing force is applied to a joint, it activates the muscles around the joint to resist the perturbation via a stretch reflex. Simultaneously, there is an inhibitory reflex on the muscles that pull in the same direction as the perturbation. This results in a coordinated coactivation of the muscles affected by the perturbation to stiffen the joint and maintain stability (Borsa et al. 1994; Fitzgerald et al., 2000). These reflex stabilization exercises provides a mechanism for the development of dynamic joint stability (Borsa et al. 1994; Lephart & Henry, 2000).

Activities in this category enhance brainstem activity. They are performed on a surface that will provide sudden, unpredictable changes in the position and load upon the joint, both with and without visual input. With specific regard to the upper extremity plyometric type activity may also be placed within this category (Borsa et al. 1994; Garn & Newton, 1988; Laskowski et al. 1997). These activities involve loading of the joint in extreme positions and emphasize eccentric muscle activity. Eccentric loading of the rotator cuff muscles may reduce injury and permit higher levels of dynamic stability because of the high stress it places on the muscles (Borsa et al. 1994; Brindle et al. 1999; Lephart et al. 1997). Neuromuscular control of joint motion requires development of muscle strength and endurance and appropriate recruitment patterns to regulate the timing and force of contraction to produce efficient movement and dynamic joint stabilization (Borsa et al. 1994; Brindle et al. 1999; Fitzgerald et al. 2000; Lephart et al. 1997).

The above mentioned mechanisms have several implications for the design of treatment programmes. The force-dependant nature of the mechanisms suggests that exposing the joint to potentially destabilizing loads during training is the stimulus encouraging the development of neuromuscular compensatory patterns for example involuntary muscular responses to destabilizing forces (Fitzgerald et al. 2000).

4. Functional Motor Patterns.

Practicing functional motor patterns are the final phase of proprioceptive rehabilitation programmes. As with any type of rehabilitation programme, functional specificity is vital. Once joint sensibility and dynamic joint stabilization are restored, the patient can progress to specific functional activities (Garn & Newton, 1988; Laskowski et al. 1997; Lephart et al. 1997). The objective of exercises in this category is to restore the functional motor patterns that the individual will encounter during their normal daily routines, for example, a sportsperson must work with the movement patterns needed during his/her sport participation (Garn & Newton, 1988; Laskowski et al. 1997).

In the lower extremities, the majority functional activity are performed in a closed kinetic chain or weight-bearing position. The mechanoreceptors located in these joints are best stimulated during closed chain exercises where the loading of the joint axis is perpendicular. These exercises should be performed at various positions throughout the full range of motion because of the difference in the afferent response at different joint positions (Barrack et al. 1994; Garn & Newton, 1988; Giraldo et al. 2000; Irrgang & Neri, 2000; Laskowski et al. 1997; Lephart et al. 1997; Lephart & Henry, 2000; Lo & Fowler, 2000). Closed kinetic chain exercise is much more effective than open kinetic chain programmes in increasing the level of hamstring co-contractions and decreasing the shear force on the knee (Barrack et al. 1994; Giraldo et al. 2000; Irrgang & Neri, 2000; Lo & Fowler, 2000). Hamstring-quadriceps co-contractions are the commonest response to perturbations (Octiff, Gardner, Albright & Pope, 2000). While closed chain exercises are more functional, they do not result in maximal activation of muscles and optimal strength development (Irrgang & Neri, 2000; Lephart et al. 1997).

The integration of these four levels is necessary if a rehabilitation programme is to restore neuromuscular control and functional stability around any joint. Completion of the progressive neuromuscular control rehabilitation programme minimizes the risk of re-injury and promotes a greater chance of successful return to competition (Lephart et al. 1997).

The Upper Extremity Functional Classification System

An alternative classification system for proprioceptive training is proposed for the rehabilitation of the upper extremities. The following four “types” of exercises should be included in an upper extremity proprioception rehabilitation programme (Irrgang & Neri, 2000; Lephart et al. 1997; Lephart & Henry, 2000).

1. Exercises with a fixed boundary and an external axial load for example performing a push-up on an unstable platform.

2. Exercises with a moveable boundary and an external axial load for example rhythmic stabilization or a traditional bench press.

3. Exercises with a moveable boundary and an external rotary load for example exercises with resistance tubing in a functional diagonal pattern.

4. Exercises with a moveable boundary and without load for example exercise that involves active and passive positioning.

Balance and Coordination Training

Balance is the single most important factor underlying movement strategies within the closed kinetic chain. Proper maintenance of balance and postural equilibrium is therefore a vital component in the rehabilitation of joint injuries and should not be overlooked (Riemann & Guskiewicz, 2000). Balance training mostly helps to train the proprioceptive system in a static way (Laskowski et al. 1997). The effects of training balance on and unstable disk, for example, appear effective but the underlying mechanisms of balance control is not fully understood. A decrease in postural sway occurs when patients stand on either foot, indicating the possibility of a centrally tuned coordination programme for re-education of impaired position sense. Disk training may also have an affect on muscular strength, which will make it easier to compensate for disequilibrium (Hewett et al. 1999).

Balance training should require the person to keep or return the COG over the base of support during various environmental conditions and changes in body position (Freeman, 1965; Riemann & Guskiewicz, 2000). Techniques to stimulate sensory input include alterations of somato-sensation (foam vs. hard surface), vision (eyes closed vs. open), and vestibular (conflict dome vs. normal vision) (Irrgang & Neri, 2000; Riemann & Guskiewicz, 2000; Shumway-Cook & Woollacott, 1995; Woollacott & Tang, 1990).

Exercises performed on a multi-axial board may improve dynamic postural balance by increasing awareness of the location of the COG and by increasing ankle strength in a functional eccentric mode. Balance board activities may also increase the sensitivity of muscle mechanoreceptors increasing the proprioceptive input to the spinal cord (Wilkerson & Nitz, 1994).

Balance control relies on visual, vestibular, and somatosensory information, which must be integrated and coordinated in such a way that neural commands to the leg and trunk muscles can correct almost instantaneously for deviations in balance. These corrections can occur so rapidly because the CNS programmes organizing balance information automatically activate the appropriate correction mechanisms. These CNS programmes are activated when sudden perturbations to balance occur and when preparing, planning, and executing willful movement (Spirduso, 1995).

Current Research about Proprioceptive Training

General recommendations about proprioceptive training programmes can be drawn from research (see Table 3) and approaches for the measurement of proprioception can be identified. In terms of training programmes, for example, some of the exercises in the programme should be repetitive, conscious movements performed slowly and deliberately while other exercises should involve externally applied perturbations to the joint position, initiating reflex muscle contractions. These rehabilitation programmes should improve functional status (Laskowski et al. 1997). To effectively restore reflex stabilization of the lower extremity Borsa et al. (1994) recommends stressing performance-based, weight-bearing, closed kinetic chain exercise for the muscles acting on the knee joint, in the rehabilitation programme. Proprioceptive training with five different phases of balance training on various boards that challenged the balance system was shown to significantly reduce the incidence of ACL injury in soccer players (Laskowski et al. 1997).

Table 3. Summary of current research on proprioceptive training describing frequency and type of programmes.

Author(s)	N	Frequency	Type of Exercises	Results
Freeman, (1965)	85	5 times	Coordination training vs. traditional physiotherapy modalities	Improved one-legged standing and decreased giving way of the foot.
Tropp et al. (1984:a)	180	6 weeks	Soccer practice: Normal vs. pathological stabilometry	Players with functional instability was more prone to ankle injuries.
Tropp, Askling & Gillquist (1985)	439	10 weeks (10 min per day)	Ankle disk training vs. ankle orthosis	Lower incidence of ankle sprains and improved stabilometric results
Gauffin et al. (1987)	10	8 weeks (10 min per day)	Ankle disk training	Reduced feeling of giving way and recurrence of ankle sprains. Increased postural control.
Irrgang et al. (1994)		6 weeks	Ankle disk training	Improved postural sway
Laskowski et al. (1997)		8 weeks	Wobble board training	Remodeling of the ankle muscles.
Hewett et al. (1999)	366	6 weeks	Preseason neuromuscular training programme	Decrease in traumatic knee injuries during season.
Lo & Fowler, (2000)		4 weeks	Dynamic balance training	Increase in dynamic balance and in passive repositioning ability.
Ihara & Nakayama in Lo & Fowler (2000)		3 months	Dynamic joint control training on unstable boards	Improvements in hamstring reaction times.
Beard et al. in Lo & Fowler (2000)	50	3 months	Traditional open chain ACL rehabilitation vs. “dynamic joint control” training	Improved reflex hamstring latency contraction.
Zätterström in Lo & Fowler (2000)		12 months	Coordination, postural reaction, and closed kinetic chain exercises	Body sway in ACL deficient knees improved to normal levels.
Fitzgerald et al. (2000)	26	5 weeks (max. 10 sessions)	Perturbation training programme	Decrease risk of continued episodes of giving way of the knee and maintains functional status for longer periods.
Söderman, Werner, Pietilå, Engström & Alfredson, (2000)	121	Soccer season (10 to 15 min per day)	Balance board training	No significant difference in either type or number of traumatic injuries during the season.
Caraffa et al. in Boden, Griffin & Garrett, (2000)	600	6 weeks (20 min. per day)	Preseason balance training with and without a variety of balance boards	Reduction in the number of ACL injuries in the season.

The Measurement of Proprioception

Because of the great importance proprioception plays in the normal joint function, a lot of work has been devoted to its assessment (Swinkels & Dolan, 1998). Proprioception can be measured objectively as well as subjectively. The different ways to measure proprioception will be briefly discussed in this section.

Objective Measurement

There are three methods used to objectively quantify joint proprioception and neuromuscular control (Allen, 2000; Barrack & Munn, 2000; Beard & Refshauge, 2000; Beynnon et al. 2000):

- Joint position sense
- Joint kinesthesia, and
- Muscle reflex latency.

Joint Position Sense: Joint position sense is usually assessed by measuring the accuracy with which a subject can reproduce passive positioning, and reproduce active positioning (Borsa et al. 1994; Koralewicz & Engh, 2000; Lephart et al. 1997). Reproduction of active positioning stimulates both joint and muscle receptors and provides a functional assessment of the afferent pathways (Allen, 2000; Lephart et al. 1997) while passive joint positioning is often used after ligamentous injury to assess afferent activity because muscle activity is negated (Lephart et al. 1997). A disadvantage of using mechanic and electronic devices for joint positioning tests is that the subject receives quite a bit of information from tactile receptors (Jerosch, 2000).

The measurement of joint position sense usually takes several seconds to complete per trial, and therefore the test results really only have validity for slow movements made over several seconds (Ashton-Miller, 2000). When measuring the joint position sense of the spine, repositioning errors tend to increase on ascending the spine. This is the effect of the increasing number of joints involved in producing the movement (Swinkels & Dolan, 1998). Measurement of joint position sense is generally considered a reliable test and has been used in several experiments investigating proprioception of the knee (Beard & Refshauge, 2000).

Joint Kinesthesia: Kinesthesia is measured by establishing the subject's threshold to detect slow passive movement (Beard & Refshauge, 2000; Borsa et al. 1994; Lephart et al. 1997; Spirduso, 1995). The point at which the subject detects movement or a change in position is called the threshold to detection of passive motion and is measured in degrees of angular displacement. The measurement device is usually a dynamometer that slowly, constantly, and passively flexes or extends a person's limb at speeds of no more than 1°/s (Beard & Refshauge, 2000; Borsa et al. 1997; Koralewicz & Engh, 2000).

Extraneous cues and sensory information from the skin are minimized by various means. Some researchers took the time or the distance moved as the kinesthesia score, while others used the number of times the subject correctly identified the direction of imposed movement, from several trials (Beard & Refshauge, 2000). The threshold for the detection of slow passive motion was reported as 2-4° in normal subjects at angular velocities of 0.5°/s. Under these conditions, the slower adapting Ruffini or Golgi mechanoreceptors are thought to be selectively stimulated (Barrack et al. 1989; Barrack & Munn, 2000).

Beynnon et al. (1999) compared the accuracy, repeatability, and precision of seven joint position sense techniques and one joint kinesthesia measurement technique in normal subjects with no history of knee injury. Joint kinesthesia was found to be more repeatable and precise than the joint position sense techniques. The threshold to detection of passive motion provides a more objective and consistent measure of proprioception than a reproduction on a visual analog scale does (Beard & Refshauge, 2000; Borsa et al. 1997; Koralewicz & Engh, 2000).

Psychophysical tests have been used to measure proprioception for over a century. These tests are based on the principles of psychophysics and require that, when testing thresholds, movement stimuli should be presented a large number of times because thresholds vary with time. Movement stimuli of different magnitudes should be presented a large number of times to determine the average location of the threshold. The criterion for consistent detection should be clearly specified because the threshold varies with the stringency of the criterion. Movement stimuli must be presented in different directions and the subject should identify movement as well as direction (Refshauge et al. 2000).

Muscle Activation: Reflex capabilities are often assessed by measuring the latency of muscle activation to involuntary perturbation. This is measured using electromyography (Lephart et al. 1997). When the capsulo-ligamentous structures are damaged, there is a latency period in reflexive muscle activation. This is probably the result of joint deafferentation (Swanik et al. 2000). Konradsen and Ravn (in Wilkerson and Nitz, 1994) interpreted the slower peroneal reaction times observed as support for the theory of proprioceptive deafferentation introduced by Freeman (1965).

Subjective Assessment

Proprioception is closely associated with stability and neuromuscular performance (Swanik et al. 2000). Functional assessment of the combined peripheral, vestibular, and visual contributions to neuromuscular control is best accomplished through the use of balance and postural sway measurements of the lower extremities (Lephart et al. 1997). A thorough balance assessment should include an assessment of sensory thresholds.

- For somatosensory function, the tests should include tests of cutaneous sensation in the feet (vibration sensation) and proprioception in the feet and ankles.
- Balance and walking tests should include situations in which vision is not available and on different support surfaces (Shupert & Horak, 1999).
- Single-limb postural stability is a commonly used technique for testing ankle proprioception. The problem with this technique is that it includes afferent information from vision and the vestibular system as well as efferent motor skills (Renström, Konradsen & Beynnon, 2000). Gauffin et al. (1987) performed single-leg stabilometric evaluations before and after a postural control training programme. When interpreting the results of stabiliometry keep the relatively static nature of the task that is performed during data collection in mind. Most joint receptors are active only near the end ranges of motion therefore a more dynamic method may be necessary for neural discharge from joint mechanoreceptors (Wilkerson & Nitz, 1994).

Balance and joint proprioception is influenced by the same sensory information. Both depend on the inherent ability to integrate joint position sense with neuromuscular control. Balance is therefore frequently used to assess functional joint stability and deficits may be the result of diminished proprioception in the lower extremities (Swanik et al. 2000). Impairment of the ability to maintain unilateral postural balance highly correlates with functional joint instability. Some authors suggest that impairment of balance among subjects with a history of functional joint instability is a manifestation of an ankle proprioception deficiency (Wilkerson & Nitz, 1994).

The validity of tests of proprioception remains a problem. The variability in the methods used for proprioceptive assessment prevents any direct comparison between studies (Jerosch, 2000; Wilkerson & Nitz, 1994). It appears that the "best measurement techniques" have yet to be defined. An ideal method should have high sensitivity and specificity while also exhibiting good repeatability, precision, and accuracy (Beynnon et al. 2000).

The Older Adult

Aging is a complex process involving many variables interacting with one another and greatly influencing the manner in which we age (Mazzeo et al. 1999). There is no perfect definition for aging (Robergs & Roberts, 2000). Thus, aging can be viewed as an inevitable, genetically programmed process that causes physiological adaptation and is characterized by some dimension of "decline" in functions (Vandervoort & Symons, 2001).

Aging has been defined as a progressive loss of physiological capacities that eventually culminates in death and it results from both internal and external forces. Chronological age can be divided into young, middle, and old age and is typically chronicled by birthdays. Biological age (a decrease in physiological processes and functions) is dependent on a person's health and fitness status, which means that a person with a chronological age of 65 years of age can have a biological age of only 45 (Kirkendall & Garrett, 1998; Spirduso, 1995). Although the rate and effects of aging vary among individuals, there is really nothing that can be done to prevent aging (Robergs & Roberts, 2000).

Normal Physiological Changes Associated with Aging

When evaluating the changes in the body due to aging, it must be considered whether each change is an effect of natural aging or whether it is due to the decline in physical activity often seen in the elderly (Christmas & Andersen, 2000; Daley & Spinks, 2000; DeVries & Housh, 1994; Kirkendall & Garrett, 1998; Kohrt, Spina, Holloszy & Ehsani, 1999; Mazzeo et al. 1999). Deconditioning and disease plays a major role in the physiological changes that occur over time (DeVries & Housh, 1994; Robergs & Roberts, 2000). A decline in all the major systems of the body contribute to weakness, fatigue, and slowing of motor performances. These changes limit the ability of the elderly to perform activities of daily living and their ability to exercise (Kirkendall & Garrett, 1998).

Pulmonary Changes Associated with Aging

Table 4 presents a summary of the changes in the pulmonary system during aging and training. It is unknown whether regular exercise throughout one's lifetime can fully override the pulmonary dynamics of aging (McArdle et al. 1996). Although these age-related changes may make ventilation more difficult, they do not impose any major problems in delivering oxygen to the working muscles (Daley & Spinks, 2000).

Table 4. Functional changes to the pulmonary system with age (Daley & Spinks, 2000; DeVries & Housh, 1994; McArdle et al. 1996; Robergs & Roberts, 1997; Robergs & Roberts, 2000).

Variable	Aging	Training
Maximum lung capacity	↓	↑
Ventilatory equivalent	↑	
Expiratory flow rate	↓	↑
Forced expiratory volume in 1 second	↓	↑
Maximal voluntary ventilation	↓	↑
Vital capacity	↓	↑
Residual lung volume	↑	↓

↑ indicates an increase ↓ indicates a decrease

Cardiovascular Changes Associated with Aging

During rest, the cardiovascular system shows only minor changes with aging, but the circulatory response to exercise shows significant differences. Table 5 lists the changes in the cardiovascular system associated with aging, as well as the effect that regular exercise can have on these changes.

Table 5. Effects of exercise and aging on selected cardiovascular functions (Christmas & Andersen, 2000; Close et al. 1999; Daley & Spinks, 2000; DeVries & Housh, 1994; Mazzeo et al. 1999; McArdle et al. 1996; Robergs & Roberts, 1997; Robergs & Roberts, 2000; Spirduso, 1995).

Variable	Aging	Training
Maximal oxygen uptake (VO2max)	↓	↑
Resting heart rate	→	→
Maximal heart rate	↓	↑
Cardiac output	↓	↑
Stroke volume during maximal exercise	↓	↑
Blood pressure	→ / ↑	↓
Blood volume	↓	↑
Capillary-to-muscle fiber ratio	↓	↑
a-vO2 difference	↓	↑
Vascular resistance	↑	↓
Hardening of the arteries	↑	↓
Coronary lumen cross-sectional area	↓	
Circulation time from arm to thigh	↑	↓
Work capacity	↓	↑
Postural hypotension	↑	↓
Hypertension	↑	↓

↑ indicates an increase ↓ indicates a decrease

Changes in Body Composition Associated with Aging

Lean body weight decreases and body fat increases with age. The changes in body composition resulting from age are primarily due to a decrease in the basal metabolic rate and the reduction of physical activity in the elderly (Akima et al. 2001; Daley & Spinks, 2000; DeVries & Housh, 1994; McArdle et al. 1996; Robergs & Roberts, 2000).

Muscle Function and the Elderly

It is important for the elderly to prevent muscle loss because of the importance of strength for the maintenance of muscle function (Kirkendall & Garrett, 1998). Table 6 presents a summary of the changes in the muscular system due to aging, as well as the effect that regular exercise has on the variables. Sarcopenia is the loss of muscle mass and strength that occurs with normal aging. It is not the result of a disease, so it is seen in all older adults (Porter 2001; Roubenoff 2001; Vandervoort & Symons, 2001).

The Skeletal System of the Elderly

Bones become more fragile as people age. This often leads to debilitating fractures (McArdle et al. 1996; Robergs & Roberts, 2000). The process of resorption and redeposition of bone is slowed with aging. This together with an age-related decrease in the total body calcium weakens bone (Daley & Spinks, 2000). The loss of bone and muscle mass can lead to serious life-threatening injuries (DeVries & Housh, 1994; Kirkendall & Garrett, 1998). By the age of 90, 32% women and 17% men have sustained a hip fracture, between 12 and 20% of these people die of related complications. Regular physical activity and resistance training can offset the typical age-associated declines in bone health by maintaining or increasing bone mineral density and total body mineral content (Mazzeo et al. 1999; Robergs & Roberts, 1997; Smith as cited in Robergs & Roberts, 2000).

Neural Function and the Elderly

Some studies show no change in function of the neural subsystems controlling posture and locomotion with age, while others show a severe decline in function in the older adult (Shumway-Cook & Woollacott, 1995). The CNS and peripheral nervous system (PNS) undergo several changes with aging (Daley & Spinks, 2000). The ability to initiate a correcting response is not slowed much with aging, but the ability to respond with a righting muscular response and prevent a fall may be impaired with aging. Regular exercise may improve monosynaptic reflexes (Spirduso, 1995). Table 7 presents a summary of the neural changes associated with aging and the effects of exercise on neural functioning.

Table 6. Muscle adaptations to aging and training in the elderly.

Variable and References	Aging	Training
Muscle mass (Akima et al. 2001; Daley & Spinks, 2000; Christmas & Andersen, 2000; DeVries & Housh, 1994; Kirkendall & Garrett, 1998; Mazzeo et al. 1999; McArdle et al. 1996; Robergs & Roberts, 1997; Roubenoff, 2001; Vandervoort & Symons, 2001)	↑	↑/→
Percentage type I fibers (Daley & Spinks, 2000; DeVries & Housh, 1994; Kirkendall & Garrett, 1998; McArdle et al. 1996; Robergs & Roberts, 1997)	↑	→
Percentage type II fibers (Daley & Spinks, 2000; DeVries & Housh, 1994; Kirkendall & Garrett, 1998; McArdle et al. 1996; Robergs & Roberts, 1997; Tang & Woollacott, 1996)	↓	→
Type I area (Akima et al. 2001; Kirkendall & Garrett, 1998; Mazzeo et al. 1999; McArdle et al. 1996; Porter, 2001)	→	↑
Type II area (Akima et al. 2001; Fiatarone et al. 1993; Kirkendall & Garrett, 1998; Mazzeo et al. 1999; McArdle et al. 1996; Porter, 2001; Tang & Woollacott, 1996; Vandervoort & Symons, 2001)	↓	↑
Capillary density (Kirkendall & Garrett, 1998; McArdle et al. 1996; Robergs & Roberts, 1997)	↓	↑
Shortening velocity (DeVries & Housh, 1994; Kirkendall & Garrett, 1998; McArdle et al. 1996; Meyer, Goggin & Jackson, 1995; Porter, 2001; Tang & Woollacott, 1996; Vandervoort & Symons, 2001)	→	↑
Muscle force (Akima et al. 2001; Daley & Spinks, 2000; Christmas & Andersen, 2000; Fiatarone et al. 1993; Kirkendall & Garrett, 1998; Mazzeo et al. 1999; McArdle et al. 1996; Meyer et al. 1995; Roubenoff, 2001; Tang & Woollacott, 1996; Vandervoort & Symons, 2001; Woollacott & Shumway-Cook, 1990).	↓	↑
Muscle endurance (DeVries & Housh, 1994; Kirkendall & Garrett, 1998)	→	↑
Muscle power (Kirkendall & Garrett, 1998; Roubenoff, 2001; Porter, 2001; Snow, 1999)	↓	↑
Muscle flexibility (Daley & Spinks, 2000; Robergs & Roberts, 1997)	↓	↑
Sarcopenia (Christmas & Andersen, 2000; Porter, 2001; Roubenoff, 2001; Vandervoort & Symons, 2001)	↑	↓
Hypertrophy (DeVries & Housh, 1994; Porter, 2001)	↓	↑
Frequency for tetanic fusion (Roubenoff, 2001)	↓	
Onset latency for muscle contractions (Robertson, 1999; Shumway-Cook & Woollacott, 1995; Spirduso, 1995; Woollacott & Shumway-Cook, 1990).	↑	↓

↑ indicates an increase ↓ indicates a decrease

Table 7. Neural changes with aging and the effects of regular exercise.

Variable and Reference	Aging	Training
Loss of neurons (DeVries & Housh, 1994; Downton 1996; McArdle et al. 1996; Roubenoff, 2001; Shupert & Horak, 1999; Wolfson et al. 1993).	↑	
Motor unit size (DeVries & Housh, 1994; McArdle et al. 1996; Roubenoff, 2001).	↑	
Motor unit recruitment and muscle innervation (Roubenoff, 2001)	↓	↑
Cortical atrophy and loss of CNS transmitters (Daley & Spinks, 2000; Downton 1996; Spirduso, 1995; Vandervoort & Symons, 2001).	↓	↑
Brain weight and metabolism (Daley & Spinks, 2000).	↓	
Cerebral blood flow (Daley & Spinks, 2000).	↓	
Nerve conduction velocity (Daley & Spinks, 2000; DeVries & Housh, 1994; Downton 1996; Light, 1990; McArdle et al. 1996; Meyer et al. 1995; Roubenoff, 2001; Wolfson et al. 1993).	↓	↑
Reaction times (Birren et al. in DeVries & Housh, 1994; Frank et al. 1996; Daley & Spinks, 2000; Light, 1990; McArdle et al. 1996; Meyer et al. 1995; Robertson, 1999; Shupert & Horak, 1999).	↑	↓
Movement times (Daley & Spinks, 2000; Birren et al. in DeVries & Housh, 1994; Light, 1990; McArdle et al. 1996; Meyer et al. 1995; Robertson, 1999; Vandervoort & Symons, 2001; Wolfson et al. 1993).	↑	↓
Proprioception (Berg, 1989; Daley & Spinks 2000; Frank et al. 1996; Mazzeo et al. 1999; Shupert & Horak, 1999; Tang & Woollacott, 1996; Wolfson et al. 1993).	↓	↑
Vestibular function (Frank et al. 1996; Mazzeo et al. 1999; Tang & Woollacott, 1996; Wolfson et al. 1993).	↓	
Visual sensitivity (Frank et al. 1996; Mazzeo et al. 1999; Robertson, 1999; Tang & Woollacott, 1996; Wolfson et al. 1993).	↓	
Standing postural sway (Horak, 1987; Mazzeo et al. 1999; Robertson, 1999; Shih, 1997; Shumway-Cook & Woollacott, 1995; Wolfson et al. 1993).	↑	↓
Onset latencies (Robertson, 1999; Spirduso, 1995;Tang & Woollacott, 1996; Woollacott & Shumway-Cook, 1990).	↑	↓
Balance time (Berg, 1989; Frank et al. 1996; Tang & Woollacott, 1996; Wolfson et al. 1993; Woollacott & Shumway-Cook, 1990).	↓	↑

↑ indicates an increase ↓ indicates a decrease

Two models have been suggested to describe the aging process of the human nervous system.

- The genetic model assumes that the function of the nervous system is genetically programmed to decline linearly or curvi-linearly with advancing age. As the decline reaches a certain threshold, functional impairment, such as postural instability, becomes evident.

- The catastrophe model hypothesizes that the nervous system continues to function at a high level until death, unless the individual encounters environmental catastrophe or disease resulting in a rapid decline of behavioral function. Figure 3 is a representation of these two models for human aging (Shumway-Cook & Woollacott, 1995; Shupert & Horak, 1999; Tang & Woollacott, 1996).

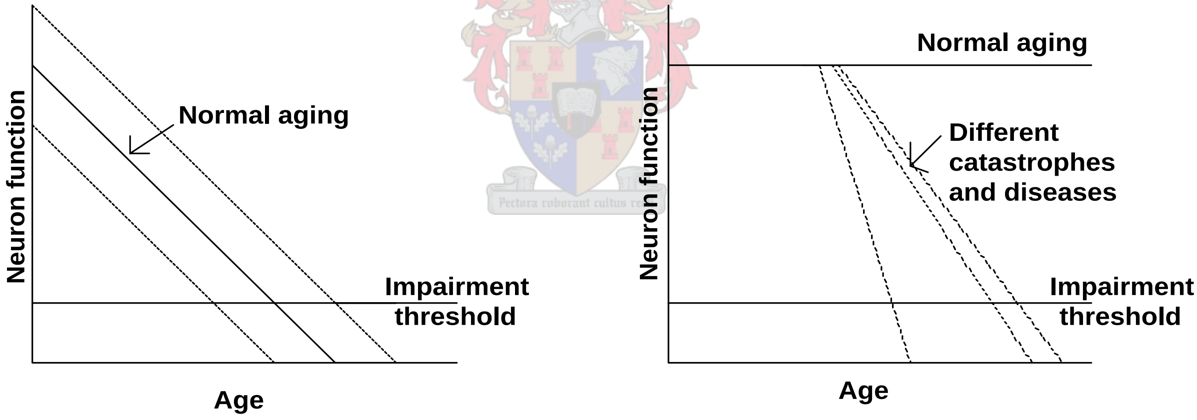

Figure 3

Two models of aging (Shumway-Cook & Woollacott, 1995; Shupert & Horak, 1999; Tang & Woollacott, 1996).

The Effects of Aging on Balance and Postural Control

Balance in the elderly deserves special attention because of its importance in functional mobility and safety. Several studies have shown impaired balance to be a factor associated with falls in this age group. Falls may lead to a decrease in mobility and a decline in functional independence. Changes in the ability to balance can occur as a result of disease or aging. Evidence exists for age-related changes associated with each of the three sensory systems involved in postural control, the vestibular, visual and somatosensory systems (Berg, 1989).

Postural control is the ability to maintain equilibrium in a gravitational field by keeping the center of body mass over the body's base of support (Horak, 1987). In stressful situations like when the eyes are closed postural sway is exaggerated. This happens in all ages, but especially so in the elderly (Berg 1989; Daley & Spinks, 2000; Downton, 1996; Judge et al. 1993; Tang & Woollacott, 1996; Shumway-Cook & Woollacott, 1995; Spirduso, 1995). Postural stability is affected by alterations in the sensory and motor system, the higher level systems, and the perceptual system (Berg, 1989; Mazzeo et al. 1999; Ringsberg et al. 1999; Shupert & Horak, 1999). Older adults have a slower ability to adapt postural control and maintain their balance (Mazzeo et al. 1999; Shumway-Cook & Woollacott, 1995).

When a person experiences a sudden support surface perturbation, somatosensation is the primary sense triggering the automatic postural responses. These responses include the activation of the distal leg muscles at a short latency followed by more proximal muscles on the same aspect of the body. Somatosensation serves as the primary defense mechanism, supplemented by visual and vestibular inputs, to prevent a fall when a person encounters an unexpected support surface displacement such as a slip. This is due to the muscle activation via short latency reflexes (Tang & Woollacott, 1996).

Balance can be viewed as a prerequisite to functional capabilities because it sets a baseline requirement necessary to carry out activities of daily living. Good balance is necessary for activities of greater force, velocity or magnitude. From a neurophysiological point of view, balance involves interaction of sensory information of the vestibular, somatosensory, and visual systems. The vestibular system provides input concerning the position of the head in relation to gravity and acceleration of the head. The somatosensory system provides information about the movement of the different body segments in relation to each other. The visual system provides information about the body's position relative to the environment (Berg, 1989).

The following characteristics were found when comparing older and younger adults (Robertson, 1999; Shumway-Cook & Woollacott, 1995; Spirduso, 1995; Tang & Woollacott, 1996; Wolf & Gregor, 1999; Wolfson et al. 1993; Woollacott & Shumway-Cook, 1990).

- Older adults show a slowed response to losses of balance and a decrease in righting responses. The latency of tibialis anterior muscle responses in response to platform perturbations is significantly increased in the elderly. Some older adults demonstrate a temporal reversal (i.e. a proximal to distal sequence) of muscle activation.

- Older adults show a larger incidence of short-latency spinal monosynaptic reflexes, when subjected to platform rotations.

- Ankle dorsiflexor muscle weakness is a factor in balance dysfunction in the elderly.

- The elderly tend to coactivate the antagonist muscles along with the agonist muscles at a given joint.

- Older adults revealed a greater variability of the magnitude ratio between distal and proximal muscle activity.

- Older adults often favor hip movement strategies over ankle strategies in response to sudden perturbations. They also exhibit a loss of ankle sway.

- The elderly have abnormal sensory selection or weighting, they tend to overuse vision or under use proprioception.

- Older adults show changes in their perceived limits of stability mainly due to a loss in their confidence levels.

Functional Balance and the Elderly

Functional balance is all the balance skills a person needs to live independently. The better an individual's functional balance are, the better their functional skills would be and the less prone they would be for serious injuries resulting from falls. An individual with good functional skills will also be able to lead a “richer” life as they will be able to do what they want when they want it, not needing anyone to help them with anything. This independence will definitely increase their quality of life.

Motor performance depends on the activation of a muscle synergy to achieve a functional task. Coordinated movements are organized around the functional goal of the movement. Coordinated movements are the result of interactions among internal and external factors (Tang & Woollacott, 1996). Postural sway is related to the risk of falling and therefore is significant in the performance of many functional skills (Spirduso, 1995). Poor postural stability is associated with frequent falling. This means that the improvement of postural stability can be used to prevent falls (Mazzeo et al. 1999).

The Importance of Functional Balance

Normal gait requires joint mobility, appropriate timing, powerful muscle contractions and normal proprioceptive, vestibular, and visual sensory input. Older adults commonly show changes in gait as a result of impairments in one or more of these areas. These impairments result in imbalance, increased energy expenditure, muscle weakness, and falling. One in five older adults have disorders in gait or their ability to transfer themselves from one position to another. A study by Tang & Woollacott (1996) found that among persons over 75 years of age, 30% reported difficulty with climbing stairs, 40% could not walk one-half mile and 7% needed assistance to walk at all. Elderly people who are bed or chair-bound become deconditioned, and risk developing edema, contractures, and pressure sores. Such patients are at risk for falls and nursing home placement.

The development of movement disabilities among the elderly is most frequently assessed by examining limitations in activities of daily living, such as transferring from a bed to a chair, using the toilet, dressing, bathing, preparing meals, and walking. The time over which movement disabilities develop varies in older adults. While movement disability is mostly the result of a progressive decline in musculoskeletal and neuromuscular function, it can be accelerated by trauma such as a stroke or heart attack (Martin & Grabiner, 1999). According to Isaacs (in Berg, 1989), voluntary movement is evaluated or “graded” as either basic, extended, or extreme. Turning or sitting down in a chair is a basic movement. Both movements require a minimum of displacement and are common in everyday life. Reaching to a high shelf is an extended movement. Sport or dance activities are examples of extreme movements, consisting of larger, faster movements needing quicker reactions to maintain balance control.

Although little is understood about the transition from functional independence to physical frailty, it is known that physical impairments, such as balance or gait deviations, may place the older adult at risk to regress more rapidly towards dependency. The reaction of the elderly to their own perceived decrease in function often makes it difficult for them to participate in functional mobility activities or exercise programmes. This contributes to deterioration in their quality of life with an evil and progressive loss of independence and purpose of life (Nicholson, 1999).

The Effects of Aging on Functional balance

Sarcopenia is directly associated with the limited mobility and physical performance in the elderly, as well as the increasing incidence of accidents suffered by those with muscle weakness and poor balance (McArdle et al. 1996; Porter, 2001; Roubenoff, 2001; Vandervoort & Symons, 2001). Muscle strength relates to walking speed, the ability to move from sitting to standing positions, and stair climbing (Frank et al. 1996; Kirkendall & Garrett, 1998; Wolfson et al. 1993). There are an alarmingly large number of older adults whose functional capacity is so poor that they are unable to do relatively simple physical tasks or perform necessary personal hygiene skills without assistance (McArdle et al. 1996).

The age-related deficit in skill performance is more noticeable at higher velocities of movement. It has been demonstrated that the power output of the elderly is considerably reduced. Since many activities of daily living involve dynamic movements where power needs to be generated by the muscles e.g. walking, stair-climbing, sports, the functional impairments associated with a low capacity to generate power are a big problem needing urgent attention (Vandervoort & Symons, 2001).

The systems approach helps to understand which subsystems contribute most to the decreased capacity for balance control. If the function of only one balance control subsystem is reduced, it may be difficult to pick it up in a gross balance measurement because of the compensatory mechanisms of the balance control system (Shupert & Horak, 1999; Tang & Woollacott, 1996). Several changes occur in the gait of the elderly such as slower walking speed, shorter step length, and smaller swing to support ratios. Slower walking speed in the elderly are more marked in those limited in activity and even more so in hospitalized fallers (Daley & Spinks, 2000; Downton, 1996; Horak, 1987; Spirduso, 1995). There is a significant correlation between muscle strength and preferred walking speed in the elderly. Leg power represents a more dynamic measurement of muscle function, and may be useful to predict the functional capacity in the very old (Mazzeo et al. 1999).

The Effects of Training on the Elderly

> The benefits of regular exercise and physical activity contribute to a more healthy, independent lifestyle for seniors, greatly improving their functional capacity and quality of life (Rikli & Jones, 2001:3)

Beginning moderately vigorous physical activity is associated with lower rates of death in the middle aged and elderly, and decreases the incidence of falling and fall related injuries (Downton, 1996; Frank et al. 1996; McArdle et al. 1996; Nicholson, 1999; Butler, Norton, Lee-Joe, Cheng & Campbell, 1996; Owings et al. 1999). The Surgeon General of the US stated that “physical activity…appears to be protective against falling…probably by increasing muscle strength and balance” (U.S. Department of Health and Human Services in Owings et al. 1999). DeVries and Housh (1994) found that healthy seventy- and eighty-year olds have the same relative capacity for training as the young. Lack of exercise is an independent predictor of mobility decline, and mobility decline is related to an increased risk of falling. Exercise training programmes enhance the functional independence of elderly people through increased mobility (Daley & Spinks, 2000; Masdeu, Sudarsky & Wolfson, 1997).

Balance Training: There are numerous studies showing that specific risk factors in older adults, such as weakness and instability, can be reversed or improved following exercise or balance training (Daley & Spinks, 2000; Masdeu et al. 1997). Balance exercises consist of static and dynamic balancing tasks. Difficulty is increased by increasing the speed or duration of the exercise or by reducing relevant sensory input (Hain, Fuller, Weil & Kotsias, 1999). Balance and muscular exercise might decrease the incidence of falls if better balance could be achieved by muscular training (Frank et al. 1996). Balance rehabilitation may make subjects more aware of other sources of sensory information and encourage subjects to try to make use of other sources but is unlikely to improve muscle onset latencies (Shupert & Horak, 1999). Postural stability measurements improved after an intensive training programme that repeatedly challenged different aspects of balance in the elderly. When assuming that a person's overall system response can be enhanced, it can be concluded that exercise can improve postural stability and decrease the risk of falling in the elderly (Mazzeo et al. 1999).

Shumway-Cook and Woollacott (1995) found significant improvements in a group participating in a balance-training protocol focussing on the use of different sensory inputs and integrating these inputs under conditions of reduced sensory inputs compared to a control group. The training group improved significantly in five of the eight training conditions. The training group showed changes in their muscle response characteristics to platform perturbations such as significant decreases in the coactivation of antagonist and agonist muscles.

Rose and Clark (2000) completed a study to determine the short-term effectiveness of a biofeedback based, computerized intervention programme applying the principles of the ecological theory of perception and control, on older adults with a history of falling. Each participant assigned to the intervention group attended two 45-minute balance-training sessions per week for 8 weeks. Significant improvements were found in the intervention groups' functional performance. This suggest that interventions emphasizing task-specific practice are not the only means by which an older adult's ability to perform daily activities requiring postural control can be improved.

In general, balance-training programmes with successful outcomes appeared to take a more intensive approach to training than those that were less successful. Propulsive movement and activities involving endurance and quick turns were the most common types of activities in balance training programmes. Ambulation, jogging, aerobic dancing, and calisthenics were incorporated in many of the task-specific balance training studies (Masdeu et al. 1997).

Strength Training: Healthy adults performed better in basic functional movement abilities compared to frail adults. The increased risk of falls and chronic disorders found in the frail elderly may be due to lower overall strength. Stronger individuals reacts and moves faster, spend less time in acceleration and deceleration, produce fewer adjustments and generates higher peak velocities and generally have more control over their movements than frail individuals (Meyer et al. 1995).

When the musculoskeletal changes of aging occur in important muscle groups it is likely that clinically harmful alterations in gait, postural control and activities requiring functional mobility will follow. It is theorized that progressive resistance training programme for clinically important muscle groups performance in gait, balance and daily activities will improve (Fiatarone et al. 1993). It is highly probable, that walking exercises, strength training, and encouragement to walk faster could greatly improve the walking speed and mobility of older adults (Spirduso, 1995). Resistance training increases muscle strength and mass, leading to improved gait and enhanced performance of ADL. The fit elderly also have better motor control and coordination than their sedentary counterparts (Daley & Spinks, 2000). Strength training is an effective way to increase energy requirements, decrease body fat, and maintain metabolically active tissue mass in healthy older people (Mazzeo et al. 1999).

A combined resistance-walking programme increased the 6-minute walk distance and the maximum gait velocity in the elderly (Masdeu et al. 1997). Fiatarone et al. (1993) investigated a training programme emphasizing muscle strength training to improve balance. The study focused on strengthening the leg muscles, and had considerably greater success than general programmes. They found highly significant and clinically meaningful gains in muscle strength in all subjects as well as a decrease in walking time.

Power may be even more important for daily function and preventing falls than strength alone. Recent studies on training in the elderly used training programmes consisting of faster, high intensity contractions to concentrate on improving power as well as strength. Eccentric contractions might be required for hypertrophy and improved neural activation strategies in the elderly, but eccentric contractions cause greater muscle damage. It was found that eccentric training alone lead to increases in both concentric and eccentric ankle dorsiflexor strength, while eight weeks of concentric training on the same subjects did not change either concentric or eccentric strength (Porter, 2001).

A Boston study enrolled 100 nursing home residents who had a baseline gait velocity of 0.46m/s and who were randomly assigned to a control group or resistance training group. Subjects were also randomized to a nutritional supplement or placebo supplement, which had no effect on performance. After 10 weeks of high-intensity resistance training, the usual gait velocity increased with 0.05m/s for the training group, whereas the control group members’ velocity did not improve (Masdeu et al. 1997). A Seattle study wanted to determine the extent to which physiological improvement (emphasis on strength and aerobic capacity) produces improvement in functional status (emphasis on gait and balance). The major aim of the study was to determine whether the health status effects of exercise differ according to the type of exercise (Buchner et al. 1993).

Strength training, in addition to its positive effects on insulin action, bone density, energy metabolism, and functional status, is also an important way to increase levels of physical activity in the elderly. Levels of spontaneous activity increased in healthy community based older adults as well as frail very old subjects after increases in their muscle strength (Mazzeo et al. 1999).

Balance and Strength Training: Judge et al. (1993) combined 12 weeks of high-intensity isotonic resistance exercise with balance training to determine if exercise improved gait velocity. Muscle groups strengthened included hip abductors, knee extensors, hip flexors and extensors, and ankle dorsiflexors. Balance exercises included postural alignment exercises, lateral weight shifting, anterior-posterior weight shifting, and some tai chi movements. Significant improvements in muscle strength and gait velocity were found. The greatest improvements occurred in subjects who walked the slowest at baseline testing.

Active older females demonstrate less postural sway than sedentary females. Strength and balance training have been shown to be effective for improving balance. Balance control is very complex and the beneficial effects of an exercise programme is a function of the individual deficits and the type of exercise chosen (Daley & Spinks, 2000).

A combined resistance- and balance-training protocol increased usual as well as maximum gait velocity in life-care community residents. A study on community dwelling subjects found no increase in gait velocity after 13 weeks of either resistance training, balance training, or combined resistance and balance training. Baseline gait velocity was higher in the community-dwelling subjects (Masdeu et al. 1997). Campbell et al. (1997) demonstrated that a programme of strength and balance training exercises, organized by general practices and done at home, significantly reduced the number of falls and injuries experienced by women 80 years and older. The most successful interventions to date have included both balance training and strength building exercises (Shupert & Horak, 1999).

Endurance Training: Masters athletes are better at controlling their balance in clinical and functional (walking) tests than their non-active peers are. Older subjects who are physically fit showed similar muscle activation patterns as young subjects. Regular, lifelong physical activity can be expected to improve balance because it provides daily challenges and practice opportunities for balance mechanisms (Spirduso, 1995).

A randomized 12-month study compared an endurance-and-strength-training programme with a stretching-and-flexibility programme. The results showed that both groups profited, but in different ways. The first group gained significantly in cardiovascular fitness, strength, endurance, self-confidence, and energy expenditure, whereas the other group declined in these areas. The second group reported having less daily pain, while the first group reported more. This shows that stretching should not be neglected in a training programme, and the best exercise programme combines all three, strength, endurance and flexibility training (Porter, 2001).

Regular endurance training lowers blood pressure in normal as well as hypertensive older adults when compared to no exercise or to resistance training. Endurance training also reduces resting heart rate and the risk of cardiovascular events. The long-term benefits of endurance exercise include reduced mortality risk from coronary heart disease, improved weight control, lower blood pressure, increased aerobic fitness, improved cholesterol levels and prolonged life expectancy up to 2 years (Daley & Spinks, 2000). Early research on exercise for older adults emphasized endurance training or low intensity resistance exercise. However, this type of training has not resulted in appreciable gains in strength or muscle mass. A programme of combined endurance and resistance training led to greater increase in strength than endurance programmes alone (Porter, 2001).

General Exercises: If given sufficient practice, it is possible for elderly subjects to establish new motor programmes and shift toward automatic information processing. The elderly have difficulty with programming new movements because aging alters the movement control systems. Older individuals require more time to process neural information, progress slower when learning a skill, and need more time to accommodate to small changes in task demands than younger subjects do. It is theorized that the slowdown observed with aging results from a lack of movement practice and failure to receive reinforcement for activity (Light, 1990).

The mobility skills of older adults (including 26 ambulation skills, proprioception, and balance skills) have been shown to improve significantly as a result of exercise (Mazzeo et al. 1999). One hundred frail community-dwelling older adults improved strength, gait speed, mobility tasks, and confidence in their ability to avoid a fall during the performance of ADL after a 10-week home-based exercise intervention (Christmas & Andersen, 2000).

The combined analysis of the seven FICSIT trials revealed that general exercise and balance training have beneficial effect on the incidence of falling. It is impossible to determine which type of exercise is the most effective because many different types of exercise were studied (Masdeu et al. 1997).

A relationship between aerobic fitness, grip strength, and postural sway has been observed. Several investigators believe that increases in postural sway may represent a deterioration of the nervous system that cannot be improved by exercise training. These investigators found that a 12-week exercise programme aimed at increasing postural stability produced no apparent changes in the postural sway of women ages 72 to 92 even though their fitness improved (Spirduso, 1995).

Flexibility decreases with age leading to a loss of mobility and stability in the joints. There is a significant relationship between the ability to move around in one’s environment and ROM in knee flexion, the ability to bend down and hip flexion ROM, and the ability to undertake activities requiring the use of hands and arms and ROM of the upper extremities (Daley & Spinks, 2000). The basis for exercise interventions to improve flexibility is that the muscle or connective tissue properties can be improved, joint pain can be reduced, and muscle recruitment patterns can be altered (Mazzeo et al. 1999).

Among the studies that evaluate fall risks, a couple of studies used multidimensional programmes designed by physical therapists including some strength training and are individualized for each subject. Other studies strictly emphasized weight training and applied generalized programmes to all participants. The programmes improved balance and mobility, but given the varied nature of these protocols, it is difficult to ascertain the exact amount of exercises needed in order to get the response wanted. It is also impossible to generalize results (Snow, 1999).

Tai Chi: Tai Chi (T’ai Chi) Chuan receives special attention here as an exercise form practiced by Chinese elders. It involves both “internal” and “external” efforts, consisting of slow, rhythmic movements, dignified postural alignment, and axial rotation while progressing toward a narrower base of support. Tai chi (T’ai Chi) offers health benefits that are particularly attractive to older adults. The goal of health-orientated tai chi is enhancement of body awareness (proprioception) and overall well being. Participation has been shown boost the immune system, improve digestion, decrease depression and anxiety, and promote relaxation (Cheng, 1999; Hain et al. 1999; Jacobson, Ho-Cheng, Cashel & Guerrero, 1997; Shih, 1997; Wolf et al. 1996).

Regular participation in Tai Chi may have the potential to delay the onset of falls, attenuates the fear of falling, and generally have a favorable impact on the quality of life. There are no biomechanical data describing how Tai Chi might change a person's movement capabilities. Information about kinetic changes during Tai Chi exercise training under conditions of gait initiation, self-paced ambulation, and perturbations induced by unexpected turns during ambulation might lend insight into what aspects of movement control is affected by Tai Chi (Cheng, 1999; Wolf & Gregor, 1999; Wolfson et al. 1993). It has been hypothesized that Tai Chi exercises will train older adults in weight shifting and upper body rotations and that it will have a positive effect on gait during periods where weight transition takes place (Hain et al. 1999; Wolf & Gregor, 1999). There is evidence that older adults can become stronger, improve their balance, and increase their gait speed with Tai Chi training (Wolf et al. 1996; Cheng, 1999).

Tai Chi appears to dynamically tax balance mechanisms while facilitating concentration of body position within the immediate environment (Wolf et al. 1996). Tai Chi has several advantages over balance training on an electronic balance-training device. Advantages include its focus on internal rather than external feedback. It also requires no technological equipment, and takes a holistic approach to the development of flexibility, strength, and cardiovascular improvements (Wolf, Kutner, Green & McNeely, 1993; Wolf et al. 1996). Twelve weeks of Tai Chi training decreased the loss in left-hand grip strength, reduced ambulation speed, and lowered systolic blood pressure after a 12-minute walk. It also decreased the incidence of falling (Wolf et al. 1996; Wolfson et al. 1993).

Tai Chi is carried out with a lowered center of gravity (knees and hips held in flexion) therefor strength gains expected from short-term resistance exercise could be maintained with tai chi training. A Tai Chi maintenance programme sustained improvements in balance and strength for six months after the intervention (Wolf et al. 1996). Hain and co-workers (1999) revealed that eight weeks of Tai Chi training and practice showed significant improvements in several measures of balance. The results are compatible with other reports suggesting that tai chi is beneficial for health and may reduce falling in the elderly.

Owings et al. (1999) formulated exercise interventions including low-level endurance and flexibility exercises, resistance exercises and balance training on a balance platform, balance training using Tai Chi exercises, and participation in functional activities. The results revealed that the Tai Chi intervention showed a significant reduction in fall risk while some of the other exercise interventions actually may have increased the risk of falling.

Wolf et al. (1996) found that Tai Chi training was not associated with reduced sway, even though subjects had fewer falls and less fear of falling than the control group. The results of previous studies examining the effect of conventional exercise programmes on improving balance in the elderly have been mixed. Crilly et al. (in Hain et al. 1999) found no significant reduction in static postural sway after a 12-week programme of balancing and strengthening exercises. Liechtenstein et al. (in Hain et al. 1999) also reported no effects with respect to postural sway after participation in a similar exercise programme. A 10-week exercise programme benefited 10 individuals who were sedentary and institutionalized, improving the amount of time that they could stand on one leg. Hopkins et al. (in Hain et al. 1999) reported that low-impact aerobic dance significantly improved the duration of one-leg standing in elderly women.

Functional Assessment

A valid functional assessment battery should provide a reliable index that helps to identify older people who have difficulty managing daily mobility tasks and thus also are at a higher risk of falling (Rose & Clark, 2000). The basic assumption is that balance control is an essential component of many daily activities. By direct observation and measurement of one’s performance in daily mobility tasks that require static and dynamic balance control in various environments, clinicians can identify problems in balance control (Berg, 1989; Berg, Wood-Dauphinèe, Williams & Gayton, 1989).

Results from functional assessments can indicate the need for therapy as well serve as a baseline performance for future reference when training/treating an individual. When repeated at regular intervals, the results of these assessments can provide objective proof about the change in functional status that took place during training. There are a number of tests available to measure functional balance related to postural control. In addition to the functional assessment itself, it is recommended that information be gathered about the number and types of falls and near falls an individual has had (Shumway-Cook & Woollacott, 1995).

The evaluation of balance in the clinical setting is generally subjective in character. The Get Up and Go Test (Berg, 1989) was developed as a quick screening tool for detecting balance problems in elderly patients. Because of the global rating scoring system, this test can only be used to screen patients, it would not be suitable to monitor changes in their status. The Up and Go Test modifies the original test by adding a timing component to performance. Neurologically intact adults who are independent in balance and mobility skills are able to perform the test in less than 10 seconds. Adults who took more than 30 seconds to complete the test were dependent in most activities of daily living, and mobility skills (Rose & Clark, 2000; Shumway-Cook & Woollacott, 1995).

Assessment of the functional aspects of mobility looks at functional abilities such as sit to stand and transfers but does not identify the quality of movement or the underlying cause of the balance deficit. A mobility assessment seeks to quantify mobility, testing the ability of the patient to perform a specific task (Robertson, 1999). The Functional Reach Test was developed to analyze the ability of older adults to maintain equilibrium while reaching forward. Tinetti's Balance and Mobility Scale (Tinetti et al. 1993) is a test to screen for balance and mobility skills in older adults and to determine the likelihood of falls. Tinetti et al. developed a mobility score, incorporating gait and balance in order to identify individuals prone to falls. The reliability of the mobility score is acceptable. Inter-rater reliability showed agreement on 85% of the items and a total score that differed by less than 10%. Information on test-retest reliability has not been provided. This scale is promising because of the reliability demonstrated in grading the performance assessment as a viable method of evaluating balance (Berg, 1989).

The Berg Functional Balance Scale (Berg, 1989) uses 14 different test items, rated 0 to 4. It assesses tasks such as sitting balance, sit to stand, reaching in sitting and standing, transfers, picking up an object from the floor and turning 360 degrees. The test is reported to have good test-retest and inter-rater reliability. To date there are no norms for this test (Berg, 1989; Berg et al. 1989; Rose & Clark, 2000; Shumway-Cook & Woollacott, 1995; Spirduso, 1995). The Berg Scale does not quantitatively predict the risk of falling but it is generally accepted that a score of more than 45/56 indicates a very low risk of falling (Robertson, 1999). The assessment is based on a rating scale, which may be influenced by a rater's bias, so the reproducibility of the ratings is also important.

The Sensory Organization Test (SOT) requires the subject to stand for 30 seconds under six different sensory conditions. The therapist use condition 1 as a baseline reference, and then observes the patient for changes in the amount and direction of sway over the subsequent five conditions. If the patient is unable to stand for 30 seconds, a second trial is given (Masdeu et al. 1997; Horak, 1987; Shumway-Cook & Woollacott, 1995; Tang & Woollacott, 1996; Woollacott & Shumway-Cook, 1990). Neurologically intact young adults are able to maintain balance for 30 seconds on all six conditions with minimal amounts of sway. A single fall, regardless of the condition, is not considered abnormal for the elderly but two or more falls indicate difficulties in adapting sensory information for postural control (Horak, 1987; Shumway-Cook & Woollacott, 1995). The dominance of the somatosensory input to balance is demonstrated by the high degree of postural stability subjects have under the first three conditions of the SOT, when the support surface is fixed. When somatosensory information is eliminated, the influence of vestibular and visual systems is evident (Masdeu et al. 1997). There is a significant correlation between functional mobility and static balance measures under similar sensory environmental conditions. These results indicate that impaired sensory functions in balance control may influence functional mobility performance in older adults (Tang & Woollacott, 1996).

Timed standing tests using a progressively smaller base are frequently included in a balance assessment. Some authors set a time interval while others record the maximal amount of time a position could be held. The ability to stand on one leg declines with age, so when working with the elderly, it is advised to use time intervals shorter than 30 seconds (Berg, 1989). Sway is a good indicator for balance, therefore an increase in sway is indicative of declining balance control as people age (Shumway-Cook & Woollacott, 1995). The six-minute walking test appears promising as a simple measure of functional exercise capacity for clinical trials in patients with chronic heart failure (Guyatt et al. 1985). Grip strength is related inversely to deficits in Instrumental Activities of Daily Living (Christmas & Andersen, 2000). Peak oxygen uptake has been found to predict ability to perform activities of daily living in healthy older women (Daley & Spinks, 2000).

The functional status of the individual may be determined using the ability to feed, control excretory function, transfer to and from a chair or a bed, toilet, dress, bathe, and ambulate, and the amount of assistance required to perform these tasks. The Senior Fitness Test (previously known as the Fullerton Functional Fitness Test), has been developed by Rikli and Jones (2001). It is sufficiently sensitive to assess the physical functioning continuum, with physically fit seniors at the one end and physically frail, dependent seniors at the other. It is a user-friendly and inexpensive battery of community-based tests, and has been used with success in South Africa (Nicholson, 1999; Rikli & Jones, 2001).

The Instrumental Activities of Daily Living scale (IADLs) has been used by Lawton and Brody (in Wolf et al. 1996) to determine the subjects' independence. The capacity to perform functional tasks necessary to meet the demands of daily life is the measure of activities of daily living (ADLs). These ADLs include the Basic ADLs, which are necessary for an individual to care for themselves within a limited environment (e.g., getting dressed, using the toilet, walking) and the Instrumental ADLs, which are the abilities necessary to function in the community (e.g., driving, shopping, paying bills). Impairments in ADLs have been identified as risk factors for falls and institutionalization (Robertson, 1999).

Conclusion

Proprioception is a critical factor in movement control. As persons age, the capacity for proprioception diminishes, which leads to the impairments in balance/postural control that ultimately result in increased dependence in terms meeting the functional movement challenges of daily living as well as an increased likelihood of having a life-threatening fall. This study is aimed at the design and delivery of a training programme to improve proprioception among older adults. It is important to keep several facts about perception in mind when considering the design of this kind of programme.

- Proprioception is learned, not inherited (Jerosch, 2000). Prophylactic programmes designed to comprehensively address proprioceptive aspects of the joint may protect the athlete against injury (Hewett et al. 1999; Laskowski et al. 1997).
- Athletic training improves proprioceptive function, and several researchers have reported significant improvements in proprioceptive ability in highly trained athletes (Barrack & Munn, 2000; Borsa et al. 1994; Giraldo et al. 2000; Laskowski et al. 1997; Lo & Fowler, 2000; Octiff et al. 2000).
- Trauma to tissues containing mechanoreceptors may result in partial deafferentation of the joint and lead to proprioceptive deficits. Proprioception plays a bigger role than pain impulses in preventing injury, because the initiation of the reflex arc stimulated by mechanoreceptors occurs at a faster rate than the signals of the nociceptors (Borsa et al. 1997; Lephart et al. 1997).
- There may be real differences between proprioceptive mechanisms operating at finger joints and the large proximal joints of the limb (Grigg, 1994).
- The ability to detect movement is best when both flexor and extensor muscles are active and worst when both the flexor and extensor muscles are passive in the movement (Gandevia et al. 1983).
- Detection of external rotation appears to be more sensitive than detection of internal rotation (Allen, 2000; Barrack & Munn, 2000; Jerosch, 2000). It is unclear whether there is a directional dependence during joint kinesthesia (Beynnon et al. 2000).
- Proprioception is best at the end range of motion (Barrack et al. 1994; Barrack & Munn, 2000; Jerosch, 2000).
- Proprioception is not dependent on the sex of the subjects (Jerosch, 2000).
- Arm dominance does not affect proprioception (Allen, 2000; Borsa et al. 1994).
- Proprioception improves with the application of elastic bandages and braces in young athletes, as well as with older patients who have arthritic knees (Barrack et al. 1994; Borsa et al. 1994; Lo & Fowler, 2000; Renström et al. 2000).

This study was formulated with the idea that a proprioceptive training programme might be able to decrease the incidence of falling in the elderly. The programmes generally used in the literature to prevent falls in the elderly focus on balance training, strength training or a combination of the two. This study incorporated both of these facets, but with some differences. The programme designed and implemented in this study was characterized by balance and strength-training activities, although increasing balance and strength were not its goals. The goal of the participation in the programme was to improve the capacity to perform functional balance through increasing the individual’s proprioceptive sensitivity.

- The strength training exercises used in this study were aimed at improving postural stabilization, not at increasing strength as such. The strength component consisted of closed kinetic chain exercises looking to improve the dynamic joint stability of the individuals.

- The balance training exercises in the programme were included to improve position sense, reactive neuromuscular control of the joints and the coordination of functional motor patterns.

Some other characteristics of this training programme is that it focussed on the body as a whole and not just on the lower extremities like many other integrated balance and strength training programmes. Another important feature of this programme is that it was designed to be practical – it can be performed with minimum equipment in almost any facility. It was also an economically viable programme because only low-tech apparatus was used. The next chapter will describe the methodology of this study in detail.

Chapter Three

Methodology

The approach used in this study was field-based and required no expensive equipment. This chapter is a description of the methods followed.

Assessment

According to Irrgang et al. (1994), the selection of a method of assessment should meet the clinical needs of the population to be tested. Other considerations to bear in mind are the time required to administer and score the test, the cost of administering the test, and its reliability, sensitivity, objectivity, and validity. The two tests used to collect the data for this study were selected with these considerations in mind. The first test measured proprioception while the second measured the functional skill levels of the subjects.

- Both tests are field tests, which made it possible to go to old age homes and conduct the tests there.
- The tests were also easy to administer, did not need expensive equipment and did not take too much time to complete. This was very important, because the elderly can be very frail and easily fatigued.
- Both tests administered are designed specifically for the elderly and can be used with confidence knowing that the test procedures are sensitive to the safety needs of the subjects.

Harrison’s Recovery Test

G. W. Harrison, MCSP, Registration No 21426, developed this test over a period of fifteen years. During this time, he worked as a Senior Physiotherapist in charge of Physiotherapy Services in a stroke and head injury unit within the United States National Health Service. Harrison kindly donated his test material for use in this study (Harrison, 2001). Unfortunately he could not supply the validity and reliability figures of the test, as he no longer has access to the facilities since his retirement (Harrison, personal communication, March 6, 2002).

The Harrison Recovery Test (HRT) was designed as a formative evaluation to measure quantitatively patient recovery from strokes or head injuries. It consists of a sensory, proprioceptive and motor section. The items in the motor section, for example, compare the patient to normal movement patterns, which are graded according to increasing complexity. From this information recovery curves are drawn. These graphs show if the patient has improved, plateaued, or regressed. The tests can be repeated months or years later and a comparison made.

Only the proprioception section of the HRT was used in this study. This section consists of three different actions with nine different parts of the body. The actions are:

1. Position sense (PS).

When testing position sense, the patient's affected limb is moved into various positions. The person then has to copy the position with the unaffected limb. For the purpose of this study, the non-dominant limb was moved first, and the movement to copy the position was attempted with the dominant limb.

2. Appreciation of movement (AM).

During appreciation of movement, the limb is moved steadily towards a certain position and a question is asked, e.g. "is your elbow being bent or straightened?”

3. Appreciation of fine movement (FM).

When assessing the appreciation of fine movement, the movements are the same as when assessing the appreciation of movement, however, the movement is done very slowly to determine when the subject can detect motion, e.g. “tell me when you can feel your elbow begin to move.” All subjects were blindfolded for the duration of the test. If the subject was successful in the action, the corresponding box on the score sheet was marked. If the subject was unsuccessful, the corresponding box was left blank.

Because the HRT was designed for individuals who had a stroke, there was a concern that it might not be sensitive enough to identify weak proprioception in normal, healthy older adults (the sensitivity of a test refers to the percentage of the subjects tested who have a condition and show positive test results for the condition). The following adaptations were made to the Harrison’s Recovery Test to make the test more suitable for the purposes of the present study and to discriminate between older adults with poor proprioception and those who have good proprioception.

- Subjects were instructed to identify the movement and its direction as soon as it was perceived.
- Unlike the original HRT, no prompting of subjects was provided during the test.
- Some "placebo" actions were included to identify subjects who were guessing. A placebo action for the purpose of this study could be defined as a time frame in which there was no movement. If the subject stated that there was movement during this time frame, the action was considered unsuccessful.
- For each action on each body part, three trials were given. Two out of three attempts had to be correct for the action to be successful.
- All the tests were done in mid-range of motion, the reason for this is that, as stated in Chapter Two, several researchers have indicated that proprioception is more sensitive in a joint's end ranges of motion.
- Swinkels and Dolan (1998) presented mean movement sense thresholds for the elbow, shoulder, and knee joints, as found in the literature. These thresholds were based on joint movement of 0.5° per second and were 0.2°-2.8° for the elbow, 0.3°-1.8° for the shoulder, and 1.2°-5.9° for the knee joint. So, it normally takes subjects 1-5 seconds to detect movement of the elbow, 1-3.5 seconds to detect movement in the shoulder, and 2.5-12 seconds to detect movement in the knee joint. This assumes the joint is moved at 0.5° per second, and the movement is in mid ranges of motion.

  When moving a limb with the hand and not an electronic dynamometer, it is impossible to guarantee movement of a limb at 0.5° per second. For the purposes of this study, it was assumed that for the appreciation of fine movement section of the HRT, the joints were moved at 1° per second. Looking again at the norms that Swinkels and Dolan (1998) provided, it could be concluded that for joint movements of 1° per second, a person with normal proprioception would be able to identify joint movement in the elbow, shoulder, and knee joints in less than 2.5, 2 and 6 seconds respectively.
- To increase the reliability of the results of the HRT, only one person was used to administer the test throughout the study.

The accuracy of the subject's responses could have been a problem in this test if the subject did not understand the instructions of the test, and therefore did not reply immediately when the movement of the joint was felt. In such a case, the subject would be identified with poor proprioception when indeed they did not have a problem with proprioception.

A problem with the Harrison's Recovery Test that was not addressed in the present study, was the amount of sensory information received from the cutaneous receptors in the skin. Another aspect that has to be kept in mind throughout the study is the population with whom one is working. Older adults might find it more difficult to "listen" to their bodies than say for example athletes do. Harrison (2001) requested that a copy of the Harrison's Recovery Test would not be published.

The Berg Balance Scale

Balance is critical to functional capabilities because it is a requirement for carrying out activities of daily living. The equipment required for studying balance in the laboratory is expensive and involves highly trained personnel. These measures are not easily accessible to clinicians in their daily practice or to clinical researchers with limited budgets (Berg, 1989). These are the factors that Berg and associates considered when they designed the Berg Balance Scale (Berg, 1989) and it is because of these same factors that the Berg Balance Scale (BBS) was used as the measurement instrument of functional balance in the present study.

The BBS has been developed with evaluation and monitoring of patient status as primary objectives. The BBS was developed with a sufficient range of scoring to note small yet significant changes in patient status (Berg, 1989). This was important for the present study because the proprioceptive system is only one of many factors that affect balance, therefore it is expected that the effect that improvements in proprioception might have on functional balance will be small but hopefully, significant.

The BBS is a clinical test used to assess functional limitations in balance and mobility in the clinical setting, as well as to measure improvement. The BBS has demonstrated both validity and high test-retest reliability when administered to older individuals. It consists of 14 test items, scored from zero to four on an ordinal rating scale.

- To achieve the maximum score of four for a movement, the subjects must perform the movements independently and hold the position for a prescribed amount of time, or perform the action within a set time frame.

- Progressively fewer points are awarded as the time requirements are not met, and as the patients needs greater assistance in the activity.

- Test items include sit-to-stand, transfers, retrieval of an object from the floor, and other movements associated with daily functioning.

- The total score achieved out of 56 possible points was submitted for further analysis.

The administration of the test requires a stopwatch and a ruler and takes approximately 15 to 20 minutes to complete. The time it took to complete the tests was an important consideration in choosing the test items because this study worked with a special population.

The test is simple and easy to administer, and is safe for elderly patients to perform. The scale also has a high internal consistency, which facilitates interpretation of test scores. The inter-rater reliability shows a high degree of agreement among the raters in scoring the items in the balance scale. The intraclass correlation coefficients measuring the inter- and intra-rater reliability for the test as a whole were .98 and .99 respectively. The correlation coefficient for the individual items ranged from .71 to .99 (Berg et al. 1989).

The lack of an item that requires a postural response to an external stimulus or uneven support surface is a limitation to this scale. This is a limitation on the utility of the scale when assessing very active persons with minimal deficits. An assessment of walking was not incorporated into the test, however, stepping with one foot forward, standing on one leg, and stool stepping are necessary to some degree for independent walking and stair climbing (Berg et al. 1989). Appendix A is an example of the Berg Balance Scale as referenced in Shumway-Cook and Woollacott (1995), that was used for the purposes of the present study.

Subjects

The subjects participating in this study were all volunteers. The only criteria was that the subject had to be over 64 years of age and that they did not plan to leave town for longer than a weekend until the study was finished. In total, 25 people participated in the study. Of these 25, 15 were assigned to the intervention group and 10 to the control group. The subjects ranged from ages 65 to 87 with a mean age of 73.2 years. The mean age of the control group was 70.2 years and of the intervention group was 75 years of age. Both of these groups consisted of people who lived in old age homes, as well as community dwelling citizens. The subjects were drawn from the black, white and coloured racial groups.

All of the subjects were asked not to alter their usual activity levels during the period of this study. If they were already involved in physical activity, they were asked to keep on their usual exercise programmes. The subjects in the intervention group were provided with proprioceptive training sessions. They had to attend at least 16 (70%) of the proprioceptive training sessions in order to be post-tested and their results to be used in this study.

Procedures

This section contains a step by step description of the procedures that were followed during this study. It describes the procedures used in capturing and editing the data, debriefing of the subjects, measures to minimize error and the data analysis procedures used.

Pre-test

Once the subjects were identified, a date was set and the pre-testing began. The subjects from the old age home were tested in the home, in the lounge that the management kindly provided for the purposes of this study. The other subjects came to the Stellenbosch Biokinetics Centre where they were tested. On arrival each of the subjects signed an indemnity form (see Appendix B). The pre-test consisted of a short questionnaire regarding personal details such as age, medical history, medication and conditions, and activity levels of the subject. It also included a sitting and standing blood pressure measure to determine if the person had postural hypotension or hypertension.

This is important information for the person running the intervention programme in order to provide a safe training environment for the subjects.

After the blood pressure was measured, the subjects were divided into two groups. At one station a trained biokinetics intern administered the Berg Balance Test and at the other station the researcher administered the Harrison's Recovery Test. Special care was taken during the BBS, for example, when turning in a full circle or transferring from one chair to another, because little was known about the subjects and their ability to maintain balance during motion. When the subjects had completed the assessment, they went to the other station. Appendix C provides an example of the score sheets used for the pre-tests. Once they had finished at both stations, times for the training sessions were scheduled and they were free to go. The entire assessment took approximately one hour per subject.

Training Protocol

Each subject assigned to the intervention group attended three 20-minute proprioceptive training sessions per week for eight weeks. The first session started the day after the baseline testing. The sessions were organized to accommodate the schedule of the subjects. The researcher, with the help of two trained biokinetics interns from the Stellenbosch Biokinetics Centre, presented the programme. All the exercises were done on a one-on-one basis with one intern for each participant.

The goals of the training programme were to improve each participant’s ability to:

1. Maintain and control balance when subjected to different tasks and surfaces.
2. Maintain and control balance through different sensory conditions.
3. Adapt postural strategies in order to accommodate changes in support surface and task constraints.

The programme was a proprioceptive training programme focussing on the upper and lower extremities as well as the trunk region. It consists of a basic programme with several progressions available for every exercise. This made it possible to adapt the programme to each individual’s needs and capabilities, while still achieving the same goals. According to Rose and Clark (2000), a successful balance-training programme should progressively challenge each individual subject without exceeding his/her capabilities. Making use of biokinetics interns helped to achieve this with the intervention programme of the present study as they are skilled to judge a person’s performance of a task and are able to progress them without going beyond their abilities. Table 8 is a summary of the items included in the basic programme, as well as the repetitions of each exercise and the element of proprioceptive rehabilitation that it affects.

Table 8. The baseline programme.

Exercises	Repetitions	Element in rehabilitation
Lower Extremities		
Weight shifting (left/right; anterior/posterior)	1 x 10	Dynamic stabilization Position sensibility Functional motor patterns
Applied perturbations (left/right; anterior/posterior)	1 x 10	Reactive neuromuscular control Functional motor patterns
Standing on a foam pad	2 x 30sec	Reactive neuromuscular control Functional motor patterns
Wobble boards (left/right; anterior/posterior; multi-axial)	2 x 30sec	Reactive neuromuscular control
One legged standing (left and right)	2 x 30sec	Reactive neuromuscular control Functional motor patterns
Upper Extremities		
Weight shifting, leaning against the wall	1 x 10	Dynamic stabilization Position sensibility Reactive neuromuscular control
Wall push-ups	1 x 10	Dynamic stabilization Reactive neuromuscular control
Trunk Region		
Kneeling on all fours	1 x 10	Dynamic stabilization Position sensibility Reactive neuromuscular control Functional motor patterns
Therapeutic ball exercises	2 x 30sec	Dynamic stabilization Reactive neuromuscular control

Balancing activities are dependent on the proper functioning of complex higher-order neural mechanisms. Different balancing activities need different intensities of movement control when balance tasks vary in degree of difficulty (e.g., a moderate lean versus a maximum reach). The sensory input available to the subject can be manipulated by requiring exercises to be performed with and without vision, or in conditions of altered somatosensation, for example, performing a task on a foam surfaces or by stimulating the vestibular system with head movements in multiple planes. Increasing the time or number of repetitions can also be used as a basis for progressions.

Initially all of the activities in a proprioceptive training programme should be performed while the individuals concentrate on their sense of body position, muscle control, joint positions, and joint movements. Over time as the subject's balance improves, activities to distract his/her attention from focussing on balance control, is included. Irrgang and Neri (1999) suggested activities such as catching and throwing a ball, while other researchers have made use of more cognitive involvement, such as mathematical problems. For the purposes of this study, the subjects were originally cued to focus on their body and to concentrate on the movement, while later in the programme, conversations were held with them as a distraction.

The following sections provide a brief description of the different kinds of exercises in the basic programme and the progressions used for the purposes of the present study are indicated.

Weight Shifting

The subjects began in an initial position of standing with feet shoulder width apart, and then shifting the weight from the one foot to the other. The subjects were cued to try and move their bodyweight as close as possible to the edge of their base of support. When doing anterior/posterior weight shifting a set was done for each leg.

1. Weight shifting combining head movements from side to side as well as looking up and down.
2. Weight shifting with eyes closed.
3. Weight shifting and reaching for objects.
4. Weight shifting on a foam pad.
5. Weight shifting on a foam pad with eyes closed.
6. Weight shifting on a foam pad while reaching for objects.

See Figure 4 for an example of anterior/posterior weight shifting on a thick foam surface while reaching for objects.

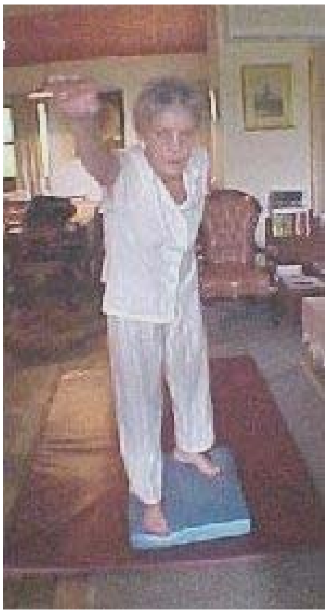

Figure 4
Weight shifting on a thick foam surface while reaching for objects.

Applied Perturbations

The subject stands with his/her feet together while the trainer applies perturbations in all directions. The subject is cued to try and keep his/her feet together at all times and not to hold on to the trainer.

1. On floor, eyes closed.
2. On mat (thin foam pad), eyes open.
3. On mat, eyes closed.
4. On thick foam, eyes open.
5. On thick foam, eyes closed.

Figure 5 is an example of the trainer applying perturbations to the subject who is standing on a thick foam surface, with eyes closed.

Figure 5

Applied perturbations on a thick foam surface with eyes closed.

Standing on Thick Foam Surface

1. Standing with feet together, supported, and eyes open.
2. Standing with feet together, supported and eyes closed.
3. Standing with feet together, unsupported, eyes open.
4. Standing with feet together, unsupported, eyes closed.
5. Standing on one leg, supported, eyes open.
6. Standing on one leg, supported, eyes closed.
7. Standing on one leg, unsupported, eyes open.
8. Standing on one leg, unsupported, eyes closed.
9. Standing on one leg, unsupported while reaching for objects.

Figure 6 is an example of a subject doing a one legged stance on a foam surface as well as an example of further increasing the difficulty of the exercise by increasing the thickness of the surface, for very weak subjects, only the thin foam surface could be used.

Figure 6

One legged standing on a thick foam surface (left).

A thick foam surface placed on a thin foam surface to increase difficulty (right).

Balance Boards

Exercises of this type were chosen since in everyday life, the tendency for the foot to “give way” is most noticeable when walking on uneven ground when the muscles of the leg have to make rapid adjustments to passive displacements imposed on the foot. It was hoped that the boards would select the essential part from this everyday situation so that, if a patient could be trained to balance on the boards, he/she would be able to transfer that training to walking on uneven surfaces (Freeman, 1965). For the purposes of this study, three different balance boards were used, one that moves in each of the three planes of motion.

1. Stand supported with eyes open.
2. Stand supported and include head movements.
3. Stand supported with eyes closed.
4. Stand with only one hand supporting, eyes open.
5. Stand with only one hand supporting, and head movements.
6. Stand with only one hand supporting, with eyes closed.
7. Stand unsupported with eyes open.

Figure 7 is an example of two of the three balance boards used in the present study, one moving in the frontal and one moving in the saggital plane of motion. The subject is receiving one-handed support from the trainer.

Figure 7
Balance boards with one handed support, anterior-posterior instability (left) and lateral instability (right).

One-legged Standing

1. On the floor, supported, and eyes open, 2 x 30sekonds.
2. On the floor, supported, eyes open, 1 x 1minute.
3. On the floor, supported, eyes closed, 1 x 1minute.
4. On the floor, unsupported, eyes open, 1 x 1minute.
5. On the floor, unsupported, eyes closed, 1 x 1minute.
6. On the floor, unsupported, eyes open while reaching for objects.
7. On the floor, unsupported, eyes closed while reaching for objects.

Figure 8 is an example of a subject doing an one-legged stance without support and with the eyes closed, while standing on a thin foam surface.

Figure 8

One-legged standing on a thin foam surface without support and eyes closed.

Wall Standing and Weight Shifting

Assume the position for a wall push-up. The further away the feet are from the wall the harder the exercise will be.

1. Shift the body weight form the one arm to the other with eyes open.
2. Weight shifting with eyes closed.
3. Weight shifting with eyes open while pressing on a foam pad.
4. Weight shifting while pressing against a small ball.
5. Weight shifting while pressing against a medium size ball.
6. Weight shifting while pressing against a therapeutic ball.

Figure 9 is an example of a subject doing weight shifting against the wall with eyes closed. While Figure 10 is an example of progressions of this exercise where the subject is first pressing against a small ball and then against a therapeutic ball. Note that with these progressions the subject is working a lot more stabilising muscles than previously.

Figure 9

Wall standing and weight shifting with eyes closed.

Figure 10

Wall-weight shifting on a small ball (left) and a therapeutic ball (right).

Wall push-ups

1. Do as many wall push-ups as you can (up to 30 repetitions).
2. Press against a small ball while doing wall push-ups.
3. Press against a medium size
4. Press against a therapeutic ball.

Figure 11 is an example of firstly ordinary wall push-ups and then secondly wall push-ups against a small ball.

Figure 11

Wall push-ups (left) and wall push-ups on a small ball (right).

Kneeling on All Fours

1. Shift weight from the one side to the other.
2. Lift the arms alternately, and hold for 5 seconds. Repeat with the legs.
3. Lift the opposite arm and leg simultaneously, hold for 5 seconds, work up to six repetitions on each side (“supermans”).
4. The same as number three (“supermans”) but rest the abdominal area on a therapeutic ball with only the hands and feet touching the floor.

Figure 12 is an example of the last progression of kneeling on all fours.

Figure 12

“Supermans” on a therapeutic ball.

Therapeutic Ball

All of these exercises are done while sitting on a therapeutic ball.

1. Shift the weight laterally, supported, eyes open.
2. Roll the ball with pelvic movements clockwise and anti-clockwise, supported, eyes open.
3. Same as number two, but unsupported, eyes open.
4. Hip flexion, supported, eyes open.
5. Hip flexion combined with knee extension, supported, eyes open.
6. Hip flexion combined with knee extension, supported, eyes closed.
7. Hip flexion combined with knee extension exercises, unsupported, but holding on to the ball, eyes open.
8. Hip flexion combined with knee extension, unsupported, without holding onto the ball, eyes open.
9. Hip flexion combined with knee extension, unsupported, holding onto the ball, eyes closed.
10. Hip flexion combined with knee extension, unsupported, not holding onto the ball, eyes closed.

Figure 13 is a subject doing weight shifting on a therapeutic ball (left) as well as hip flexion (right), with eyes open while holding on to the ball.

Figure 13

Weight shifting on a therapeutic ball with the eyes open (right).

Hip flexion without support while holding onto the ball (left).

Figure 14 is an example of a subject doing hip flexion without holding onto the ball (left), and hip flexion combined with knee extension while holding onto the ball, but with the eyes closed (right).

Figure 14
Hip flexion without support or holding onto the ball (left). Hip flexion and knee extension without support, with eyes closed while holding onto the ball (right).

General Comments

When exercises were performed unsupported on the therapeutic ball, someone was standing close by in case anything should happen, so the subject was safe at all times. The time was increased first, so that the individual was able to do all the exercises for one minute, before progressions were followed. The reason the programme started with only 30 seconds at a time was because Berg (1989) found that frequently, the muscles of the elderly are too weak to keep a one-legged stance for more than 30 seconds.

Fitzgerald et al. (2000) provided the following general guidelines for progressions of activities to enhance neuromuscular control:

- From slow speed to fast speed
- From low force to high force
- From controlled (expected) to uncontrolled (unexpected) activities.

Many of the progressions in the basic programme as well as the progressions to individualise the programme were based on these guidelines. Initially, activities to enhance neuromuscular control should be performed within the safe ranges of joint motion. Control of motion in positions vulnerable to instability requires gradual introduction of activities that perturb the joint to initiate proprioceptively mediated reflexes that dynamically stabilize the joint (Fitzgerald et al. 2000).

Post-test

The post-test was completed the day after the last training session. The protocol included the Harrison's Recovery Test and the Berg Balance Scale. The same persons who administered the baseline testing of the tests were responsible for the post-testing. This was done in order to increase the reliability of the test results, as both of the tests used in the present study, are subjective of nature. Appendix D is an example of the post-test score sheet.

Post-Post Test

A post-post test was done on five of the subjects of the intervention programme the day after the post-test. The aim of this post-post test was to determine the reliability of the test results by measuring the repeatability of the tests used in the test-battery. The results of the post-post test are discussed in the end of chapter four after the research questions have been answered.

Debriefing of Subjects

The intervention was ended with a social function at the Oude Werf Country Inn in Stellenbosch. During this function all the subjects were thanked for their time, enthusiasm, patience and devotion. The subjects were asked to share some of their thoughts about the programme. The subjects rated both the programme and the function as a success and all appeared to enjoy themselves thoroughly. It is common knowledge that social contact is of great importance for older adults. Many subjects commented that the social aspect of the programme was as important to them as the movement aspect of the programme. It can be imagined why this would be true for older adults who live in old age homes. For the one woman in this study, the social function was the first time in two years that someone had taken her out of the home.

Treatment of the Data

Unpaired and paired t-tests for dependent samples were applied to determine whether a short-term proprioceptive training programme would lead to significant improvements in the functional balance and the proprioception of older adults. A Pearson's correlation coefficient was determined to reveal correlations between age and functional skill level of the subjects as well as correlations between age and proprioception of the subjects. The alpha level of significance for these analyses was set at $p<0.05$.

The data were analysed with the help of Dr. M. Kidd from the Department Statistics, using STATISTICA (StatSoft Inc. 2001) data analysis software system, version 6.

Summary

All the subjects used in the present study, was over 65 years of age. Some of them are community-based while others live in old age homes. The subjects who participated in this study were assigned to either a control group or an intervention group.

The intervention programme in this study focussed on improving proprioception and functional balance of the participants. The programme was specifically designed to progressively challenge the capabilities of each individual participant. This programme was not expensive in terms of apparatus and it did not require a specialised facility. For the purposes of the present study, a trained professional was available for every subject, which allowed closer monitoring of patient progress and making the appropriate adaptations to the programme.

Pre-test and post-test data were collected using the Harrison's Recovery Test (Harrison, 2001) for the measurement of proprioception and the Berg Balance Scale (Berg, 1989) for the measurement of functional balance. The next chapter describes the results of the statistical analysis done between and within the two sub groups on their test results.

Chapter Four

Results and Discussion

In this chapter, the data gathered and analysed to answer the research questions presented in Chapter One. The statistical analysis of the results of the group is discussed, and then the participants are individually discussed as short sketches.

Descriptive Data

The sample consisted of 25 subjects, 15 in the intervention group and 10 in the control group. The ages of the subjects ranged from 65 years of age to 87 years of age with the average age of 73.1 years (SD = 7.2). Table 9 is a summary of the descriptive data.

Table 9. Descriptive data for the subjects participating in the study.

Group	Number of Subjects	Average Age	Age Range	Standard Deviation
Total group	25	73.12	65-87	7.22
Intervention group	15	75.07	65-86	6.63
Control group	10	70.2	65-87	7.41

Research Question One

1. Can a proprioceptive training programme consisting of proprioceptive exercises for the upper and lower extremities as well as the trunk, be effectively used as modality for improving the functional balance of older adults?

The results of this study demonstrate that a proprioceptive training programme is an effective modality for improving the functional balance of older adults. These results support the findings of Rose and Clark (2000), who found a statistically significant difference in the Berg Balance Scale scores of the older adults who participated in their eight-week balance-training programme.

Comparisons between Groups

A comparison of scores on the Berg Balance Scale between the intervention and the control group at the beginning of the study was done to determine whether or not there was a difference between the two groups in terms of their functional status before the intervention programme was offered. An unpaired t-test was used to determine this. Figure 15 graphically displays the results of the unpaired t-test comparing the pre-test Berg Balance Scale scores of the two groups. This data is also presented in the tables in Appendix E. As expected, the difference between the Berg Balance Scale scores of the two groups at the beginning of the study was not significant (p = .27).

When looking at the graph, it can be seen that the intervention group had a slightly higher pre-test score for the Berg Balance Scale. Because this difference was not significant, it can be assumed for the purposes of the present study that the functional skill level of the two groups started out on the same level. A possible reason for the intervention group’s slightly higher pre-test scores could be that they volunteered to participate in a training programme, while the members of the control group were recruited by the researcher. Therefore it is possible the members of the intervention group had a slightly higher level of functional fitness, which would have an effect on their performance on this test.

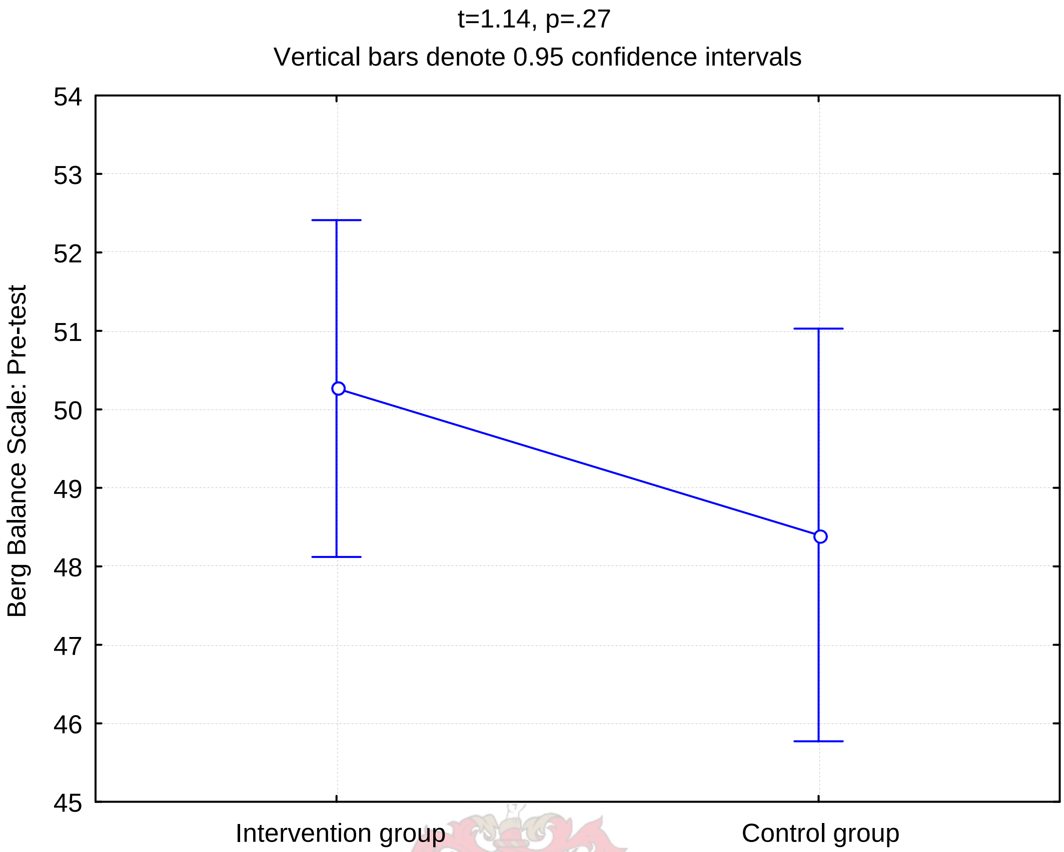

Figure 15

Comparison of the Berg Balance Scale scores of the control and the intervention group at the beginning of the study.

To investigate whether the intervention group improved in their functional status compared to the control group, an unpaired t-test was done on the post-test scores. This t-test compared the post-Berg Balance Scale scores of the two groups. Figure 16 graphically presents the results of this unpaired t-test. These results support the expected significant improvement in the functional balance levels of the intervention group when compared to the control group after the study (p = .03). A summary of these results is in the tables in Appendix E.

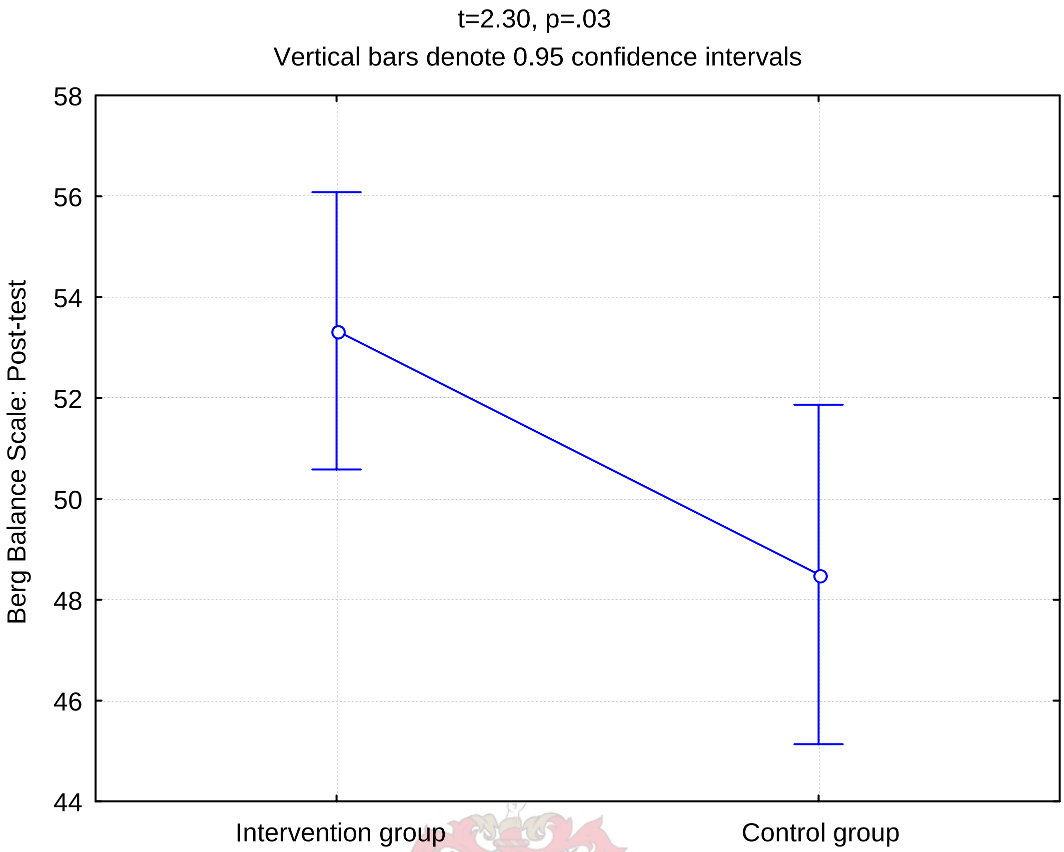

Figure 16

Comparison between the Berg Balance Scale scores of the intervention and the control groups after the intervention.

Comparisons within Groups

To determine whether the control group's functional status improved during the time that the intervention group were on the proprioceptive training programme, a paired t-test for dependent samples between the pre- and the post-test Berg Balance Scale scores of the control group was done. The results of the paired t-test between the pre- and the post-Berg Balance Scale scores of the control group are presented in Figure 17. These results are also presented in the tables in Appendix E. As expected, no statistical significant difference was found between the scores of the control group (p = .92). Therefore, it could be assumed that the control group had approximately the same functional balance level at the end of the programme as at the start.

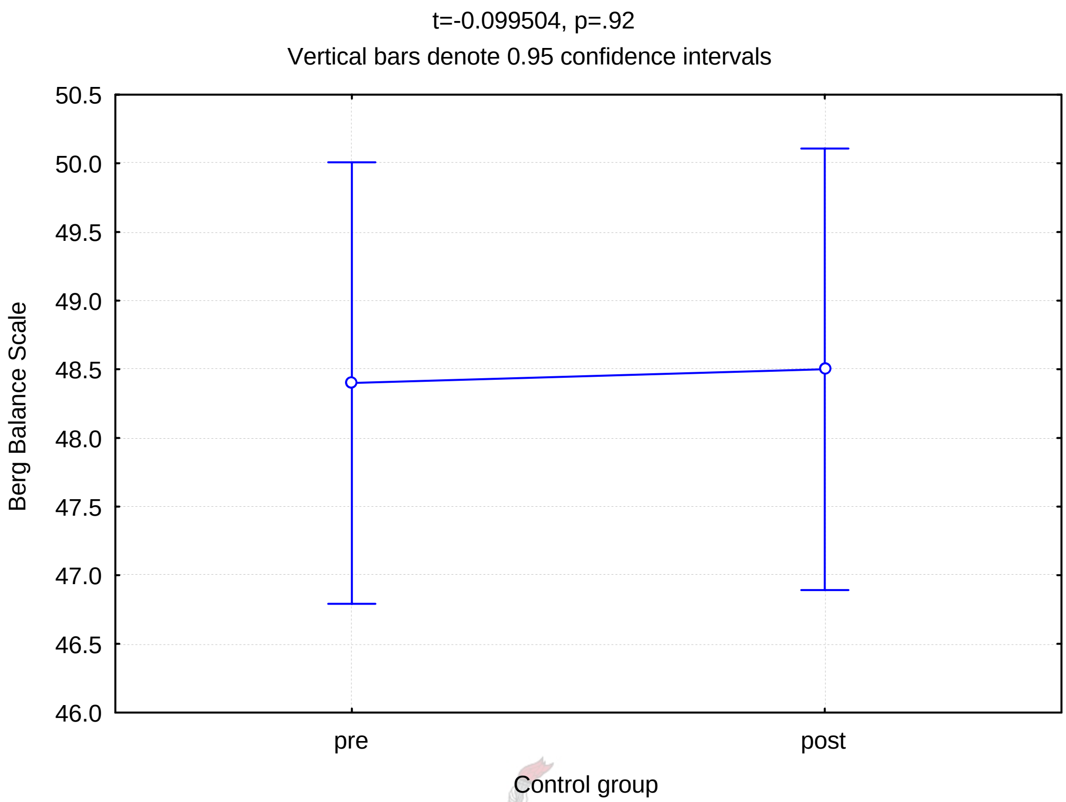

Figure 17

Comparison of the Berg Balance Scale scores of the control group before and after the study.

A paired t-test for dependent samples was also used to determine whether the intervention group's functional status improved following the eight-week proprioceptive training programme. The results of this test are presented in Figure 18. These results are also presented in tables in Appendix E. The difference between the intervention group's pre- and post-test scores for the Berg Balance Scale was statistically significant (p = .01), supporting the conclusion that the proprioceptive training programme in this study was an effective modality.

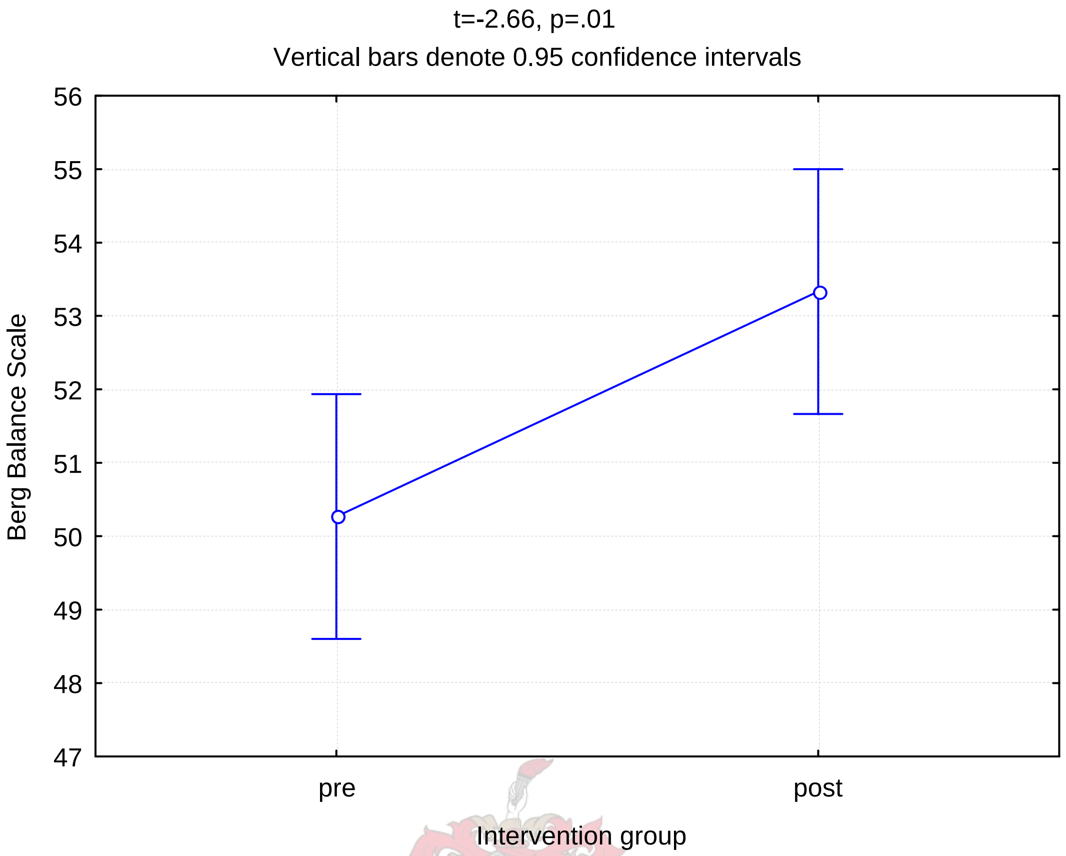

Figure 18

Comparison between the pre- and the post-test scores on the Berg Balance Scale of the intervention group.

Correlation between Functional Balance and Age

During the course of the study, the researcher noted marked differences in subjects' performance on the Berg Balance Scale, and wondered if a correlation existed between the baseline scores of the Berg Balance Scale and the age of the subjects. In other words, was there a relationship between a subject's age and their level of functional balance? A Pearson's correlation coefficient was done to determine the effect that aging has on functional balance. The results showed a very weak negative correlation between the participant's functional balance levels and their age ($r = -0.36$). Figure 19 is a scatter plot and regression line of the Berg Balance Scale pre-test scores correlated with the age of the participants.

This weak correlation was unexpected as the literature reviewed suggested a strong negative correlation between functional balance and aging i.e. that functional balance level decrease with aging. This weak correlation supports the point of view that aging is a highly individualised process and that chronological age may not be a good indicator of functional age.

It is possible that the participants of this study had above average physical activity levels for their age, which could have meant they would achieve higher scores on tests of functional balance. This would suggest that in the elderly, activity levels are more important when it comes to the level of a person's functional balance than their age. The sample used in the present study was a very small sample, consisting of only 25 subjects. The small sample used, made the correlation coefficient more sensitive for individual scores.

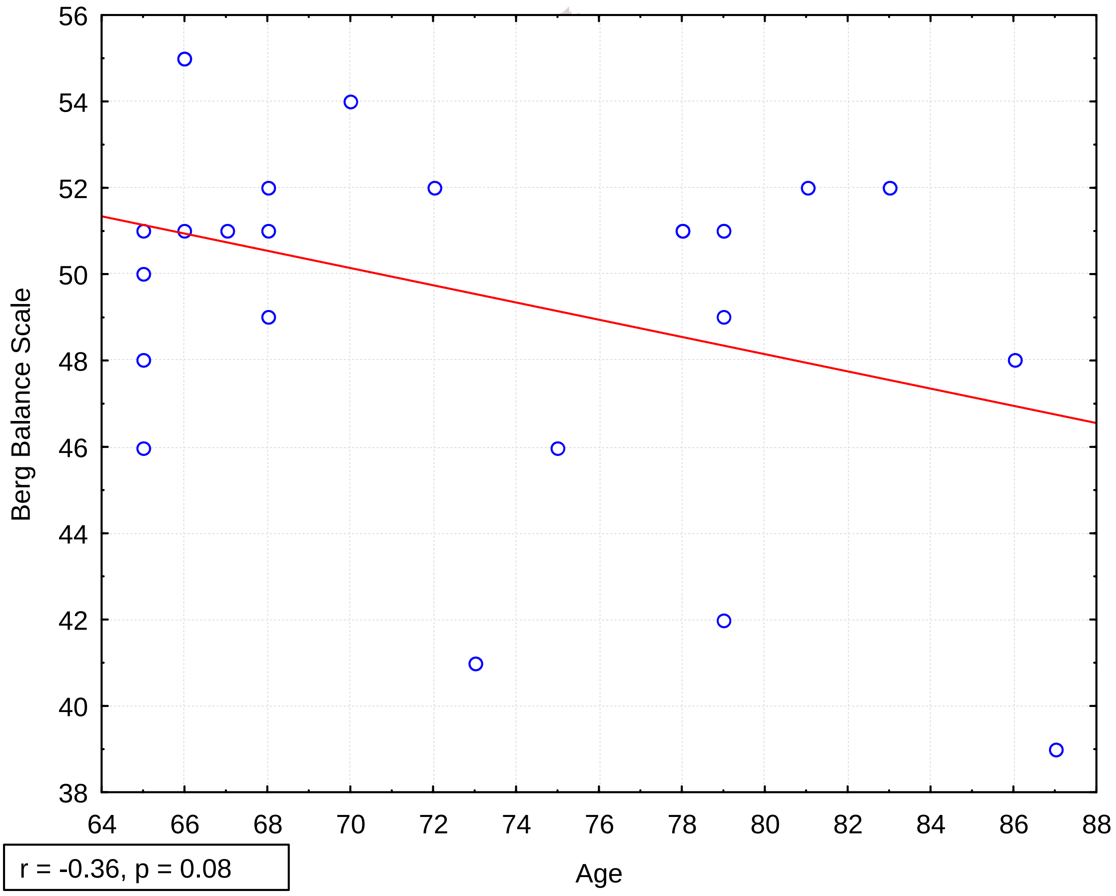

Figure 19

A graphic display of the correlation and the regression line between the Berg Balance Scale scores of the participants at the beginning of the study and their age (N=25).

Research Question Two

2. Can a proprioceptive training programme consisting of proprioceptive exercises for the upper and lower extremities, as well as the trunk, be effectively used as modality for improving the proprioception of older adults.

The Harrison's Recovery Test was used to measure proprioception and improvements in proprioception in the present study. Differences in proprioception are considered to be significant at $p>0.05$. The statistical analysis of the results of the proprioception tests done in this study supported the above statement. Therefore it can be concluded that the proprioception of older adults improved following a proprioceptive training programme.

Comparison between Groups

To determine whether the intervention group and the control group's proprioception were on the same level at the start of the programme, an unpaired t-test was used. Figure 20 graphically displays the results of the unpaired t-test comparing the baseline Harrison's Recovery Test results of the intervention and the control group. As shown in Figure 20 there is not a statistically significant difference between the baseline Harrison's Recovery Test scores of the intervention and the control group ($p = .61$). Therefore, it can be concluded with confidence that the two groups were the same in terms of proprioception levels at the beginning of the study.

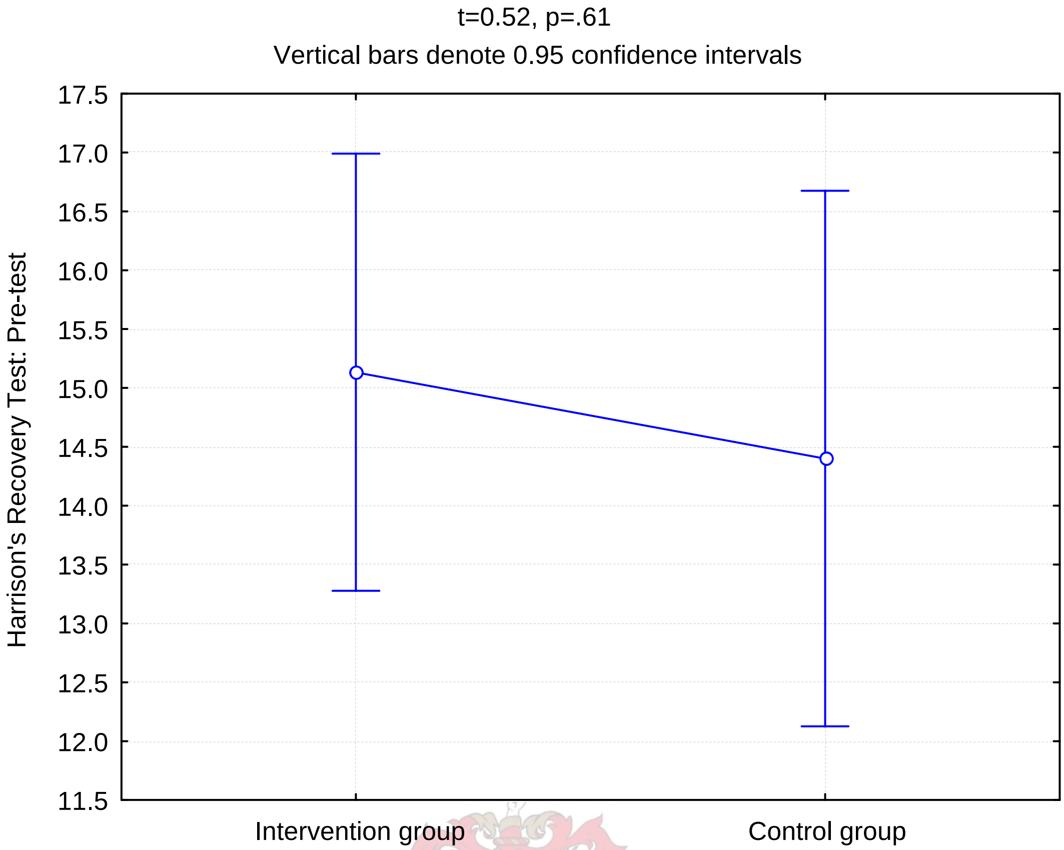

Figure 20

Comparison of the Harrison’s Recovery Test scores of the control and the intervention group at the beginning of the study.

To determine whether the intervention group improved their proprioception following the eight-week proprioceptive training programme compared to the control group, who did not participate in the training programme, an unpaired t-test was done. Figure 21 graphically presents the results of the unpaired t-test done between the Harrison’s Recovery Test scores of the intervention and the control group after the programme. The results indicate the expected significant improvement of the proprioception of the intervention group following the proprioceptive training programme ($p < .001$). Therefore it could be assumed that the proprioceptive training programme significantly improved the proprioception of the older adults who participated in this study.

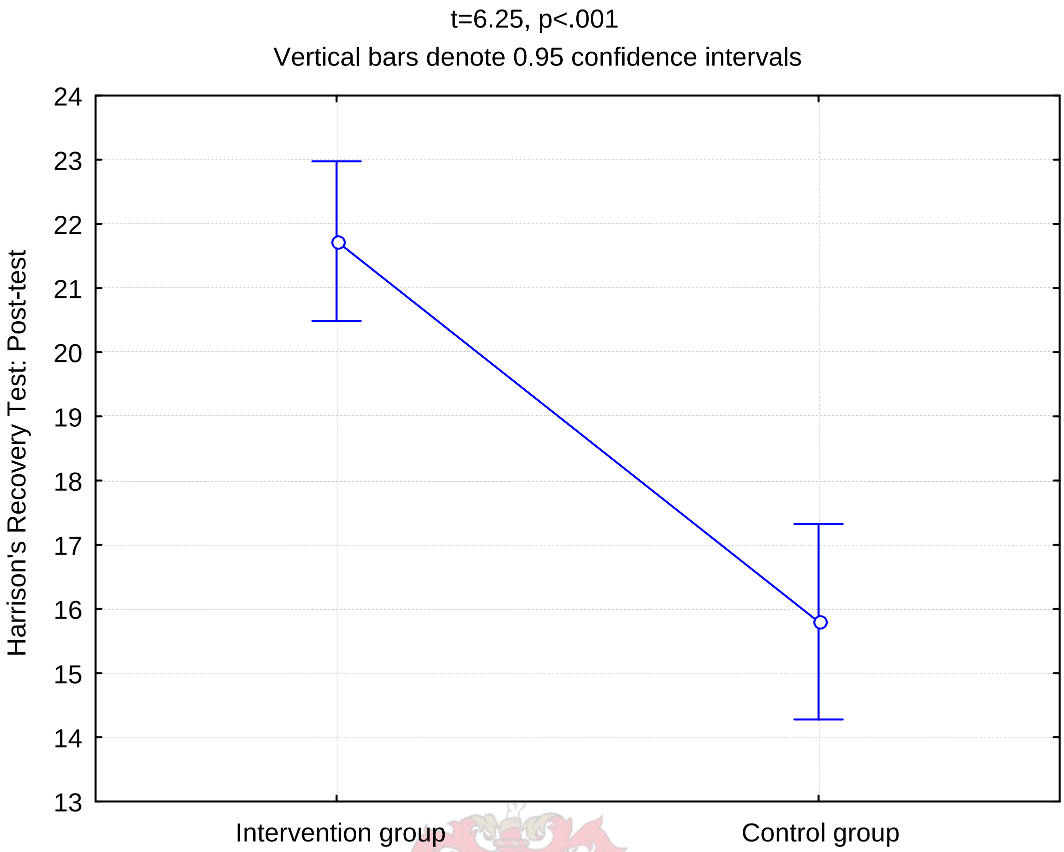

Figure 21

Comparison between the Harrison's Recovery Test scores of the intervention and the control groups after the intervention.

Comparison within Groups

To determine whether the control group improved in terms of proprioception during the study, a paired t-test for dependent samples, the control group's pre- and post-test scores of the Harrison's Recovery Test were compared. Figure 22 presents a summary of the comparison between the control groups pre- and post-test scores for the Harrison's Recovery Test. As shown in Figure 22, no statistically significant difference was found between the proprioception of the control group before and after the study (p = .31). This means that their proprioception did not improve significantly during time of the study, and can it be assumed that the control group's proprioception is still on the same level as at the beginning of the study.

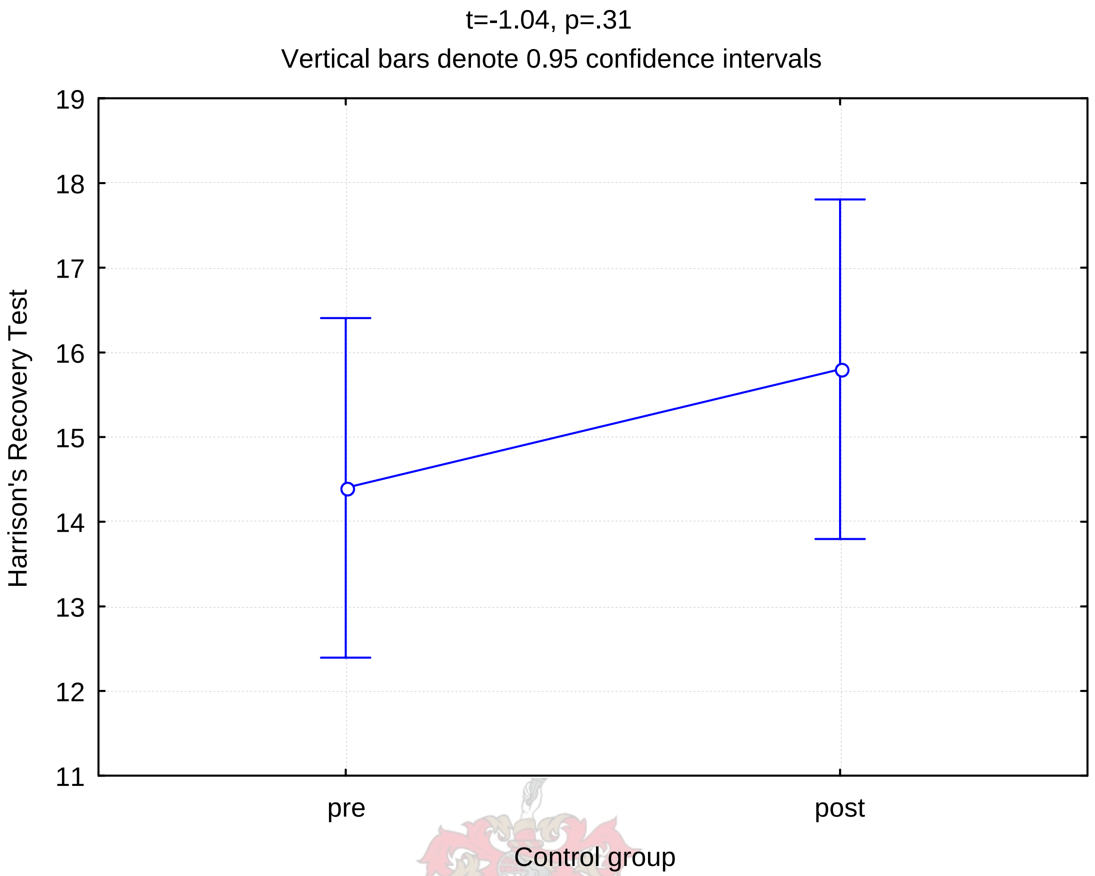

Figure 22

Comparison of the Harrison’s Recovery Test scores of the control group before and after the study.

To determine whether the intervention group improved their proprioception during the intervention programme, a paired t-test for dependent measures were done, comparing their pre- and post-Harrison’s Recovery Test scores. Figure 23 shows the results of the paired t-test comparing the pre- and post-Harrison’s Recovery Test scores of the intervention group. There was a statistically significant difference between the pre- and the post-test scores for the Harrison’s Recovery Test of the intervention group ($p < .001$). Therefore, it can be concluded that the intervention group’s proprioception, as measured with the Harrison’s Recovery Test improved statistically significantly following an eight-week proprioceptive training programme.

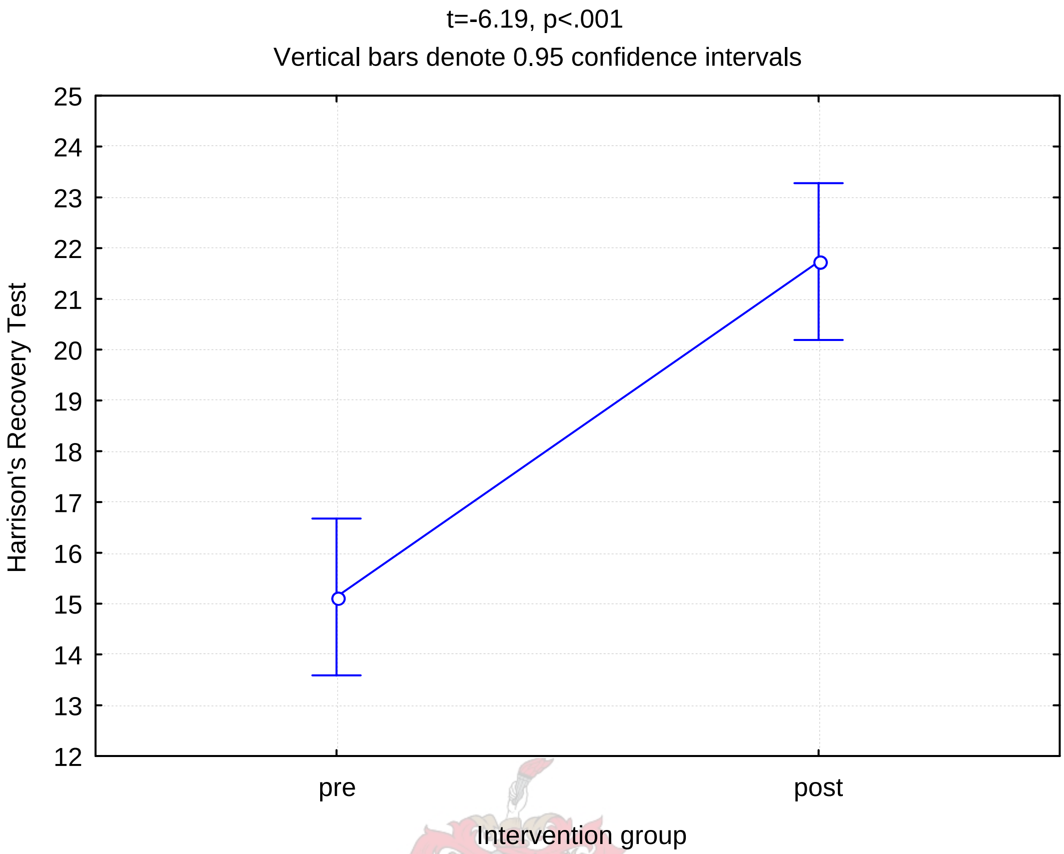

Figure 23

Comparison between the pre- and the post-test scores of the Harrison’s Recovery Test of the intervention group.

Correlation between Proprioception and Age

To examine the extent to which proprioception as measured by Harrison’s Recovery Test and age are related, a Pearson’s product moment correlation coefficient was applied. The baseline Harrison’s Recovery Test scores as well as the age of all the participants (N=25) was used for this. Figure 24 graphically presents a scatter plot the correlation as well as the regression line between the subject’s proprioception and their age. Figure 24 indicates there is a very weak positive correlation between the subjects’ proprioception and their age (r = .25). This is an interesting finding, because it would be expected that a negative correlation between age and proprioception would be found (the older the individual, the lower the score on the test). As mentioned when discussing the correlation between functional balance and age, the present study used a small sample that was not chosen at random. This could affect the validity of the results. The literature also indicated that proprioception improves with physical activity. Because the sample used in this study consisted of volunteers who may be more activity than many of their peers, it is possible that they also have above average proprioception. The literature clearly indicates that proprioception decreases with an increase in age. It is also important to remember that the Harrison’s Recovery Test used to assess proprioception is very subjective. This could also influence the reliability of the results.

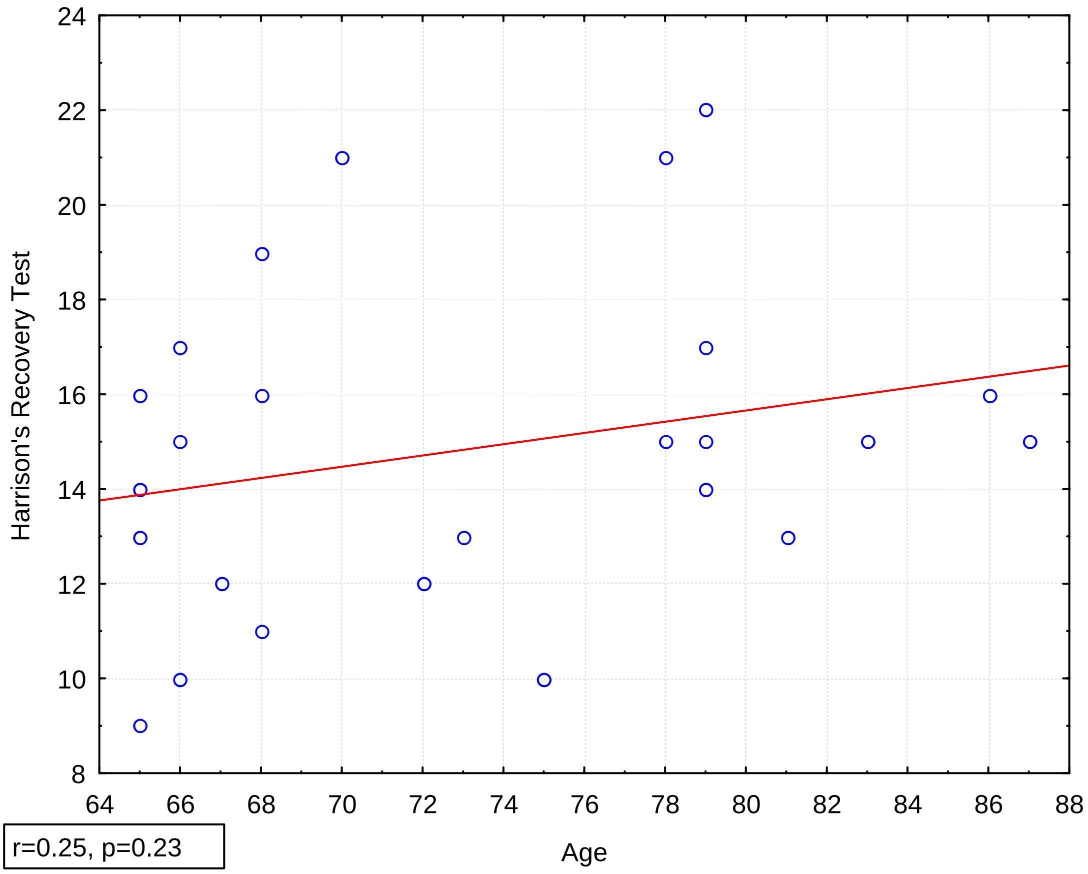

Figure 24

A graphic display of the correlation and the regression line between the pre-test scores on the Harrison’s Recovery Test scores and their age (N=25).

Background Sketches of Subjects in the Intervention Group

This section contains a short summary of each participant in the intervention group and general notes on their reaction to the training programme. It is provided to give a background to the presentation of data and insight into the variety of factors that influence the movement performance of older adults. The individual's scores on Harrison's Recovery Test (HRT) and the Berg Balance Scale (BBS) are provided.

Sketch 1

Age: 66

Medical conditions: Hypertension
Diabetes

Blood pressure: 152/68mmHg (Sitting)
160/64mmHg (Standing)

Test-scores: HRT1: 17 HRT2: 21
BBS1: 51 BBS2: 56

Activity levels: He/she has never participated in organized activity in his/her life, but is active through housekeeping. He/she frequently goes for walks. He/she cares for his/her son, who lost his/her vision and was disabled in a motorcycle accident about two years ago.

General: He/she enjoyed the exercises thoroughly. The researcher perceived increases in his/her self-confidence and self-efficacy and he/she reported an increased feeling of well being. This was the first time in his/her life that he/she participated in organized activity, therefore it might be possible that he/she gained even more psychological advantage than his/her peers who were used to participating in sports. The fact that he/she is socially very limited and that he/she has to look after his/her son could also have increased the psychological effect of the programme.

Sketch 2

Age: 81

Medical conditions: None

Blood pressure: 110/60mmHg (Sitting)
110/62mmHg (Standing)

Test results: HRT1: 13 HRT2: 23
BBS1: 52 BBS2: 52

Activity levels: He/she lives in a flat in an old age home and participates twice a week in the exercise programme that is presented in the old age home by one of the caretakers.

General: He/she appears to be healthy and in good shape. He/she enjoyed the exercises, but did not progress at all in his/her Berg Balance Scale scores. It could be that fear was responsible for this, as he/she did not make progress with many of the exercises. At the end of the programme, he/she could not do any of the exercises unsupported. His/her proprioception, however showed improvement. Another possible reason for the unchanged Berg Balance Scale score is that his/her score of 52 are already a good score for someone his/her age with very light activity levels.

Sketch 3

Age: 83

Medical conditions: Pace maker

Blood pressure: 168/98mmHg (Sitting)
168/110mmHg (Standing)

Test results: HRT1: 15 HRT2: 23
BBS1: 52 BBS2: 52

Activity levels: He/she lives in a room in an old age home and participates twice a week in the old age home’s exercise group.

General: He/she has moderate hypertension, which made his/her a high-risk subject. Special care was taken with the upper extremity exercises as these type of exercises can increase the blood pressure. The original Rate of Perceived Exertion (RPE) scale was also used frequently to monitor his/her level of exertion and make sure that none of the exercises were to taxing. As a precaution, his/her RPE score were kept under 12 (somewhat hard).

Sketch 4

Age:	70	
Medical conditions:	None	
Blood pressure:	112/60mmHg (Sitting) 112/62mmHg (Standing)	
Test results:	HRT1: 21	HRT2: 23
	BBS1: 54	BBS2: 56

Activity levels: He/she does not participate in any organized physical activity, but he/she stays active through cleaning the house and doing gardening as well as going for frequent walks.

General: He/she reported that he/she enjoyed the programme thoroughly and made the most progress of anyone on the programme. In the opinion of the researcher, he/she may have benefited emotionally from the programme as well, because he/she recently moved to a small flat from his/her house where he/she lived for over forty-five years. The Berg Balance Scale might not have been sensitive enough to monitor his/her full progression.

Sketch 5

Age: 65

Medical conditions: High Cholesterol
Obesity
Low back pain
Foot pain

Blood pressure: 126/86mmHg (Sitting)
130/88mmHg (Standing)

Test results: HRT1: 13 HRT2: 19
BBS1: 50 BBS2: 55

Activity levels: He/she is still working as a receptionist for a physiotherapist. He/she does not participate in organized sports, walks infrequently but gardens regularly.

General: Nobody has been able to diagnose the pain in his/her left foot. He/she feels stabbing pains during any weight bearing activity and the foot is swollen and red. This pain definitely influenced proprioception - he/she had a very low score for the Harrison's Recovery Test at the beginning of the study. The low back pain flared up once during the training programme. It subsided after two physiotherapy sessions. The researcher as well as the physiotherapist doubted whether the training programme had anything to do with this flare-up. Both his/her functional balance and proprioception improved significantly following the intervention programme. The participant also reported an increased feeling of well being after the exercise programme.

Sketch 6

Age: 79

Medical conditions: None

Blood pressure: 160/90mmHg (Sitting)
162/90mmHg (Standing)

Test results: HRT1: 22 HRT2: 21
BBS1: 51 BBS2: 54

Activity levels: He/she lives in a small flat in an old age home where he/she still cooks and cleans. He/she is part of the home's exercise group that trains twice a week.

General: Even though he/she did not declare any medical conditions, according to this study's measurement, he/she has mild to moderate hypertension. His/her BBS results improved only slightly while the HRT score decreased slightly. This might be due to the fact that he/she walked into a chair one night on his/her way to the bathroom. He/she did not fall, but he/she did bruise her hip, and as stated in Chapter Two, trauma decreases proprioception.

Sketch 7

Age: 78

Medical conditions: Spondolythesis
Hypertension
Polymialgia
Osteoarthritis
Asthmatic

Blood pressure: 134/88mmHg (Sitting)
138/90mmHg (Standing)

Test results: HRT1: 15 HRT2: 22
BBS1: 51 BBS2: 55

Activity levels: He/she trains twice a week at the Stellenbosch Biokinetics Center, and he/she goes for a walk at least once a week.

General: He/she had a severe fall in December 2000, where he/she broke his/her arm and due to heart failure during the operation was in ICU for two weeks. It took him/her until April, 2001, to get his/her strength back, and to be able to participate his/her Biokinetics sessions again. This may the reason for the weak proprioception at the beginning of the study. Following the programme, proprioception increased considerably.

Sketch 8

Age:	68	
Medical conditions:	None	
Blood pressure:	104/70mmHg (Sitting) 110/80mmHg (Standing)	
Test results:	HRT1: 11	HRT2: 23
	BBS1: 52	BBS2: 55

Activity levels: He/she lives in a room in the old age home, and is part of the exercise group that trains twice a week.

General: This subject had poor proprioception at the beginning of the study. He/she responded well to the programme and her proprioception improved rapidly. The researcher noticed two things about the participant: First, he/she was by far the strongest of all the participants, and second, he/she had very poor flexibility. His/her strength may explain why his/her functional balance score was so high in the beginning of the programme, even though his/her proprioception was weak. The poor flexibility may be why he/she did not score full marks for his/her proprioception test after the training programme. This highlights a very important point: one cannot consider only one or two specific factors when working with older people - one has to look and treat a person as a whole.

Sketch 9

Age: 72

Medical conditions: High Cholesterol (in her legs)

Blood pressure: 130/72mmHg (Sitting)
136/76mmHg (Standing)

Test results: HRT1: 12 HRT2: 20
BBS1: 52 BBS2: 55

Activity levels: He/she plays tennis twice a week, and walks and gardens regularly. He/she can only walk for about 12 minutes, then his/her legs hurt badly as a result of the decreased blood flow due to the high cholesterol.

General: The programme had to be adapted a bit for this participant because of his/her cholesterol problem. He/she started out by doing three sets of 20 seconds on all of the balancing exercises, switching legs after every set, and giving the legs a rest. This was then increased to two sets of 30 seconds for each leg. The upper extremity and trunk exercises were also rotated so that the legs were used only every second exercise.

Sketch 10

Age: 86

Medical conditions: Hypertension
Severe osteoarthritis in her knees

Blood pressure: 164/90mmHg (Sitting)
158/90mmHg (Standing)

Test results: HRT1: 16 HRT2: 22
BBS1: 48 BBS2: 43

Activity levels: He/she lives in a room in the old age home and is part of the exercise group, training twice a week.

General: He/she is unable to kneel on all fours due to very bad osteoarthritis in the knees, therefore the programme was adapted by inserting one of the progressions for the therapeutic ball and leaving the standing on all fours. He/she fell over a chair a week before the final assessment, and even though he/she did not fracture anything, he/she got hurt badly. This fall also heightened his/her fear of falling. According to Rose and Clark (2000), a heightened fear of falling is often accompanied by a loss of confidence and self-efficacy in the person's ability to perform routine activities associated with daily life. This may be why his/her post-test scores were actually worse that the pre-test scores on the Berg Balance Scale, even though his/her proprioception increased. Another thing to keep in mind is the age of the participant. One of the members in the control group, who was one year older than he/she is, also showed large decreases in the Berg Balance Scale scores, from 39 to 34, over the eight-week period. So it is possible that it was not only the fall, but also a tendency of the functional balance of "older" older adults to decrease despite interventions.

Sketch 11

Age: 79

Medical conditions: Type II Diabetes
3xCardiac bypasses
Gullian Barré Syndrome

Blood pressure: 104/56mmHg (Sitting)
100/54mmHg (Standing)

Test results: HRT1: 14 HRT2: 24
BBS1: 42 BBS2: 50

Activity levels: He/she led a very passive life until he/she had Gullian Barré Syndrome in the beginning of 2000. The disease left him/her paralysed for two months. He/she became a patient at the Stellenbosch Biokinetics Center in June, 2000. At this time he/she was still in a wheelchair. Since June, 2000, he/she trained three times a week at the center, where his/her programme has concentrated on strengthening of the muscles and increasing his/her flexibility.

General: September, 2000, he/she has been able to walk short distances (about 10 paces) with support. He/she has very gradually gained strength, and his/her stamina has slowly increased. He/she progressed rapidly up to April, 2001, when his/her progression started to level off. In August, 2001, he/she began the intervention programme in this study as a supplement to his/her programme at the biokinetics center. Not only did he/she improve in his/her post-test performance, but he/she also started to move with more ease than before the proprioceptive training programme. He/she also reported feeling more comfortable and steady during ambulation. Even though it was not measured, there appeared to be a reduction in his/her normal postural sway. When he/she started on the programme, his/her postural sway was exaggerated. The intervention programme also appeared to help the flexibility in his/her joints, which was something that he/she has struggled with since his/her illness.

Sketch 12

Age: 79

Medical conditions: Depression
Hypertension

Blood pressure: 160/98mmHg (Sitting)
188/110mmHg (Standing)

Test results: HRT1: 15 HRT2: 21
BBS1: 51 BBS2: 53

Activity levels: He/she helps caring for his/her partner, who has Gullian Barré Syndrome. He/she does all of the house keeping and gardening self.

General: The results showed increases in both functional balance and proprioception levels after the training programme.

Sketch 13

Age: 78

Medical conditions: Hypertension
Asthmatic
Skin cancer

Blood pressure: 140/90mmHg (Sitting)
152/92mmHg (Standing)

Test results: HRT1: 21 HRT2: 25
BBS1: 51 BBS2: 56

Activity levels: He/she has been active all his/her life, and has been a patient at the Stellenbosch Biokinetics Center for over six years, where he/she trains three times a week.

General: He/she progressed quickly through the programme, and reported that he/she enjoyed doing different exercises for a change. Although he/she was fit, strong, and supple for his/her age when he/she started on the intervention programme, he/she could only achieved 51 out of 56 points on the Berg Balance Scale. After the completion of the programme he/she achieved full marks for this test. This indicates that proprioceptive training should be included as part of the general conditioning programme of the older adult. For six years he/she has already participated in a programme consisting of endurance, strength and flexibility exercises for the whole body. Only after including exercises specifically for the proprioceptive component, did he/she optimize his/her performance on the test of functional balance.

Sketch 14

Age: 75

Medical conditions: Alzheimer’s disease

Blood pressure: 128/80mmHg (Sitting)
122/84mmHg (Standing)

Test results: HRT1: 10 HRT2: 20
BBS1: 46 BBS2: 53

Activity levels: He/she is a day visitor at the old age home and participates in the training sessions twice a week.

General: He/she had the largest improvement in the results of her Berg Balance Scale scores of all subjects in this study. In the opinion of the researcher, he/she has an undiagnosed balance problem. For the duration of the programme, he/she stumbled and tripped frequently, although stumbling and tripping decreased towards the end of the intervention programme. This may have been due to the training leading to an improvement in her balance control. Her proprioception score also increased considerably following the intervention programme.

Sketch 15

Age: 67

Medical conditions: None

Blood pressure: 152/90mmHg (Sitting)
140/88mmHg (Standing)

Test results: HRT1: 12 HRT2: 19
BBS1: 51 BBS2: 55

Activity levels: He/she is a gardener of occupation and walks 10km a day to and from work. He/she is the most physically fit of all the participants.

General: It was surprising that his/her proprioception score was so low in the beginning of the study, because he/she is relatively young and quite active and the literature indicates that proprioception improves with physical activity. He/she reacted well to the programme and showed good improvements in the scores on both tests.

Reliability of the results

As mentioned in chapter three, a post-post test was done on five of the participants of the intervention group in order to assess the reliability of the tests used in the present study. If a measure is reliable, the results obtained from its use by different raters (inter-rater reliability) and at different points in time by the same rater (intra-rater reliability) will be similar, assuming there have been no actual changes in the phenomena being studied (Berg, 1989). An intra-rater reliability has been used for the purposes of the present study, comparing the results of the post-test, with the results of the post-post test. Reliability refers to the reproducibility and consistency of the results.

A Pearson's correlation coefficient was done to determine the reproducibility of the test results. As shown in Figure 25 there is a strong correlation between the post-test scores of the Berg Balance Scale and the post-post test results of the Berg Balance Scale (r = .95). Therefore it could be concluded that the results of the Berg Balance Scale is reproducible and consistent, which means that it could be assumed that the Berg Balance Scale is a reliable test.

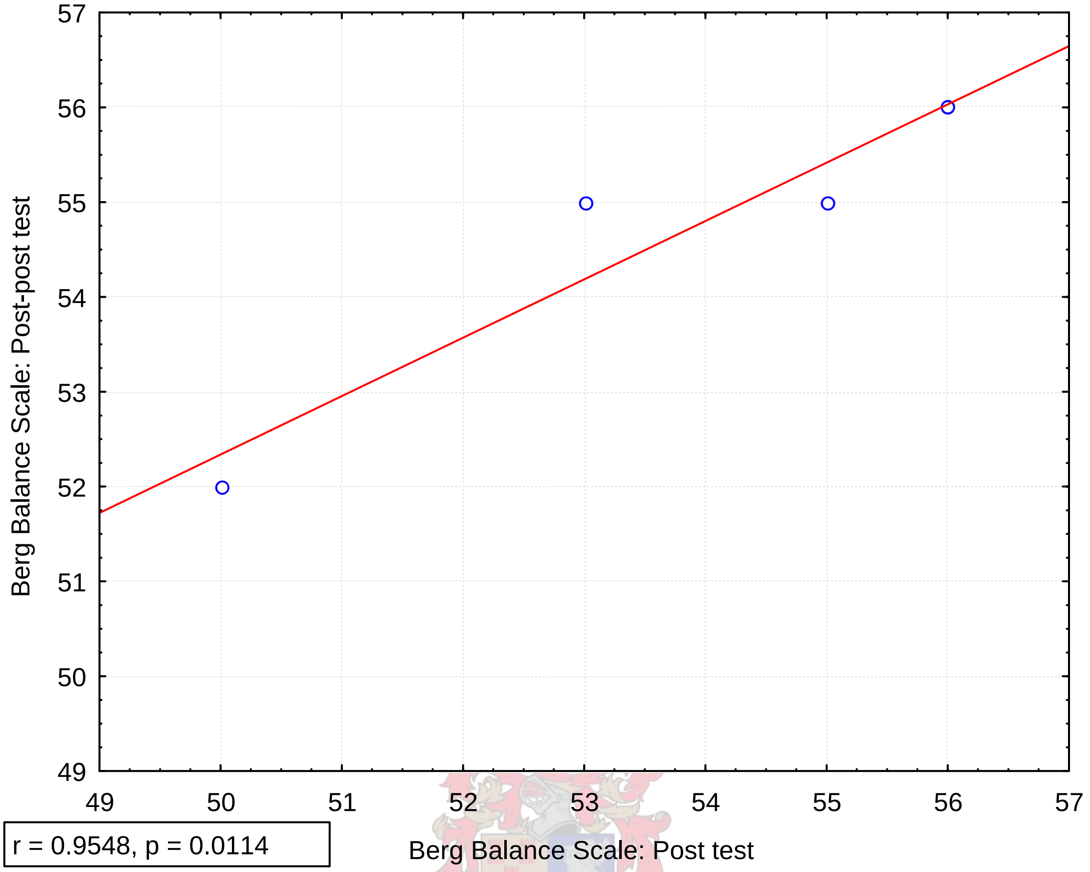

Figure 25

Scatter plot and regression line of the results of the post-test and post-post of the Berg Balance Scale.

Figure 26 is a graphic illustration of the results of the Pearson's correlation coefficient comparing the results of the post-test and post-post test of the Harrison's Recovery Test. This figure indicates that the correlation between the post-test and the post-post test results of the Harrison's Recovery Test have a fair correlation (r = .38). This correlation is much weaker than that of the Berg Balance Scale. This was expected as the Harrison's Recovery Test relies on a lot of factors that is very variable, for example the speed that the tester move the subject's limb. As stated in Chapter two, proprioception is better for faster joint motions than slow ones. To move all the limbs of all the subjects at the same speed is impossible, unless expensive technological equipment is used. It was one of the aims of this study to develop a programme that only relies on low technology equipment. Other factors like the cutaneous information that the subject receives from the tester's touch is also hard to regulate or eliminate. Then lastly the Harrison's Recovery Test is extremely subjective, as one has to "guess" factors such as joint angles etc. All of these factors will affect the reliability of the Harrison's Recovery Test.

It is possible though that the magnitude of the improvements in the results of the Harrison's Recovery Test after the intervention programme as compared to before the programme is large enough to enable one to conclude that the participant's proprioception did indeed improve significantly after the intervention programme. The exact improvement might just not be illustrated through the test results, it is just an indication of the improvement.

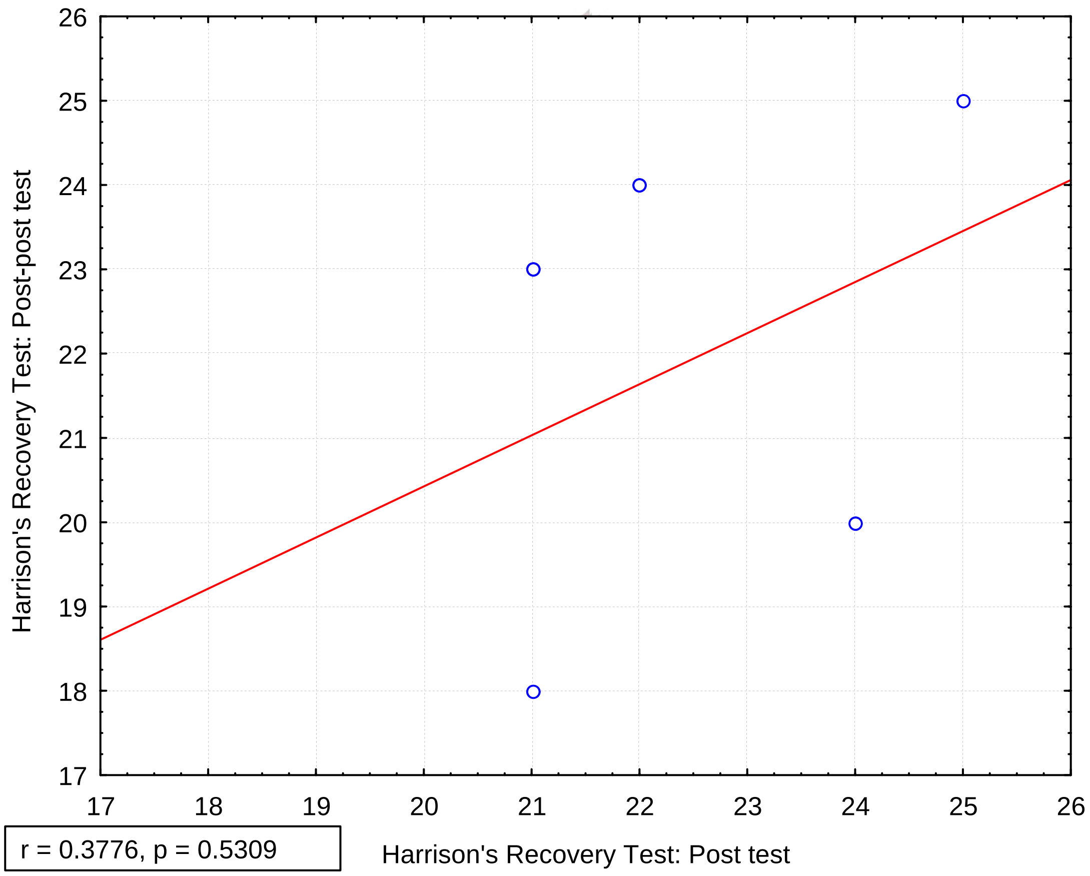

Figure 26
Scatter plot and regression line of the results of the post-test and post-post of the Harrison's Recovery Test.

Conclusion

The statistical analysis of the data supports a positive answer to both of the research questions. The performance of the intervention group in terms of their functional balancing activities was positively enhanced after participation in the proprioceptive training programme. The ability to transfer, to pick up objects, to assume a reduced base of support, and to engage in dynamic weight shifting activities are examples of the types of functional balancing tasks that were significantly improved during the intervention programme.

In summary, the findings of this study suggest that proprioceptive training programmes of relatively short duration can have a positive effect on one's control of bodily orientation. Therefore, proprioceptive training can be used to improve an older adult's ability to control his/her bodily orientation in daily task environments, and therefore help maintain or increase his/her independence. As said previously, increased independence would increase one's quality of life, as you are able to do what you want and do not need to wait around for someone to come and help you. When considering the status of the staff in the old age homes in South Africa it is especially important.

Chapter Five

Conclusions and Recommendations

The previous chapter presented data to illustrate that the proprioceptive training programme presented in this study helped participants achieve significant improvements in their ability to perform functional activities, such as sit-to-stand, transfers, and obstacle retrieval.

Conclusions

In previous studies using computerized balance-training systems, improvements have been achieved in various dimensions of postural control, e.g. standing sway. Of these studies, only one (Rose & Clark, 2000), has investigated the whether the improvements observed in postural control due to balance training, could be positively transferred to the performance of functional daily activities. They presented an eight-week biofeedback-based, computerized intervention consisting of balance training exercises to rehabilitate older adults with a history of falling. They concluded that their programme could significantly improve the control of bodily orientation of older adults in static and dynamic environments. They found significant improvements in the functional performance of the intervention group. They also stated that interventions emphasizing task-specific practice are not the only means by which older adults can improve their ability to perform daily activities. They concluded with the following statement:

> Whether improvements of the magnitude observed in the present study can be achieved in the same period of time without the use of the technology available to conduct this particular intervention, remains to be determined (Rose & Clark, 2000:282).

The proprioceptive programme implemented in this study used only low technology equipment and the success of the programme answers the Rose and Clark (2000) question - yes, training without technology can be effectively used to improve the functional balance of older adults. The proprioceptive training programme in this study relied only on simple equipment such as balance boards and foam pads. This means that there are inexpensive methods that can be used to implement training programmes for older adults.

The Training Programme

Different kinds of training, including balance training, resistance training, and transfer and gait training, are all relatively inexpensive interventions that help prevent dependence and dysfunction in older adults (Hirsch, Rider, Toole & Hirsch, 1998). The programme followed in this study took into account the following considerations:

- The deterioration in the balance control abilities of older adults can be improved through repeated exposure to certain balance tasks. Several researchers have investigated and found support for this statement (Tang & Woollacott, 1996).

- If an individual's daily routine contains certain balance challenges, training to gain confidence in meeting these challenges should replicate as many of these challenges as possible (Masdeu et al. 1997).

- Rose and Clark (2000) stated that if manual guidance and feedback are used frequently with older subjects, rapid improvements in skill performance and increased self-confidence would occur. However, they cautioned that both these forms of guidance should be reduced and then removed completely as soon as possible in the learning process. Their reason was that motor learning research has demonstrated when feedback that is provided too often during the acquisition of a skill, will have a negative influence on the final learning of the movement skill.

In the present study, all the subjects were supported initially. This support was reduced gradually to only one-handed support, and then to only a slight touch. When they felt confident, support was removed completely. The subjects in case studies number two and three did not show any improvement in their Berg Balance Scale scores. Both of them had a fear of falling and did not feel confident to reduce their support. This could therefore be a possible reason for the lack of improvement shown in their functional status at the end of the study.

- Hirsch and co-workers (1998) identified lower limb weakness as an independent risk factor for falls. One of the most prominent problems of older adults is muscle weakness. Even healthy fit older adults could struggle with muscle weakness. It is the personal opinion of the researcher that many of the improvements seen after participation in the proprioceptive training programme in this study, were the result of the strength gains in the small muscles surrounding the joints, as a result of the surfaces and the type of exercises included in the intervention programme. This is especially true for the muscles around the ankle joint. The function of these muscles is to stabilize the joint so the person will develop an improved feeling of stability. This might also be the mechanism behind the decrease in standing postural sway that many balance training programmes have reported. This will not only decrease the person's risk of falling, but it will also improve their functional balance.

The results of this study clearly indicate the benefits of proprioceptive training for older adults. It can be recommended with confidence that proprioceptive training should be part of the general training programme of older adults.

Holistic Approach to Exercise Prescription

Following the personal experiences with the older adults in this study, it is the opinion of the researcher that a holistic approach is needed to providing exercise programmes. A training programme following a holistic approach concentrates on the whole person - the body, as well as the mind and the spirit of the individual.

The Body

The results of the present study indicated that a proprioceptive training programme not only improves the proprioception of older adults, but also increases their functional balance. Despite of the positive results of the present study, a proprioceptive training programme as an older adult's only exercise modality is not advised. It is recommended that a proprioceptive training component be implemented as a part of a balanced general conditioning programme that includes endurance, strength, and flexibility components.

In a balanced approach, one trains the person as a whole, which is important because the person ages as a whole. The proprioceptive component was especially important, for example, when considering sketch 13. This subject has participated in exercise all his/her life. He/she has trained at the Stellenbosch Biokinetics Center for the last six years, three times a week. He/she does an individualized exercise programme under the supervision of a biokineticist, intern or student-in-training. His/her exercise programme is adapted every three to four weeks in order to prevent customization and a decrease in the effectiveness of the programme (no adaptations were made to exercise programmes for the duration of the study). His/her programme consists of endurance, strength (for all the large muscle groups) and flexibility components. Even after doing a scientifically designed, individualized general conditioning programme for all this time, his/her baseline score on the Berg Balance Scale was only 51. After the eight weeks of proprioceptive training combined with his/her normal general conditioning programme, he/she achieved a score of 56 points for the Berg Balance Scale. This indicates the need for a proprioceptive component in the exercise programmes of all older adults, and not just for those people who have a problem with falling.

Training programmes for older adults should include cardiovascular, strength, endurance and flexibility components as well. As these components are essential for the maintenance of all the different sub-systems in the body like the cardiovascular and pulmonary systems. It is important to treat the person as a whole and not just the symptoms or the problem. For example, in sketch number 8, this subject had poor flexibility and no matter how much her proprioception and balance improves, her flexibility will still create a deficit in her functional balance.

The Mind

It is possible that proprioceptive exercises can stimulate the individual's mind, because there must be attention and concentration when performing the exercises. This is especially true where the content of the programme follows an increasingly challenging progression, as was the case in the present study.

Another mental aspect includes that of transfer of skills. A person has the ability to transfer what he/she has learned across different practice conditions and movement skills. Progressive changes in the task and environmental constraints throughout the intervention forces the participant to adapt to the changing conditions, while investigating different ways of solving movement problems. Through varying the practice environment in these ways, cognitive effort is needed. This leads to significantly better retention of movement skills (Lee, Swinnen & Serrien, 1994).

The Spirit

Enjoyment is a very important factor for exercise adherence. This is definitely applicable when working with older adults. Some of them also seek the social contact of the exercise session more than the physical activity. The subjective information gathered from the subjects in this study revealed they gained experienced gains in self-efficacy, confidence, and morale.

Falling and Fear of Falling

Virtually all studies dealing with balance and older adults have shown an increasing risk of falling with increasing age (Downton, 1996). The rationale for exercise in preventing falls and frailty are based upon the following: Exercise improves physiological function, which improves functional status, which reduces the risk of falls (Buchner et al. 1993). Even though the training programme of the present study was not specifically aimed at decreasing risk of falling among the subjects, falling cannot be ignored all together.

Falling

The rationale behind the development of a training programme to improve the functional balance of older adults is that as their functional balance improve, they will be less prone to falling, would be more independent and would have a higher quality of life. Weak functional balance has frequently been identified as a risk factor for falling in older adults. Therefore, because of the positive effect that proprioceptive training has on functional balance, it can be concluded that proprioceptive training could also decrease the occurrence of falling and risk of falling in this population group.

Exercise interventions aimed at reducing falls in the elderly rest on several important assumptions. One of the most important assumptions is that falling in the elderly is related to poor control of balance and that balance can be improved by practice and exercise (Shupert & Horak, 1999). Therefore it could be concluded that a proprioceptive training programme could be successfully used as a fall prevention measure in older adults.

Psychological Aspects

Prevalence of fear of falling (low confidence) and poor mobility (balance and gait) increase a person’s risk on a fall (Tinetti et al. 1993). There is also a strong relationship between increased number of impairments and increased prevalence of falls, low confidence and immobility. This supports the need for a comprehensive strategy to help reduce the risk of falls in the elderly.

According to Downton (1996) many elderly express a fear of falling, and this fear of falling may be present even if no falls have actually occurred. Fear of falling can have major effects on the subject's quality of life, and may even produce an inability to walk. Falls and fear of falling also lead old people to restrict their activity, or to their activity being restricted by care-givers. Spirduso (1995) found that older adults who had a fear of falling performed significantly less well in blindfolded, spontaneous-sway tests and in eyes-open, one-legged balance test. Many professionals strongly believe that a fear of falling contributes to a "stiffening" of the body due to the unnecessary contraction of muscles, which changes adjustment patterns when walking and contributes to the loss of balance.

An experience of falling leads to a heightened fear of falling, which is accompanied by a loss of confidence or self-efficacy in one's ability to perform routine activities associated with daily life. This in turn often leads to a self-imposed reduction in the level of physical and social activities enjoyed, resulting in physical deconditioning and increased social isolation. This increases the person's fear of falling even more, and leads to more immobility. Sketch 10 had a fall during the time of the intervention programme. This fall significantly decreased his/her post-Berg Balance Scale scores.

Self-efficacy refers to the amount of confidence a person has in his/her ability to perform specific tasks or activities. Personal experience as well as verbal persuasion influence self-efficacy (Tinetti et al. 1993). A sense of personal control is vital to both physical and psychological health and, as individuals age, the accompanying deterioration in function and the restriction in performance of activities of daily living serve to reduce their sense of control. In the physical activity and aging literature, this sense of control in older adults has been broadly demonstrated to influence and be influenced by physical activity. These relationships hold for both healthy and clinical populations. Relative to non-clinical populations, self-efficacy has been consistently identified as a determinant of exercise behavior in older individuals.

Factors like improved self-confidence, improved vigor, and a more positive outlook on life were among the things that were reported by the participants in this study during self-reports. Several researchers stated that promoting physical functioning should lead to increased confidence and a reduced fear of falling (Perrin et al., 1999; Snow, 1999). Most of the subjects reported a reduced fear of falling as the training programme progressed. According to the presenter of the intervention programme and the results of the test battery, the participants moved with greater ease and more confidence after their participation in the intervention programme.

The exact contribution the improved proprioception of the participants played in their improved functional balance cannot be identified. As stated above, the intervention programme appeared to have a positive psychological effect on the participants, therefore it is possible that it was the psychological effects rather than the improved proprioception that led to improvements in the performance of functional balance. A further study including a psychological measure in the test-battery might be able to quantify these psychological changes and give clarity on this matter.

Recommendations

In view of the conclusions drawn as a result of the investigation, the following recommendations are made.

1. The number of subjects of the present study was a limitation. The data collected is insufficient to generate conclusive results. A similar study with more subjects, additional criteria (such as current activity levels, no cognitive impairments etc.), and a sample chosen at random would be needed to confirm the results of the present study.

2. There still are a lot of unanswered questions about the role of exercise in preventing falls, and in particular whether certain exercise modalities produce greater health effects than other. Comparing a proprioceptive training programme to a general conditioning programme (containing a strength, endurance, and flexibility component), and a general conditioning programme containing a proprioceptive training component as well, could provide more insight into the best kinds of exercise programmes for the elderly.

3. The long-term benefits of proprioceptive training programmes needs further study. The optimal frequency, intensity and duration of the programme, for example, still need to be established.

4. The Timed Up and Go test could have been added to the test-battery in order to add a measure of functional mobility. This test not only measures mobility (the Berg Balance Scale focuses more on functional balance activities than on the person’s mobility), but it is also more sensitive to change as it measures in seconds, and not on a rating scale.

5. To increase the sensitivity of the Berg Balance Scale, it would have been helpful to write down the actual distances and amount of time that the subjects achieved in the different sections of the scale. For example, for stool touches, the subject may have taken 18 seconds to complete the eight touches at baseline testing and only 14 seconds to complete it during the post-test. A score of four would be awarded in both these instances, but it is clear that the person did improve, even though the Berg Balance Score did not indicate it. This might be a way to make the Berg Balance Scale more sensitive to changes in performance.

The lack of sensitivity in the Berg Balance Scale is a problem. In this study, the mean for the baseline Berg Balance Scale tests for the intervention group was 50.27 (SD=2.94). This does not leave too much space for improvement, as the highest possible score is only 56. When scales are to be used for evaluating changes in patient status over time, it is of particular importance to determine how responsive the scale is to clinically significant changes in patient status.

6. The amount of sensory cues generated by the touch of the test-administrator, is a problem with the proprioceptive measure. Although the contribution of skin receptors to joint position sense remains unclear, there is experimental evidence suggesting that skin receptors may play an important role in joint position sense (LaRiviere & Osternig, 1994).

7. A study where objective rather than subjective measures of proprioception are used might be considered to enable us to precisely determine to what extent proprioception of the older adult increases with training. It might be possible to draw up normative tables for proprioception.

8. It is recommended that a holistic approach be followed when prescribing exercises. This is very important when prescribing exercises for older adults. When it comes to generic exercise prescription, care must be taken when establishing the type, intensity, duration and frequency of the exercise, as this is a population with a wide range of health and fitness levels. The exercise modality should not impose too much orthopedic stress; it should be accessible, convenient, and enjoyable to the participant. The intensity must be sufficient to stress the cardiovascular, pulmonary, and musculoskeletal systems without overtaxing them. When working with older adults, it is recommended to increase the exercise duration rather than the intensity at first. It is also recommended to alternate between days that involve primarily weight-bearing and non-weight-

bearing exercises. Exercise sessions lasting longer than 60 minutes may have a detrimental effect on exercise adherence in the older adult. These guidelines for training the older adult are provided by The American College of Sports Medicine (ACSM, 1995).

Final Remarks

> Most individuals hope that they have a quantitatively long life span, they may not want a long life if the quality of that life is poor. Being physically independent and having the capacity to be active plays a large role in defining quality of life for all older individuals (Spirduso, 1995:331).

The present study used a proprioceptive training programme to improve the functional balance of older adults. The basis of the study was that older adults have a problem with functional balance, and that by improving their proprioception, their functional balance will improve. This improvement in functional balance will then bring about an increase in functional skills, an increase in functional skills will help one to live more independently. The problem older adults have with their functional skills and therefore their functional balance needs to be addressed, because if one can become less dependent on others, you will increase your quality of life. Proprioceptive training was used as the intervention because the literature indicates clearly that both functional balance and proprioception decline with aging. Therefore it was hypothesized that if one’s proprioception improved, there could be an improvement in functional balance as well.

A proprioceptive training programme was used as intervention modality for the following reasons. Spirduso (1995) stated that as locomotion and basic mechanisms of balance deteriorate, older people have to focus more attention on formerly automatic processes to compensate for the loss of feedback and neuromuscular integration. One would expect a proprioceptive training programme to improve this loss of feedback and neuromuscular integration and thereby decrease the amount of attention that shifts towards automatic processes with aging. Perrin et al. (1999) supported this with their conclusions that participation in physical and sporting activities decreases the individual’s dependency upon visual input. They suggested that a possible reason for this might be the better use of somatosensory inputs through physical and sporting activity practice and improved balance control.

Postural sway increases with age due both to strength loss of the ankle dorsiflexor muscles and to decreasing tactile sensitivity, joint position sense and proprioception. Proprioception and sensory input from the plantar surface of the feet have been reported to be the most important sensorial system for maintaining balance. As most forms of ambulation are dependent on one's ability to balance on one leg, improving proprioception will improve the most important sensorial system for maintaining balance. Conscious awareness of joint motion and position in the knee is essential for placement of the lower extremity during ambulation, while preparatory and reflexive muscle activation provide necessary dynamic stabilization for joint protection (Swanik et al. 2000).

This intervention programme used in this study focussed on improving the performance of specific daily activities (e.g. transfers; stair climbing; object retrieval) as well as performing a variety of dynamic movements in conditions of altered support surfaces and sensory inputs. This intervention was designed to progressively challenge, but not exceed, the capabilities of each individual participant. Rose and Clark (2000) identified these factors as important for the success of a balance training intervention programme. This study complements the Rose and Clark (2000) study because it demonstrate that the use of balance training can result in significant improvements in the abilities of older adults to perform functional activities associated with daily living. This is, however, the first study to demonstrate that this can be done without the use of expensive technological balance training systems, but rather with inexpensive equipment in any facility.

References

AMERICAN COLLEGE OF SPORTS MEDICINE (1995). *Resource manual for guidelines for exercise testing and prescription, 5th edition.* Philadelphia: Lea & Febiger.

ALLEN, A.A. (2000). Neuromuscular contributions to normal shoulder joint kinematics. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 109-115). Champaign Illinois: McGraw-Hill.

AKIMA, H.; KANO, Y.; ENOMOTO, Y; ISHIZU, M.; OKADA, M.; OISHI, Y.; KATSUTA, S. & KUNO, S. (2001). Muscle function in 164 men and women aged 20-84 yr. *Medicine and Science in Sports and Exercise,* 33(2): 220-226.

ASHTON-MILLER, J.A. (2000). Proprioceptive thresholds at the ankle: Implications for the prevention of ligament injury. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 279-291). Champaign Illinois: McGraw-Hill.

BARRACK, R.L.; LUND, P.J. & SKINNER, H.B. (1994). Knee joint proprioception revisited. *Journal of Sports Medicine,* 3(1): 18-43.

BARRACK, R.L. & MUNN, B.G. (2000). Effects of knee ligament injury and reconstruction on proprioception. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 197-213). Champaign Illinois: McGraw-Hill.

BARRACK, R.L.; SKINNER, H.B. & BUCKLEY, S.L. (1989). Proprioception in the anterior cruciate deficient knee. *American Journal of Sports Medicine,* 17(1): 1-6.

BEARD, D. & REFSHAUGE, K. (2000). Effects of ACL reconstruction on proprioception and neuromuscular performance. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 213-225). Champaign Illinois: McGraw-Hill.

BERG, K. (1989). Balance and its measure in the elderly: a review. *Physiotherapy Canada,* 41(5): 240-245.

BERG, K.; WOOD-DAUPHINéE, S.; WILLIAMS, J.I. & GAYTON, D. (1989). Measuring balance in the elderly: preliminary development of an instrument. *Physiotherapy Canada,* 41(6): 304-311.

BEYNN0N, B.D.; RENSTRöM, P.A.; KONRADSEN, L.; ELMQVIST, L.G.; GOTTLIEB, D. & DIRKS, M. (2000). Validation of techniques to measure knee proprioception. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 127-139). Champaign Illinois: McGraw-Hill.

BIEDERT, R.M. (2000). Contribution of the three levels of nervous system motor control: Spinal cord, lower brain, and cerebral cortex. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 23-31). Champaign Illinois: McGraw-Hill.

BODEN, B.P.; GRIFFIN, L.Y. & GARRETT, W.E (2000). Etiology and Prevention of noncontact ACL injury. *The Physician and Sports medicine*, 28(4): 53-60.

BORSA, P.A.; LEPHART, S.M.; KOCHER, M.S. & LEPHART, S.P. (1994). Functional assessment and rehabilitation of shoulder proprioception for glenohumeral instability. *Journal of Sport Rehabilitation,* 3(1): 68-84.

BORSA, P.A.; LEPHART, S.M.; IRRGANG, M.S.; SAFRAN, M.R. & FU, F.H. (1997). The effects of joint proprioception and direction of joint motion on proprioceptive sensibility in anterior cruciate ligament deficient athletes. *The American Journal of Sports Medicine,* 25(3): 336-340.

BRINDLE T.J.; NYLAND, J.; SHAPIRO, R.; CABORN, D. & STINE, R. (1999). Shoulder proprioception: latent muscle reaction times. *Medicine & Science in Sports & Exercise,* 31(10): 1394-1398.

BUCHNER, D.M.; CRESS, M.E.; WAGNER, E.H.; DE LATEUR, B.J.; PRICE, R. & ABRASS, I.B. (1993). The Seattle FICSIT/MoveIt study: The effect of exercise on gait and balance in older adults. *Journal of the American Geriatrics Society,* 41(1):321-325.

BUTLER, M.; NORTON, R.; LEE-JOE, T.; CHENG, A. & CAMPBELL, A.J. (1996). The risks of hip fracture in older people from private homes and institutions. *Age and Aging,* 25(11): 381-385.

CAMPBELL, A.F.; ROBERTSON, M.C.; GARDNER, M.M.; NORTON, R.N.; TILYARD, M.W. & BUCHNER, D.M. (1997). Randomised controlled trial of a general practice programme of home based exercise to prevent falls in elderly women. *Brittish Medicine Journal,* 315(10): 1065-1069.

CHENG, J. (1999). Tai Chi Chuan: A slow dance to health. *The Physician and Sportsmedicine,* 27(6): 109-110.

CHRISTMAS, C. & ANDERSEN, R.A. (2000). Exercise and older patients: Guidelines for the clinician. *Journal of the American Geriatrics Society,* 48(3): 318-324.

CLOSE, J.; ELLIS, M.; HOOPER, R.; GLUCKSMAN, E.; JACKSON, S. & SWIFT, C. (1999). Prevention of falls in the elderly trial (PROFET): a randomised controlled trial. *The Lancet,* 353(1): 93-96.

DALEY, M.J. & SPINKS, W.L. (2000). Exercise, mobility and aging. *Sports Medicine,* 29(1): 1-12.

DE VRIES, H.A. & HOUSH, T.J. (1994). *Physiology of exercise: For physical education, athletics and exercise science, 5th Edition.* Boston, Massachusetts: WCB/McGraw-Hill.

DOWNTON, J.H. (1996). Falls in the elderly: a clinical view. In A.M. Bronstein; T. Brandt & M.H. Woollacott (Eds), *Clinical disorders of balance, posture, and gait* (pp. 326-343). The bath press: Bath.

DYE, S.F. (2000). Functional anatomy of the cerebellum. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 31-37). Champaign Illinois: McGraw-Hill.

FIATARONE, M.A.; O'NEILL, E.F.; DOYLE, N.; CLEMENTS, K.; ROBERTS, S.B.; KEHAYIAS, J.J.; LIPSITZ, L. & EVANS, W. (1993). The Boston FICSIT study: The effects of resistance training and nutritional supplementation on physical frailty in the oldest old. *Journal of the American Geriatrics Society,* 41(1); 333-337.

FITZGERALD, G.K.; AXE, M.J. & SNYDER-MACKLER, L. (2000). The efficacy of perturbation training in nonoperative anterior cruciate ligament rehabilitation programs for physically active individuals. *Physical Therapy,* 80(2): 128-140.

FRANK, J.S.; WINTER, D.A. & CRAIK, R.L. (1996). Gait disorders and falls in the elderly. In A.M. Bronstein; T. Brandt & M.H. Woollacott (Eds), *Clinical disorders of balance, posture, and gait* (pp. 287-301). The bath press: Bath.

FREEMAN, M.A.R. (1965). Co-ordination exercises in the treatment of functional instability of the foot. *Physiotherapy,* 51(2): 393-395.

GANDEVIA, S.C.; HALL, L.A.; McCLOSKEY, D.I. & POTTER, E.K. (1983). Proprioceptive sensation at the terminal joint of the middle finger. *Journal of Physiology,* 335(3): 507-517.

GARN, S.N. & NEWTON, R.A. (1988). Kinesthetic awareness in subjects with multiple ankle sprains. *Physical Therapy,* 68(11): 1667-1671.

GAUFFIN, H.; TROPP, H. & ODENRICK, P. (1987). Effect of ankle disk training on postural control in patients with functional instability of the ankle joint. *International Journal of Sports Medicine,* 9(2): 141-144.

GIRALDO, J.L.; FINK. C.; VASSILEV, I.; WARNER, J.J.P. & LEPHART, S.M. (2000). Overview of the neuromuscular control of the shoulder, its status in patients with degenerative joint disease and after shoulder arthroplasty. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 339-347). Champaign Illinois: McGraw-Hill.

GRIGG, P. (1994). Peripheral neural mechanisms in proprioception. *Journal of Sport Rehabilitation,* 3(1): 2-18.

GUYATT, G.H.; SULLIVAN, M.J.; THOMPSON, P.J.; FALLEN, E.L.; PUGSLEY, S.O.; TAYLOR, D.W. & BERMAN, L.B. (1985). The 6-minute walk: a new measure of exercise capacity in patients with chronic heart failure. *Canadian Medicine Association Journal,* 132(4): 919-923.

GUYTON, A. (1996). *Textbook of medical physiology, 9th Edition.* Philadelphia: Saunders, 595.

HAIN, T.C.; FULLER, L.; WEIL, L. & KOTSIAS, J. (1999). Effects of t'ai chi on balance. *Archives Otolaryngol Head and Neck Surgery,* 125(11): 1191-1195.

HALL, L.A. & McCLOSKEY, D.I. (1983). Detections of movements imposed on finger, elbow and shoulder joints. *Journal of Physiology,* 335(3): 519-533.

HARRISON, G.W. "Harrison's Recovery Test: Version 1.0." 19 April 2001. http://www.strokeassessment.com.

HEWETT, T.E.; LINDENFELD, T.N.; RICCOBENE, J. & NOYES, F.R. (1999). The effect of neuromuscular training on the incidence of knee injury in female athletes. *The American Journal of Sports Medicine,* 27(6): 699-705.

HIRSCH, M.A.; RIDER, R.A.; TOOLE, T. & HIRSCH, H.V. (1998). Falls prevention in individuals with Parkinson's disease: the importance of balance and resistance training. *Palaestra,* 21(3): 15-19.

HORAK, F.B. (1987). Clinical measurement of postural control in adults. *Physical Therapy,* 67(12): 1881-1885.

IHARA, H. & NAKAYAMA, A. (1986). Dynamic joint control training for knee ligament injuries. *American Journal of Sports Medicine,* 14(4): 309-315.

IRRGANG, J.J. & NERI, R. (2000). The rationale for open and closed kinetic chain activities for restoration of proprioception and neuromuscular control following injury. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 363-375). Champaign Illinois: McGraw-Hill.

IRRGANG, J.J.; WHITNEY, S.L. & COX, E.D. (1994). Balance and proprioceptive training for rehabilitation of the lower extremity. *Journal of Sport Rehabilitation,* 3(1): 68-83.

ISHII, Y.; TERAJIMA, K.; TERASHIMA, S. & MATSUEDA, M. (2000). Joint proprioception in the elderly with and without hip fracture. *Journal of Orthopaedic Trauma,* 14(8): 542-545.

JACOBSON, B.H.; HO-CHENG, C.; CASHEL, C. & GUERRERO, L. (1997). The effect of T'ai Chi Chuan training on balance, kinesthetic sense, and strength. *Perceptual and Motor Skills,* 84(1): 27-33.

JEROSCH, J.G. (2000). Effects of shoulder instability on joint proprioception. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 247-265). Champaign Illinois: McGraw-Hill.

JOHANSSON, H.; PEDERSEN, J.; BERGENHEIM, M. & DJUPSJöBACKA, M. (2000). Peripheral afferents of the knee: Their effects on central mechanisms regulating muscle stiffness, joint stability, and proprioception and coordination. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 5-23). Champaign Illinois: McGraw-Hill.

JUDGE, J.O.; LINDSEY, C.; UNDERWOOD, M. & WINSEMUIS, D. (1993). Balance improvements in older women: Effects of exercise training. *Physical Therapy,* 73(4): 254-262.

KAPLAN, F.S.; NIXON, J.E.; REITZ, M.; RINDFLEISH, L. & TUCKER, J. (1985). Age-related changes in proprioception and sensation of joint position. *Acta Orthopaedica Scandinavica,* 56(1): 72-74.

KIELY, D.K.; KIEL, D.P.; BURROWS, A.B. & LIPSITZ, L.A. (2000). Identifying nursing home residents at risk for falling. *Journal of Age Related Disorders,* (5): 13-19.

KIRKENDALL, D.T. & GARRETT, W.E. (1998). The effects of aging and training on skeletal muscle. *The American Journal of Sports Medicine,* 26(4): 598-602.

KOHRT, W.M.; SPINA, R.J.; HOLLOSZY, J.D. & EHSANI, A.A. (1999). Prescribing exercise intensity for older women. *Journal of Age Related Disorders,* (12): 12-16.

KORALEWICZ, L.M. & ENGH, G.A. (2000). Comparison of proprioception in arthritic and age-matched normal knees. *The Journal of Bone and Joint Surgery,* 82-A(11): 1582-1588.

LaRIVIERE, J.J. & OSTERNIG, H.W. (1994). The effect of ice emersion on joint position sense. *Journal of Sport Rehabilitation,* 3(1): 58-67.

LASKOWSKI, E.R.; NEWCOMER-ANEY, K. & SMITH, J. (1997). Refining rehabilitation with proprioception training: Expediting return to play. *The Physician and Sportsmedicine,* 25(10): 433-445.

LAVENTURE, B. (2000). Physical education and the challenge of public health. *The Brittish Journal of Teaching Physical Education,* 20(3): 6-8.

LEE, T.D.; SWINNEN, S.P. & SERRIEN, D.J. (1994). Cognitive effort and motor learning. *Quest*, 46(5): 328:344.

LEPHART, S.M. & HENRY, T.J. (2000). Restoration of proprioception and neuromuscular control of the unstable shoulder. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 405-415). Champaign Illinois: McGraw-Hill.

LEPHART, S.; PINCIVERO, D.; GIRALDO, J. & FU, F. (1997). The role of proprioception in the management and rehabilitation of athletic injuries. *American Journal of Sports Medicine,* 25(1): 130-137.

LEPHART, S.M.; RIEMANN, B.L. & FU, F.H. (2000). Introduction to the sensorimotor system. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. xvii-xxiv). Champaign Illinois: McGraw-Hill.

LIGHT, K.E. (1990). Information processing for motor performance in aging adults. *Physical Therapy,* 70(7): 820-826.

LO, I.K.Y. & FOWLER, P.J. (2000). Surgical considerations related to proprioception and neuromuscular control. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 311-323). Champaign Illinois: McGraw-Hill.

MARTIN, P.E. & GRABINER, M.D. (1999). Aging, exercise, and the predisposition to falling. *Journal of Applied Biomechanics,* 15(1): 52-55.

MASDEU, J.C.; SUDARSKY, L. & WOLFSON, L. (1997*). Gait disorders of aging: Falls and therapeutic strategies.* Philadelphia: Lippincott-Raven Publishers.

MAZZEO, R.S.; CAVANAGH, P.; EVANS, W.J.; FIATARONE, M.; HAGBERG, J.; McAULEY, E. & STARTZELL, J. (1999). Exercise and physical activity for older adults: American College of Sports Medicine Position Stand. *The Physician and Sportsmedicine,* 27(11): 115-142.

McARDLE, W.D.; KATCH, F.I. & KATCH, V.L. (1996). *Exercise Physiology: Energy, Nutrition, and Human performance, 4th edition.* Philadelphia: Lea & Febiger.

MEYER, R.D.; GOGGIN, M.L. & JACKSON, A.W. (1995). A comparison of gripstrength and selected psychomotor performance measures in healthy and frail elderly females. *Research Quarterly for Exercise and Sport,* 66(1): 1-8.

NEWTON, R.A. (1982). Joint receptor contributions to reflexive and kinesthetic responses. *Physical Therapy,* 62(1): 22-29.

NICHOLSON, C.M. (1999). Prescribing exercise for the elderly. *The Journal of Age Related Disorders,* (11): 3-4.

NICKALL, J.J. (1990). *A service centre as a community based support system for senior citizens in Chatty, Port Elizabeth.* Unpublished master's thesis. Port Elizabeth: University of Port Elizabeth.

OCTIFF, J.; GARDNER, C.; ALBRIGHT, J. & POPE, M. (2000). A method for analyzing standing and reactive balance and neuromuscular responses of the spine and lower extremities. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 161-171). Champaign Illinois: McGraw-Hill.

OWINGS, T.M.; PAVOL, M.J.; FOLEY, K.T.; GRABINER, P.C. & GRABINER, M.D. (1999). Exercise: Is it a solution to falls by older adults? *Journal of Applied Biomechanics,* 15(1): 56-63.

PERRIN, P.P.; GAUCHARD, G.C.; PERROT, C. & JEANDEL, C. (1999). Effects of physical and sporting activities on balance control in elderly people. *Brittish Journal of Sports Medicine,* 33(1): 121-126.

PORTER, M.M. (2001). The effects of strength training on sarcopenia. *The Canadian Journal of Applied Physiology,* 26(1): 123-141.

REFSHAUGE, K.M.; KILBREATH, S.L. & RAYMOND, J. (2000). The effect of recurrent ankle inversion sprain and taping on proprioception at the ankle. *Medicine & Science in Sports & Exercise,* 32(1): 10-15.

RENSTRöM, P.A.; KONRADSEN, L. & BEYNNON, B.D. (2000). Influence of knee and ankle support on proprioception and neuromuscular control. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 301-311). Champaign Illinois: McGraw-Hill.

RHODES, R.E.; MARTIN, A.D.; TAUNTON, J.E.; RHODES, E.C.; DONNELLY, M. & ELLIOT, J. (1999). Factors associated with exercise adherence among older adults. *Sports Medicine,* 28(6): 397-411.

RIEMANN, B.L. & GUSKIEWICZ, K.M. (2000). Contribution of the peripheral somatosensory system to balance and postural equilibrium. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 37-53). Champaign Illinois: McGraw-Hill.

RIKLI, R.E. & JONES, C.J. (2001). *Senior fitness test manual.* Champaign Illinois: Human Kinetics.

RINGSBERG, K.; GERDHEM, P.; JOHANSSON, J. & OBRANT, K. (1999). Is there a relationship between balance, gait performance and muscular strength in 75-year-old women? *Age and Aging,* 28(3): 289-293.

ROBERGS, R.A. & ROBERTS, S.O. (1997). *Exercise physiology: Exercise, performance, and clinical applications.* Boston, Massachusetts: WCB/McGraw-Hill.

ROBERGS, R.A. & ROBERTS, S.O. (2000). *Fundamental principles of exercise physiology for fitness, performance, and health.* Boston, Massachusetts: WCB/McGraw-Hill.

ROBERTSON, L. *Fundamentals of balance: How to assess balance and prevent falls.* 26 July 1999. http://www.nursingceu.com/NCEU/courses/balance.html. 4 April 2001.

ROSE, D.J. & CLARK, S. (2000). Can the control of bodily orientation be significantly improved in a group of older adults with a history of falls? *Journal of the American Geriatrics Society,* 48(1): 275-282.

ROUBENOFF, R. (2001). Origins and clinical relevance of sarcopenia. *Canadian Journal of Applied Physiology,* 26(1): 78-89.

SCHMIDT, R.A. & TIMOTHY, D.L. (1999). *Motor control and learning: A behavioral emphasis, 3rd edition.* Champaign Illinois: Human Kinetics.

SHIH, J. (1997). Basic Beijing twenty-four forms of t'ai chi exercise and average velocity of sway. *Perceptual and Motor Skills,* 84(2): 287-290.

SHUMWAY-COOK, A. & WOOLLACOTT, M.H. (1995). *Motor control theory and practical applications.* Baltimore: Lippincott Williams & Wilkins.

SHUPERT, C.L. & HORAK, F.B. (1999). Adaptation of postural control in normal and pathologic aging: Implications for fall prevention. *Journal of Applied Biomechanics,* 15(1): 64-74.

SNOW, C.M. (1999). Exercise effects on falls in frail elderly people: Focus on strength. *Journal of Applied Biomechanics,* 15(1): 84-90.

SöDERMAN, K.; WERNER, S.; PIETILå, T.; ENGSTRöM, B. & ALFREDSON, H. (2000). Balance board training: prevention of traumatic injuries of the lower extremities in female soccer players? *Knee Surgery, Sports Traumatology, Arthroscopy,* 8(6): 356-363.

SPIRDUSO, W.W. (1995). *Physical dimensions of aging.* Champaign Illinois: Human Kinetics.

StatSoft, Inc. (2001). STATISTICA (data analysis software system), version 6. www.statsoft.com.

SWANIK, C.B.; RUBASH, G.E.; BARRACK, T.L. & LEPHART, S.M. (2000). The role of proprioception in patients with DJD and following total knee arthroplasty. In S.M. Lephart & F.H. Fu (Eds), *Proprioception and neuromuscular control in joint stability* (pp. 323-339). Champaign Illinois: McGraw-Hill.

SWINKELS, A. & DOLAN, P. (1998). Regional assessment of joint position sense in the spine. *SPINE,* 23(5): 590-597.

TANG, P. & WOOLLACOTT, M.H. (1996). Balance control in the elderly. In A.M. Bronstein; T. Brandt & M.H. Woollacott (Eds), *Clinical disorders of balance, posture, and gait* (pp. 268-287). The bath press: Bath.

THAPA, P.B. & RAY, W.A. (1996). Medications and falls and fall related injuries in the elderly. In A.M. Bronstein; T. Brandt & M.H. Woollacott (Eds), *Clinical disorders of balance, posture, and gait* (pp. 287-301). The bath press: Bath.

TINETTI, M.E.; BAKER, D.I.; GARRETT, P.A.; GOTTSCHALK, C.M.; KOCH, M.L. & HOWITZ, R.I. (1993). Yale FICSIT: Risk factor abatement strategy for fall prevention. *Journal of the American Geriatrics Society,* 41(1): 315-320.

TROPP, H.; ASKLING, C. & GILLQUIST, J. (1985). Prevention of ankle sprains. *The American Journal of Sports Medicine,* 13(4): 259-262.

TROPP, H.; EKSTRAND, J. & GILLQUIST, J. (1984). Factors affecting stabiliometry recordings of single limb stance. *American Journal of Sports Medicine*, 12(3): 185-188.

TROPP, H.; EKSTRAND, J. & GILLQUIST, J. (1984). Stabilometry in functional instability of the ankle and its value in predicting injury. *Medicine and Science in Sports and Exercise,* 16(1): 64-66.

VANDERVOORT, A.A. & SYMONS, T.B. (2001). Functional and metabolic consequences of sarcopenia. *Canadian Journal of Applied Physiology,* 26(1): 90-101.

WILKERSON, G.B. & NITZ, A.J. (1994). Dynamic ankle stability: Mechanical and neuromuscular interrelationships. *Journal of Sport Rehabilitation,* 3(1): 43-58.

WOLF, S.L.; BARNHART, H.; KUTNER, N.; COOGLER, C.; McNEELY, E.; XU, T. & ATLANTA FICSIT GROUP (1996). Reducing frailty in older persons: An investigation of tai chi and computerized balance training. *Journal of the American Geriatrics Society,* 44(2): 489-497.

WOLF, S.L. & GREGOR, R.J. (1999). Exploring unique applications of kinetic analysis to movement in older adults. *Journal of Applied Biomechanics,* 15(1): 75-83.

WOLF, S.L.; KUTNER, N.; GREEN, R.C. & McNEELY, E. (1993). The Atlanta FICSIT study: Two exercise interventions to reduce frailty in elders. *Journal of the American Geriatrics Society,* 41(1): 329-332.

WOLFSON, L.; WHIPPLE, R.; JUDGE, J.; AMERMAN, P.; DERBY, C. & KING, M. (1993). Training balance and strength in the elderly to improve function. *Journal of the American Geriatrics Society,* 41(1): 341-343.

WOLFSON, L.; WHIPPLE, R.; DERBY, C.; JUDGE, J.; KING, M; AMERMAN, P.; SCHMIDT, J. & SMEYERS, D. (1996). Balance and strength training in older adults: Intervention gains and tai chi maintenance. *Journal of the American Geriatrics Society,* 44(2): 498-506.

WOOLLACOTT, M.H. & SHUMWAY-COOK, A. (1990). Changes in posture control across the life span-A systems approach. *Physical Therapy,* 70(12): 799-807.

Appendix A

Berg Balance Scale

(Shumway-Cook & Woollacott, 1995:448-451)

1. Sitting to standing

Instruction: Please stand up. Try not to use your hands for support.

4-able to stand, no hands and stabilize independently
3-able to stand independently using hands
2-able to stand using hands after several tries
1-needs minimal assist to stand or to stabilize
0-needs moderate or maximal assist to stand

2. Standing unsupported

Instruction: Stand for two minutes without holding.

4-able to stand safely for 2 minutes
3-able to stand 2 minutes with supervision
2-able to stand 30 seconds unsupported
1-needs several tries to stand 30 seconds unsupported
0-unable to stand 30 seconds unassisted

IF SUBJECT ABLE TO STAND 2 MINUTES SAFELY, SCORE FULL MARKS FOR SITTING UNSUPPORTED. PROCEED TO POSITION CHANGE STANDING TO SITTING.

3. Sitting unsupported feet on floor

Instruction: Sit with arms folded for two minutes.

4-able to sit safely and securely 2 minutes
3-able to sit 2 minutes under supervision
2-able to sit 30 seconds
1-able to sit 10 seconds
0-unable to sit without support 10 seconds

4. Standing to sitting

Instruction: Please sit down.

4-sits safely with minimal use of the hands
3-controls descent be using hands
2-uses back of legs against chair to control descent
1-sits independently but has uncontrolled descent
0-needs assistance to sit

5. Transfers

Instruction: Please move from chair to bed and back again. One way toward a seat with armrests and one way toward a seat without armrests.

4-able to transfer safely with only minor use of hands
3-able to transfer safely with definite need of hands
2-able to transfer with verbal cueing and/or supervision
1-needs one person to assist
0-needs two people to assist or supervise to be safe

6. Standing unsupported with eyes closed

Instruction: Close your eyes and stand still for 10 seconds.

4-able to stand 10 seconds safely
3-able to stand 10 seconds with supervision
2-able to stand 3 seconds
1-unable to keep eyes closed 3 seconds but stays steady
0-needs help to keep from falling

7. Standing unsupported with feet together

Instruction: Place your feet together and stand without holding.

4-able to place feet together independently, stand 1 minute safely
3-able to place feet together independently, stand 1 minute with supervision
2-able to place feet together independently but unable to hold for 30 seconds
1-needs help to attain position but able to stand 15 seconds feet together
0-needs help to attain the position and unable to hold for 15 seconds

THE FOLLOWING ITEMS ARE TO BE PERFORMED WHILE STANDING UNSUPPORTED

8. Reaching forward with outstretched arm

Instructions: Lift arm to 90°. Stretch out your fingers and reach forward as far as you can. (Examiner places ruler at end of fingertips when arm is at 90°. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position.)

4-can reach forward confidently >10 inches
3-can reach forward >5 inches
2-can reach forward>2 inches safely
1-reaches forward but needs supervision
0-needs help to keep from falling

9. Pick up object from the floor

Instruction: Pick up the shoe/slipper which is placed in front of your feet.

4-able to pick up slipper safely and easily

3-able to pick up slipper but need supervision

2-unable to pick up but reaches 1-2 inches from slipper and keeps balance independently

1-unable to pick up and needs supervision while trying

0-unable to try/needs assistance to keep from falling

10. Turning to look over left and right shoulders

Instruction: Turn to look behind you over left shoulder. Repeat to the right.

4-looks behind from both sides and weight shifts well

3-looks behind one side only; other side shows less weight shift

2-turns sideways only but maintains balance

1-needs supervision when turning

0-needs assistance to keep from falling

11. Turn 360°

Instruction: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.

4-able to turn 360 safely in < 4 seconds each side

3-able to turn 360 safely one side only in < 4 seconds

2-able to turn 360 safely but slowly

1-needs close supervision or verbal cueing

0-needs assistance while turning

DYNAMIC WEIGHT SHIFTING WHILE STANDING UNSUPPORTED

12. Stool touch

Instruction: Place each foot alternately on the stool. Continue until each foot has touched the stool four times.

4-able to stand independently and safely and complete 8 steps in 20 seconds

3-able to stand independently and complete 8 steps in > 20 seconds

2-able to complete 4 steps without aid with supervision

1-able to complete > 2 steps needs minimal assistance

0-needs assistance to keep from falling/unable to try

13. Standing unsupported, one foot in front

Instruction: (Demonstrate to the subject) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot.

4-able to place foot tandem independently and hold 30 seconds
3-able to place foot ahead of other independently and hold 30 seconds
2-able to take a small step independently and hold 30 seconds
1-needs help to step but can hold 15 seconds
0-loses balance while stepping or standing

14. Standing on one leg

Instruction: Stand on one leg as long as you can without holding.

4-able to lift leg independently and hold >10 seconds
3-able to lift leg independently and hold 5-10 seconds
2-able to lift leg independently and hold = or > 3 seconds
1-tries to lift leg; unable to hold 3 seconds but remains standing independently
0-unable to try or needs assistance to prevent fall

TOTAL SCORE __________ **/56**

Appendix B

Informed Consent

Name: ______________________________

Please read the following:

1. By entering this thesis study you will perform a battery of one functional balance and one proprioceptive test.
2. You will participate in a proprioceptive training programme consisting of three twenty-minute sessions per week for eight weeks. In order for your data to be used in the statistical analysis, you have to be present for at least 70% of the sessions.
3. The tester may terminate the testing or the training sessions at any point in time if it is felt necessary or appropriate. You may also stop the testing or the programme at any time if you experience negative effects, for example pain.
4. Information you process about your health status or previous experiences of unusual feelings accompanying physical effort may affect the safety of the test battery and the training programme. Your prompt resulting of feelings with effort during the test protocol as well as the training sessions is also of great importance. You are responsible to fully disclose such information when requested by the tester.
5. The results of the tests are strictly confidential.
6. Hanlie Gertenbach or the Department of Sport Science, Stellenbosch University, will not be held liable for any injury obtained during the testing procedures.

I hereby declare that:

- The tester has explained the testing procedures to me.
- To the best knowledge I am currently free from any existing medical condition/other complaint/injury that would preclude me from full participation in this particular study.
- I give my written consent to Hanlie Gertenbach, the researcher, to undertake the battery of tests, which form part of the above-mentioned study.

Subject’s signature: ____________________ Date: ____________

Hanlie Gertenbach: ____________________ Date: ____________

Appendix C

Pretest: Score Sheet

Name and Surname: ______________________________

Date of Birth: ____________ **Today's Date:** ____________

Medical Conditions and Medications:

____

____

____

Activity levels: ______________________________

____

1. **Blood Pressure:** Sitting: __________ Standing: __________

2. **Proprioception:** (If the person identifies the movement or position correctly, mark the appropriate square. If not, leave blank.)

Non dominant leg: ________

Joint	PS	AM	FM
Shoulder			
Elbow			
Wrist			
Fingers			
Thumb			
Hip			
Knee			
Ankle			
Toes			

Total: ________ /27

3. Berg Functional Balance Scale:

1. Sitting to Standing: ______
2. Standing unsupported: ______
3. Sitting unsupported feet on floor: ______
4. Standing to sitting: _____
5. Transfers: _____
6. Standing unsupported with eyes closed: ______
7. Standing unsupported with feet together: ______
8. Reaching forward with outstretched arm: ______
9. Pick up object form the floor: ______
10. Turning to look over left and right shoulders: ______
11. Turn 360 degrees: ______
12. Stool touch: ______
13. Standing unsupported, one foot in front: _____
14. Standing on one leg: ______

Total Score: ___________ /56

Appendix D

Posttest: Score Sheet

Name and Surname: ______________________________

Today's date: ______________

1. Proprioception: (If the person identifies the movement or position correctly, mark the appropriate square. If not, leave blank.)

Non dominant leg:________

Joint	PS	AM	FM
Shoulder			
Elbow			
Wrist			
Fingers			
Thumb			
Hip			
Knee			
Ankle			
Toes			

Total: _______/27

2. Berg Functional Balance Scale:

1. Sitting to Standing: ______
2. Standing unsupported: ______
3. Sitting unsupported feet on floor: ______
4. Standing to sitting: _____
5. Transfers: _____
6. Standing unsupported with eyes closed:______
7. Standing unsupported with feet together: ______
8. Reaching forward with outstretched arm: ______
9. Pick up object form the floor: ______
10. Turning to look over left and right shoulders:______
11. Turn 360 degrees:______
12. Stool touch: ______
13. Standing unsupported, one foot in front: _____
14. Standing on one leg:______

Total Score:________/56

Appendix E

Tables of statistical analysis

Table 10. The results of an unpaired t-test comparing Berg Balance Scale scores of the control and the intervention group at the beginning of the study (N=25).

Variable	Mean	SD	SED	t	p
BBS1 (intervention)	50.27	2.94			
BBS1 (control)	48.4	5.27	1.64	1.14	0.27

Table 11. A summary of the results of the unpaired t-test comparing the Berg Balance Scale results of the two sub-groups after the intervention programme (N=25).

Variable	Mean	SD	SED	t	p
BBS2 (intervention)	53.33	3.35			
BBS2 (control)	48.5	7.09	2.10	2.30	0.04

Table 12. A summary of the results of the paired t-test comparing the Berg Balance Scale scores of the control group before and after the study (n=10).

Parameter	Mean	SD	SEM	SED	r	t	p
BBS1 (control)	48.4	5.27	1.67				
BBS2 (control)	48.5	7.09	2.24	1.01	0.91	0.10	0.92

Table 13. A summary of the results of the paired t-test comparing the Berg Balance Scale scores of the intervention group before and after the study (n=15).

Parameter	**Mean**	**SD**	**SEM**	**SED**	**r**	**t**	**p**
BBS1 (intervention)	50.27	2.94	0.76				
BBS2 (intervention)	53.33	3.35	0.87	0.81	0.51	-3.77	0.002

Table 14. A summary of the results of the Pearson's product moment correlation coefficient comparing the baseline Berg Balance Scale results and the age of the subjects.

Parameter	**N**	**r**
BBS1 VS Age	25	-0.36

Table 15. The results of an unpaired t-test comparing the Harrison's Recovery Test scores of the control and the intervention group at the beginning of the study (N=25).

Parameter	**Mean**	**SD**	**SED**	**t**	**p**
HRT1 (intervention)	15.13	3.72			
HRT1 (control)	14.4	3.06	1.42	0.52	0.61

Table 16. A summary of the results of the unpaired t-test comparing the Harrison's Recovery Test results of the two sub-groups after the intervention programme (N=25).

Variable	**Mean**	**SD**	**SED**	**t**	**p**
HRT2 (intervention)	21.73	1.79			
HRT2 (control)	15.8	2.97	0.95	6.25	0.0002

Table 17. A summary of the results of the paired t-test comparing the Harrison's Recovery Test scores of the control group before and after the study (n=10).

Parameter	Mean	SD	SEM	SED	r	t	p
HRT1 (control)	14.4	3.06	0.97				
HRT2 (control)	15.8	2.97	0.94	0.81	0.64	-1.74	0.17

Table 18. A summary of the results of the paired t-test comparing the Harrison's Recovery Test scores of the intervention group before and after the study (n=15).

Parameter	Mean	SD	SEM	SED	r	t	p
HRT1 (intervention)	15.13	3.72	0.96				
HRT2 (intervention)	21.73	1.79	0.46	0.88	0.41	-7.52	0.000

Table 19. A summary of the results of the Pearson's product moment correlation coefficient comparing the baseline Harrison's Recovery Test results and the age of the subjects.

Parameter	N	r
HRT1 Vs Age	25	0.25