THE DEVELOPMENT OF A FALL RISK ASSESSMENT AND EXERCISE INTERVENTION PROGRAMME FOR GERIATRIC SUBJECTS

GHABRIELLE ANNE DEKENAH

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SUPERVISOR: PROF JUSTHINUS BARNARD
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DECLARATION

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December 2012

"Population ageing is a triumph of humanity but also a challenge to society"
(WHO Global Report on falls prevention in older age, 2002)

ABSTRACT

Falling is a common occurrence and one of the most serious problems in the elderly population (65 years and older). Falls account for 70% of accidental deaths in persons aged 75 years and older. Falls can be markers/indicators of poor health and declining function, and are often associated with significant morbidity. More than 90% of hip fractures occur as a result of falls, with most of these fractures occurring in persons over 70 years of age (Fuller, 2000). About one third of people aged 65 years and older fall each year, resulting in a substantial decrease in quality of life in addition to placing a huge burden on current health care systems.

The purpose of this study was to determine whether a 12-week exercise intervention programme, consisting of two 30 minute exercise sessions a week, could lower the risk of falling in a group of elderly women.

Female subjects (n=22) with an average age of 79.5 years were selected from three retirement homes situated in Stellenbosch, Western Cape, South Africa, according to specific inclusion and exclusion criteria. The subjects included presented no major cardiovascular and pulmonary disease signs and symptoms as recognised by the American College of Sports Medicine (2011); had no serious illnesses or co-morbidities; were mobile with no significant musculoskeletal disorders; had no uncorrected visual or vestibular problems as well as no significant cognitive impairments or major psychological disturbances; were not taking any psychotropic medications or Benzodiazepines that could affect their progress. Subjects also had to be willing to follow the 12-week exercise intervention programme and sign an informed consent document. The selected subjects then underwent a pre- and post-intervention assessment consisting of a subjective rating of their fear of falling, the Fall Risk Assessment: Biodex Balance system, Balance Evaluations Systems Test (BESTest) and the 30-Second Chair Stand Test. Statistica 10 was used to analyse the data. Data was analysed to assess any significant improvements that the exercise intervention had on each fall risk variable tested. The main fall risk variables consisted of: fear of falling, muscular strength, balance, gait and getting up strategies.

Statistically significant improvements ($p<0.001$) were seen in: Fear of falling, muscular strength, balance, gait and getting up strategies after the 12-week exercise intervention programme.

This study suggests that exercise intervention has the potential to decrease the risk of falling among elderly women and should play an extremely important role in the prevention of falling amongst this population group.

Key Words: Elderly, falling, assessment, prevention, exercise, risk factors, getting up

OPSOMMING

Om te val is ‘n alledaagse gebeurtenis en een van die mees ernstige probleme vir ons bejaarde bevolking (65 jaar en ouer). Insidente van val verklaar tot 70% van toevallige sterftes met betrekking tot persone van 75 jarige ouderdom en ouer. Om te val kan ‘n teken van swak gesondheid en/of ‘n afname in funksionele kapasiteit wees, en is gewoonlik met morbiditeitspatrone gekoppel. Meer as 90% van heupfrakture kom as gevolg van valle voor, waar die meeste van die frakture in persone bo 70 jarige ouderdom voorkom (Fuller, 2000). Minstens een derde van persone bo 65 jaar en ouer val elke jaar, so ‘n val het ‘n noemenswaardige afname in lewenskwaliteit tot gevolg asook ‘n enorme druk wat op huidige gesondheidsorg sisteme geplaas word.

Die doel van die studie was om te bepaal of ‘n 12 week oefenintervensieprogram, wat uit twee oefen sessies van 30 minute elk bestaan, die risiko van val vir n groep bejaarde vroue kan verlaag.

Vroulike individue (n=22) met ‘n gemiddelde ouderdom van 79.5 jaar uit drie ouetehuise/aftree oorde in Stellenbosch, Wes-Kaap, Suid-Afrika geleë; is volgens bepaalde insluitings- en uitsluitingskriteria geselekteer. Individue wie ingesluit is het geen tekens of simptome van grootskaalse kardiovaskulêre of pulmonêre siekte getoon nie, soos herken deur die “American College of Sports Medicine (2011) ; het aan geen ernstige siektes of ko-morbiditeite gely nie; kon stap met geen merkwaardige muskulo-skeletale afwykings nie; het geen nie-gekorrigeerde visie of vestibulêre probleme asook geen beduidende kognitiewe gestremdhede of ernstige sielkundige steurnisse gehad nie; het nie enige psigotropiese medikasie of Benzodiazepines geneem wat hul kon beinvloed nie. Individue moes bereid gewees het om die 12 week oefenintervensieprogram te volg en moes ook ‘n ingeligte toestemmingsvorm onderteken. Die geselekteerde individue het ‘n pre- en post-intervensie assessering ondergaan wat uit ‘n subjektiewe bepaling van hul vrees vir val bestaan het, die Val Risiko Assessering asook “Biodex Balans System Test, Balance Evaluations Systems Test (BESTest)” asook die 30 Sekonde Stoel-staan Toets. Statistica 10 is gebruik om die data te analiseer. Data was geanaliseer om enige merkwaardige verandering wat die oefenintervensie op elke val risiko veranderlike wat getoets was gehad het, te bepaal. Die belangrikste val risiko veranderlikes het uit: die vrees vir val, spier sterkte, balans, stappatroon en opstaan tegnieke bestaan.

Betekenisvolle statistiese veranderinge ($p<0.001$) is gerapporteer in: die vrees vir val, spiersterkte, balans, stappatroon en opstaan tegnieke na die 12 week oefenintervensieprogram.

Die studie bevind dat die intervensieprogram die potensiaal het om die risiko van val onder bejaarde vroue te verminder en behoort ‘n uiters belangrike rol in die voorkoming van val onder die bevolkingsgroep te speel.

Sleutelwoorde: Bejaard, val, assessering, voorkoming, oefening, risiko faktore, opstaan

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DEDICATION

To my late grandparents, Ivor Wallace Erasmus and Serina Dekenah

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LIST OF ABBREVIATIONS

ACSM	American College of Sports Medicine
ADL	Activities of Daily Living
APA	Anticipatory Postural Adjustment
AW	Ankle Weights
BESTest	Biodex Balance system, Balance Evaluations Systems Test
BBS	Biodex Balance System
BBS	Berg Balance Scale
BMI	Body Mass Index
BOS	Base of Support
BP	Blood Pressure
CDC	Center for Disease Control
CNS	Central Nervous System
COG	Centre of Gravity
COM	Centre of Mass
CPR	Cardiopulmonary Resuscitation
CTSIB	Clinical Test of Sensory Integration and Balance
DB	Dumbbells
ED	Emergency Department
FES	Falls Efficacy Scale
FOF	Fear of Falling
FRT	Functional Reach Test
HPCSA	Health Professions Council of South Africa
HR	Heart Rate
ICC	Intraclass Correlation Coefficient
ICF	International Classification of Functioning, Disability, and Health
LOS	Limits of Stability
NCHS	National Center for Health Statistics
NHS	National Health Service

OH	Orthostatic Hypotension
ProFaNE	Prevention of Falls Network Europe
SD	Standard Deviation
STS	Sit-to-Stand
SU	Stellenbosch University
TB	Theraband
UCT	University of Cape Town
UK	United Kingdom
US	United States
WHO	World Health Organisation

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

The world is about to cross a demographic landmark of huge social and economic importance with the proportion of the population 65 years and over, set to outnumber children less than five years for the first time (Kinsela & He 2009:7). A report by the United States (US) Census Bureau (2009) highlights a huge shift towards, not just an ageing population, but an old population, with formidable consequences for rich and poor nations alike. Shrestha (2006:CRS-2&CRS-3), a Specialist in Demography, reported life expectancy at birth increased dramatically over the past century in the US from 49.2 years (the average for 1900-1902) to 77.5 years in 2003, the most recent year for which official data has been released by the Center for Disease Control (CDC)/National Center for Health Statistics (NCHS). The report, *An Ageing World* by Kinsela & He (2009:7) forecasts that over the next 30 years the number of 65 year olds and over is expected to more than double, from 506 million in 2008 to 1.3 billion in 2030 – a leap from 7% of the world's population to 14%. Already, the number of people in the world that are 65 years and over is increasing at an average of 870 000 each month.

The shift is due to a combination of the time-delayed impact of high fertility levels after the Second World War and more recently, improvements in health that are bringing down death rates at older ages (US Census Bureau, 2009:1&2). Improvements in healthcare were first as a result of the control of the infectious and parasitic diseases that had plagued mostly infants and children in the early part of the century, and later, because of medical advances that led to large decreases in adult mortality, especially from two of the most prevalent causes of death — cardiovascular diseases and cerebrovascular diseases. Hastened by the retirement of the "Baby Boom" generation (the cohort born between 1946 and 1964), the inexorable demographic momentum will have important implications for a large number of essential economic and social domains, including work; retirement and pensions; wealth and income security; and the health and well-being of the ageing population (Shrestha, 2006:CRS-21).

Analysts in Health Services, Shrestha & Heisler (2011:27) stress that beyond the increasing diversity of the population, the aging of the population can have profound impacts on the health and health services needed.

Thus, as the population ages, the social and economic demands on individuals, families, communities and the government will grow, with a substantial impact on the formal and informal health and social care systems, as well as on the financing of medical services in general. It is an especially grave issue for health care systems throughout the developed world, where the ageing population are more dependent on this system, with falls making up the largest percentage of accidents in the elderly population. However, an important finding of the*US Census Bureau report* (2009:10) is that the wave of ageing that has until recently been considered a phenomenon of the developed world is fast encroaching on poorer countries too. More than 80% of the increase in older people in the year up to July 2008 was seen in developing countries.

According to *the Merck manual of Geriatrics* (2005) a fall results in a person coming to rest on the ground or another lower level; sometimes a body part strikes against an object that breaks the fall. They also report that annually, 30% to 40% of elderly people fall and falls are the leading cause of accidental death. Falls in older people are an important but often overlooked problem (Gardner *et al*., 2000). Many of us trip and fall as we go about our daily lives, however, for an older person, a fall can have disastrous consequences (Morley, 2002). These may include a dramatic functional decline due to physical injury such as fractures, head injuries as well as soft tissue injury (Titler *et al*., 2005). Falls result in adverse health outcomes such as a decrease in an older person's quality of life and/or a decrease in activity leading to loss of an independent living status, which may ultimately lead to depression (Boyd & Stevens, 2009). Long term care expenses as well as an increase in medical consumption, markedly increase with age (Werblow *et al*., 2007).

Fall-incurred costs are categorized into two aspects:

- Direct costs encompass health care costs such as medications and adequate services e.g. health-care-provider consultations in treatment and rehabilitation.
- Indirect costs are societal productivity losses of activities in which individuals or family care givers would have been involved in if he/she had not sustained fall-related injuries e.g. lost income.

(WHO, 2007)

In 2006 the US had over 2.1 million Emergency Department (ED) visits for injurious falls among patients aged 65 years and older, with a total cost of US$6.8 billion for hospital care following an ED visit (Owens *et al*., 2009). This total cost for hospital care is projected to reach US$43.8 billion by 2020.

Yoshida (n.d.) shows that a similar high expenditure on falls has been reported in other developed countries. A 1999 United Kingdom study reported that ED and hospital care for fall related injuries among people aged 60 years and over, cost almost £1 billion (US$1.9 billion). Falls are listed as the leading cause of death from injury among people over 75 years in the United Kingdom (UK). Over 85% of all fatal falls are in people over the age of 65 years. It is estimated that every five hours someone dies after an accidental fall in their home in the UK. About one third of people aged 65 years and over, and more than half of people aged 85 years and older, will fall at least once a year. It is estimated that the overall direct healthcare cost due to falls to the National Health Service (NHS) for the UK is £15 million each year (NHS, 2007).

A Western Australian study estimated ED treated and hospitalized fall injuries among people aged 65 years and over cost the Australian healthcare system AUS$86.4 million (US$ 66.1 million). There were 18 706 ED visits and 6 222 hospital admissions for fall related injuries. Based on an assumption that the current rate of falls remains constant for age and gender, the projected health care system costs of falls in older adults have been estimated to increase to $181 million in 2021 (expressed in 2001-2002 Australian dollars) (Fu, n.d.).

According to Kalula (n.d), a physician specialist in Geriatric Medicine, director of the International Longevity Centre of South Africa and of the Institute of Ageing in Africa at the University of Cape Town (UCT), as well as a Fellow of the World Demographic and Ageing Forum, information on the epidemiology of falls in older persons in Africa is lacking. It can be noted that Africa's population is ageing. The 'oldest' old-age group is growing more rapidly than any other age group. The absolute number of older persons is projected to increase dramatically from 47.4 million in 2005 to 193 million by 2050. This increase in the number of older persons in Africa, specifically South Africa, together with longevity, will expose a greater risk of falls. In the older population of South Africa, falls account for 40% of injury related deaths, 10% of ED visits and 6% of hospital admissions. The incidence rate of falls is 30% in persons aged 65 years and over, this increases to a 50% incidence rate in persons aged 80 years and over. Of these falls, 20% to 30% of the patients suffer serious injury, and more than 60% of people that die from falls are 75 years and older. Of an estimated 6.26 million hip fractures globally in 2050, 4.43 million (71%) are expected to occur in developing countries including Africa. Women comprise a significant 70% to 80% of patients sustaining a hip fracture. The incidence of hip fractures in black Africans has doubled over the last decade, while the incidence in Caucasians in Africa is rising.

The British Columbian Ministry of Health (2005:36) reported that rehabilitation and recovery methods are typically much longer and more cumbersome for older adults who have experienced an injurious fall, almost up to twice as long for falls when compared to other causes of hospitalization, also contributing to the high resource burden on the health care system. The inability to get up after a fall is also considered as one of the strongest independent risk factor for serious fall related injury (Bergland & Wyller, 2004). Many recommendations exist on the importance of teaching elderly people to get up should a fall occur, including good evidence from trials for using floor rise training in tailored exercise programmes for fall prevention however, this is very rarely done (Fleming *et al*., 2008). This could be due to the fact that the elderly may be fearful to attempt such strategies due to lack of confidence in their physical ability or a false sense of security that someone will always be around should they live in an old age residential facility.

It is evident from the extremely high prevalence and costs associated with falling among the elderly, that prevention should be a top priority when dealing with this extremely significant and real issue. Specific intervention strategies to decrease the risk of falling in the elderly need to be introduced and implemented in order to alleviate the vast impact this situation has on both our health care system, as well as, and possibly more importantly, on this majority population, and the individuals concerned. It is also evident from the literature, supported by a report done by Todd & Skelton (2004), on the main risk factors for falls amongst older people that women fall more often than men, and are far more likely to incur fractures when they fall. More than one-third of women sustain one or more osteoporotic fractures in their lifetime, the majority caused by a fall. Lifetime risk of fracture in men is approximately half that observed in women.

According to the *World Health Organization* (2007), studies in developed countries show that fall prevention programmes are especially effective when targeted at individuals at an increased risk of falling. An extensive systematic review carried out by Carter & Khan (2001), between 1966 to 2001 (using keywords: randomised controlled trials, exercise, falls and elderly) proved to find exercise can theoretically modify the intrinsic fall risk factors and thus prevent falls in elderly people; however, the optimal exercise prescription to prevent falls has not yet been defined.

Statistics provided by one of the largest private hospital groups in the world, specifically for one of these private hospitals located within Stellenbosch, a town situated in the Western Cape of South Africa, highlight the extremely high incidence of fall related cases as well as the exceedingly high costs associated with these specific cases among the age group 65 years and older. This particular private hospital group reported a total number of 174 fall related ED cases in 2009 showing a 28.9% increase from 2006 to 2009, with an associated cost increase of 44.1% (Badenhorst, 2010). Stellenbosch comprises the third highest number of old age homes in the Western Cape, therefore representing a significant proportion of the Western Capes elderly population.

1.2 AIM AND OBJECTIVES OF THE STUDY

1.2.1 Aim

The aim of this research was to develop an assessment which would determine the risk of falling among elderly women. The aim was to include relevant assessment measures that would determine their fall risk status according to deterioration related to ageing and the effects this has on specific systems that can be addressed through the specifically developed exercise programme. It was then to determine whether participation in a 12-week exercise intervention programme had an effect on the risk of falling among elderly women.

1.2 Primary objectives

To investigate whether exercise has a significant effect on the following fall risk variables after a 12-week exercise intervention programme:

- Fear of falling
- Muscular strength
- Balance
- Gait
- Getting up strategies

1.3 STRUCTURE OF THE THESIS

Chapter TWO is a review of the literature regarding falling in the elderly, outlining the risk factors leading to falls, history related to risk assessments, as well as explaining how exercise potentially benefits those at a high risk of falling.

Chapter THREE covers the research design and methodology, with details of all the variables used in pre- and post-intervention evaluations and the selection criterion of subjects.

Chapter FOUR covers and discusses data captured during the study.

Chapter FIVE concludes the study, pointing out any possible limitations the study may have and providing possible recommendations for further research.

CHAPTER 2: LITERATURE REVIEW

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2.1 INTRODUCTION

The world has seen enormous changes over the past century, including historically unprecedented declines in mortality rates and increases in population, followed by equally unprecedented declines in fertility rates. This century will see a new set of demographic challenges, including a mix of falling fertility rates alongside persisting worldwide population growth, and the subsequent aging of populations in both developing and developed countries. The 20th century was the century of population growth; the 21st century will go into the history books as the century of aging (Lunenfeld, 2008).

The "oldest old" are now the fastest growing section of most western populations (Fleming *et al*., 2008). This rapidly aging population is a grave issue for the health care system (Taylor & Johnson, 2007: ix), resulting in particular healthcare challenges. One such challenge is how to effectively deal with the increased risk of sustaining a fall and fall-related injuries in old age (Granacher *et al*., 2011).

A solution that is not based on increased fees and medical costs must be found in order to avoid the complete collapse of the present health care systems (Taylor & Johnson, 2007: ix). For these reasons and more, the Social Security Advisory Board of the USA (Bilyeu *et al*., 2009), believe that it is essential that action is taken to restrain the rising cost of health care in ways that also lead to better quality of care and life. It is an issue that is at the very heart of the long-term economic security and urgent action must be taken now to contain health care costs by promoting prevention strategies that have shown to be effective and cost efficient.

2.2 PHYSIOLOGICAL AND MORPHOLOGICAL EFFECTS OF AGEING

Ageing is a concept that for most of recorded history has referred to relatively few individuals, in particular those who have surpassed the age of 90. In this new millennium it appears that we will be forced to redefine what ageing truly means. No longer is reaching 100 years considered an oddity or a miracle or even a rare occurrence (Taylor & Johnson, 2007: ix).

The term older adult (defined as people ≥ 65 years and people 50 to 64 years with clinically significant conditions or physical limitations that affect movement, physical fitness, or physical activity) represents a diverse spectrum of ages and physiologic capabilities (Thompson *et al*., 2010:190).

Spirduso *et al*. (2005:4) refer to ageing as the chronological time something has existed or the number of elapsed standard time units between birth and date of observation. Age and time are synonymous, ageing occurs with the relentless march of time.

Taylor & Johnson (2007: xviii) discuss two types of ageing that must be considered: eugeric ageing and pathogeric ageing. Eugeric ageing refers to changes in function that are not produced by disease, that is, a situation that would only exist if we lived in a perfect world or in an environmentally controlled bubble in which all humans would reach the maximum achievable life span. Pathogenic ageing refers to the ageing process as it is affected by the environmental perturbations, genetic mutations and accidents of nature or the human environment. Time related changes that lead to disability and dysfunction are thought of as adult ageing. The term "ageing" refers to a process or group of processes occurring in living organisms that, with the passage of time lead to loss of adaptability, functional impairment and eventually death. Table 2.1 shows the effects on ageing on selected physiologic and health related variables.

Table 2.1: Effects of ageing on selected physiologic and health related variables (Thompson *et al*., 2010:190)

VARIABLE	CHANGE
HR_{rest} (resting heart rate)	Unchanged
HR_{max} (maximum heart rate)	Lower
Q_{max}(maximum cardiac output)	Lower
Resting and exercise BP (blood pressure)	Higher
VO_2R_{max}(maximum oxygen uptake reserve) ($L \cdot min^{-1}$and $mL \cdot kg^{-1} \cdot min^{-1}$)	Lower
Residual volume	Higher
Vital capacity	Lower
Reaction time	Slower
Muscular strength	Lower
Flexibility	Lower
Bone mass	Lower
Fat-free body mass	Lower
% Body fat	Higher
Glucose tolerance	Lower
Recovery time	Lower

The common denominator for the ageing process is the decline in function and structure (Taylor & Johnson, 2007: xxx).

2.2.1 Cardiac, vascular and pulmonary systems

Advancing age has profound effects on the cardiac, vascular and pulmonary systems. These changes lead to a significant reduction in functional and exercise capacity and an increased risk of cardiovascular diseases. It is noteworthy, however, that many of the deleterious cardiovascular consequences of age are attributable to the effects of reduced physical activity and can be delayed or minimized through an active lifestyle (Taylor & Johnson, 2007:21).

2.2.2 Body composition

Ageing also has effects on body composition. As ageing continues and the muscles become less active, areas previously designated as muscle are replaced by fat. Muscle fibre size as well as muscle fibre numbers decreases with age. In addition, metabolic enzyme activities change and this can affect the total amount of energy available to an older person. The observable decline in muscular strength with ageing is often associated with both a decrease in activity and a decrease in various skeletal muscle functions (Taylor & Johnson, 2007:33). Muscle strength declines as much as 20% to 40% between the third and eighth decades of life (Rose, 2003:194). Many of the elderly have lost lower body strength to such an extent that they exist below the minimum strength thresholds for some Activities of Daily Living (ADL's), such as rising from a chair, walking, getting into and out of bath etc. (Spirduso *et al*., 2005:109).

2.2.3 Sarcopenia

The term "sarcopenia" (from the Greek sarx for flesh, and penia for loss) is a term utilized to define the loss of muscle mass, strength and function that occurs with ageing (Morley *et al*., 2001). It is the age associated loss of skeletal muscle mass, strength and quality of contractile function (Taylor & Johnson, 2007:34). Sarcopenia is believed to play a major role in the pathogenesis of frailty and functional impairment that occurs with old age (Morley *et al*., 2001). The prevalence of sarcopenia ranges from 9% to 18% over the age of 65 years (Sayer, 2010) and on average, it is estimated that 5% to 13% of elderly people aged 60 to70 years are affected by sarcopenia. The numbers increase to 11% to 50% for those aged 80 years and over (Von Haehling *et al*., 2010). Recognition of its serious health consequences in terms of frailty, disability, morbidity and mortality is increasing (Sayer, 2010). The main groups of factors that could be responsible are neurogenic (i.e. an age related motor unit remodelling) and myogenic (i.e. caused by contraction induced injury, selective primary muscle fibre atrophy, changes in contractile protein hormonal influences or alterations in muscle fibre signal transduction), or a combination of these factors (Taylor & Johnson, 2007:34). The role of the physiologic anorexia of aging remains to be determined. Decreased physical activity with aging appears to be the key factor involved in producing sarcopenia (Morley *et al*., 2001).

2.2.4 Bone

Major quantitative and qualitative changes occur in bone tissue during growth and maturation, with bones eventually becoming fragile. The maintenance of bone health throughout the lifecycle is therefore essential, as a decline in skeletal integrity increases the risk of osteoporosis and bone fracture increases substantially. Osteoporosis is characterized by reduced bone mass and by deterioration of the microarchitecture of the bone tissues, thereby leading to increased bone fragility (Marie, 2006). The highest rates of osteoporosis-related fractures occur in elderly women (Hannan *et al*., 2000). Many elderly women present with postural abnormalities such as hyperkyphosis and a forward head and stooped posture. The severity of a flexed posture in elderly female patients (without apparent comorbid conditions) is related to muscular impairments, and motor function and a forward posture has a measurable effect on disability (Balzini *et al*., 2003). The age associated decline in pelvic and spinal flexibility can result in a flexed/stooped posture, as shown in Figure 2.1. Often observed forward flexed head and kyphotic postures greatly restricts movement and places this group at a much greater risk of falls (Spirduso *et al*., 2005:140).

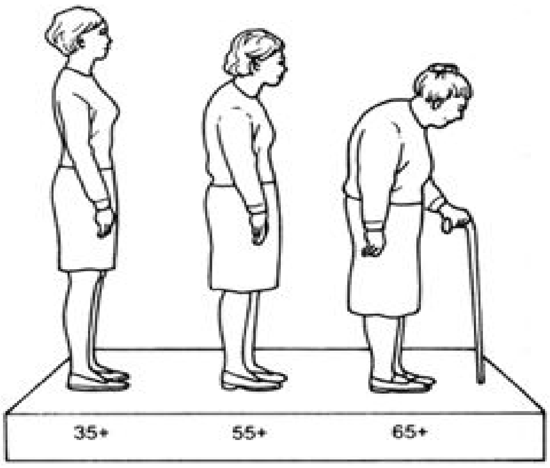

Figure 2.1: Representation of forward flexed head and kyphotic postures that may develop due to the ageing process (Desmon, 2009)

2.2.5 Balance and mobility

Unfortunately, changes in the body systems that contribute to balance and mobility are an inevitable consequence of ageing. Optimal motor function is achieved through the interaction of multiple systems that are internal and external to the central nervous system. At a behavioural level, the cumulative changes occurring in the ageing nervous system, as well as cognitive system changes, appear to manifest themselves in a reduced ability to perform a variety of complex movements that require speed and accuracy, balance, strength, or coordination (Rose, 2003:12). This loss of anticipatory control abilities places older adults at a much greater risk of falling when balance is unexpectedly perturbed or a second task is introduced (Spirduso *et al.*, 2005:139). Interventions that target the source(s) of balance related problems and repeatedly expose older adults to changing task demands or environmental constraints are particularly effective (Maejima *et al.*, 2009; Yang *et al.*, 2012; Aragão *et al.*, 2011; Granacher *et al.*, 2011; Mitchell, 2011; Hiyamizu *et al.*, 2012).

2.2.6 Gait

There are also significant age associated changes in gait, with the most significant change evident in variable gait speed. This has been shown to be largely attributable to a decrease in stride length (the distance from initial contact of one foot to the following initial contact of the same foot - sometimes referred to as cycle length and expressed in meters (Õunpuu, n.d.)) as opposed to frequency. There is a reduction in arm swing, reduced hip, ankle and knee rotation, increased double support time as well as more flat foot contact during stance phase prior to toe off. Speed has also been shown to decrease especially and notably so, when there is an obstacle that requires negotiation, such as stepping over or around something (Spirduso *et al*., 2005:149).

2.2.7 Reaction time

Slowing of simple reaction time (the interval time between the presentation of a stimulus and the initiation of the muscular response to that stimulus (Mackenzie, 1998)) (one stimulus - one response) with aging is considered one of the most measurable and recognizable behavioural changes that occurs with ageing.

Although certain of these changes are undoubtedly a normal part of ageing, lifestyle and environment also play a considerable role in the process (Taylor & Johnson, 2007:xxix). The primary contribution of consistent physical activity for quality of life varies with age. It is customary to think of physical capacity and performance as improving through the early years, peaking in the third decade and then declining linearly until death (Spirduso *et al*., 2005:29). Increasingly, physical activity is widely supported as a means to enhance quality of life in the elderly and has been shown to have positive effects on the decline of function and structure that have been observed in the ageing process. The rate of damage of these effects due to the process of ageing can be slowed and even improved with regular exercise (Taylor & Johnson, 2007:37).

2.3 GENERAL BACKGROUND

2.3.1 Falls

A fall is usually defined as 'an event which results in the person coming to rest inadvertently on the ground or other lower level' (Yoshida, n.d.). A fall occurs when a person's centre of gravity (COG) – (the average position of an object's weight distribution-standing upright, an adult human's centre of gravity is located roughly at the center of their torso at about the height of the belly button at about 55% of the total standing height) moves outside of their base of support (BOS), as depicted in Figure 2.2. An object is in balance if its COG is above its base of support - standing upright, your BOS is the area under your feet/shoes, including the area between your feet - roughly speaking, this area is traced from toe to toe and from heel to heel, and insufficient, ineffective, or no effort, is made to restore balance which may be affected by the interaction of multiple factors, such as decreased proprioception, slower righting reflexes, increased postural sway and decreased muscle tone. The main types of falls include same level falls, falls from one level to another, and falls on or from stairs and steps (Ellis & Trent, 2001).

Falling is a common occurrence (Morley, 2002) and the most serious problem is in geriatrics (Levencron & Kimyagarov, 2007). The mortality rate for falls increases dramatically with age in both sexes and in all racial and ethnic groups, with falls accounting for 70% of accidental deaths in persons 75 years of age and older. Falls can be markers of poor health and declining function and they are often associated with significant morbidity. More than 90% of hip fractures occur as a result of falls, with most of these fractures occurring in persons over 70 years of age. One third of community-dwelling elderly persons and 60% of nursing home residents fall each year (Fuller, 2000).

Kendall (2004), provincial health officer of British Columbia reported that indirect death from a fall occurs when the fall itself is not deadly, but the injuries that are sustained undermine the individual's health so much that other diseases and illnesses prove fatal. Pneumonia and infections are often the causes of indirect deaths after a fall. Consequences of fall-related injuries are the third leading cause of years lived with disability according to the World Health

Organization (WHO) report 'Global Burden of Disease'. The psychological and financial consequences can also be considerable (Dejaeger *et al*., 2010).

A United States study by Stevens & Sogolow (2005) to determine gender differences for non-fatal unintentional fall related injuries among older adults found, using National data, that the extent of these differences were striking. Women sustained fall related injury rates 40–60% higher than men of comparable age. Women's hospitalization rates for fall injuries were about 81% higher than men's, suggesting that women sustained more severe injuries. Some of the observed disparity may reflect gender differences in levels of physical activity. Muscle weakness and loss of lower body strength, often caused by inactivity, is a well-known risk factor for falling. Men were found to be more physically active and had greater lower body strength. The greatest gender difference was in women's fracture rate which was twice as high as the rate for men. This finding, along with the gender difference seen for rates of lower trunk injuries, may be due, in large part, to differences in hip fracture rates. Hip fractures, the most serious type of fall-related fracture, is a leading contributor to mortality, disability, and reduced quality of life. Women's increased likelihood of hip fracture is frequently attributed to reduced bone mass. Bone mass for both men and women peaks around age 30 and then declines about 0.5% per year for men and 1% per year for women. Additionally, women suffer a rapid loss of bone density for about five years following menopause. Another significant finding by Painter & Elliot (2009) was that women are more fearful of falling than men and notified other people about their falls more often than men.

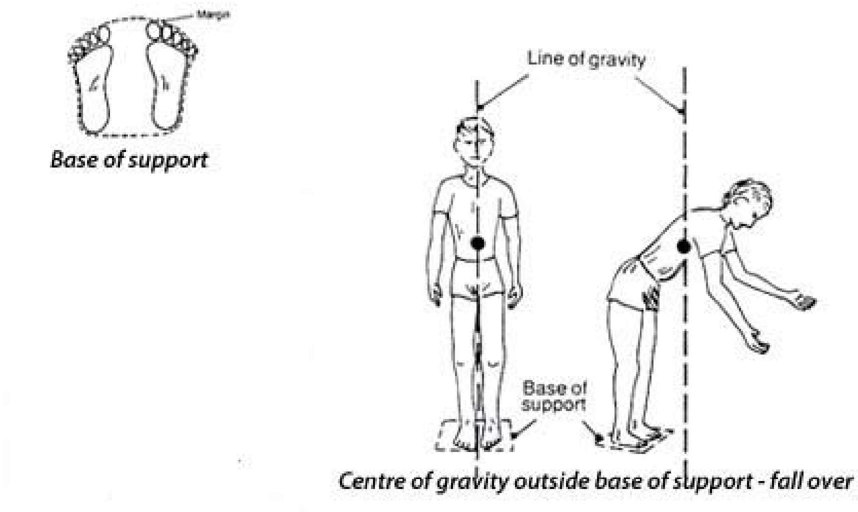

Figure 2.2: Representation of COG over the BOS and how a fall occurs if the COG falls outside of the BOS
(http://www.google.co.za/imgres?imgurl=http://www.rlca.com.pk/images/stablity_principles.jpg&imgrefurl=http://www.rlca.com.pk/cricket_biomechanics.aspx&usg=__qxgfGX7NduZRwXtz0d_bsCc4Js0=&h=288&w=471&sz=27&hl=en&start=4&sig2=EKj2XD2M5lV_Uv0uOtjxkA&zoom=1&tbnid=_ung_Mq2notLKM:&tbnh=79&tbnw=129&ei=hEDwT_CQBcWKhQemne37DA&itbs=1, 2011) 22 June 2012.

2.3.2 Risk factors

A risk factor *per se* is defined as a characteristic that is found significantly more often in individuals who subsequently experience an adverse event than in individuals who do not experience the event (Rubenstein & Josephson, 2006).

An overview of the literature relating to falling among the elderly and the risk factors involved predisposing the elderly to experiencing a fall was carried out, some of the databases covered included ERIC, Academic Search Premier, E-Journals, Health Source-consumer Edition, Health source – Nursing/Academic Edition, MEDLINE, Newspaper sources, books, SPORTDiscus as well as Pubmed. The main physical risk factors leading to falling among the elderly indicated in the literature included decreased postural balance and stability, the fear of falling, gait abnormalities as well as muscle weakness. Only articles used for specific information depicted in the text have been referenced.

Das & Joseph (2005) state that falls are as a result of extrinsic risk factors, intrinsic risk factors or a combination of both, as well as exposure to risk. Falls often result from dynamic interactions of risks in all three of the categories.

A report carried out by Dr Skelton and Professor Todd, co-ordinators of the Prevention of Falls Network Europe (ProFaNE) (2004) providing a synthesis of the best available evidence, including a summary of the main findings, listssome of the other main risk factors leading to falls among the elderly. This synthesis of research has concentrated on identifying evidence that emerges from published systematic reviews of the literature general reviews and key studies published in English.

Intrinsic risk factors include:

- **History**
  A history of falls is associated with increased risk.
- **Age**
  The incidence of falls increases with age.
- **Gender**
  Women fall more often than men and are far more likely to incur fractures when they fall.
- **Living alone**
  It may imply greater functional ability, but injuries and outcomes can be worse, especially if the person cannot rise from the floor which could result in consequences such as hypothermia, dehydration, bronchopneumonia and the development of pressure sores (Fleming & Brayne, 2008).
- **Ethnicity**
  Evidence from the United Kingdom and the United States suggests Caucasian ethnic groups fall more frequently than Afro-Caribbeans or Hispanics.

- **Medical conditions**

  The prevalence of falling increases with rising chronic disease burden. Thyroid dysfunction leading to excess circulating thyroid hormone, diabetes and arthritis leading to loss of peripheral sensation also increases risk. The prevalence of cardiovascular related causes of falls in the general population is not known, but dizziness is common in fallers. Depression and incontinence are also frequently present in populations of fallers.

- **Orthostatic hypotension**

  Orthostatic hypotension (OH) is a clinical condition which frequently results in troublesome symptoms such as dizziness, giddiness, blurred vision and light headedness. It is a common disorder associated with an increased risk of falling, especially in older individuals. OH is the presenting haemodynamic manifestation of several different and diverse underlying pathological conditions, including disorders of blood pressure (BP) regulation and disorders leading to reduced intravascular volume (Moore & Lyons 2003).

- **Sedentary behaviour**

  Fallers tend to be less active and may inadvertently cause further atrophy of muscle around an unstable joint through disuse.

- **Impaired mobility**

  Impaired mobility such as rising from a chair, or any lower-extremity disability (loss of strength, orthopaedic abnormality or poor sensation).

- **Muscle weakness**

  The decline in strength and endurance after the age of 30 years (10% loss per decade) and muscle power (30% loss per decade) results in physical functioning dropping below the threshold where ADL's become difficult and then impossible to carry out – this can occur in early old age for those who have been sedentary most of their lives. When strength, endurance, muscle power, and hence function, declines sufficiently, one is unable to prevent a slip, trip or stumble from becoming a fall.

- **Gait deficits**

  Variable gait speed, a reduction in arm swing, reduced hip, ankle and knee rotation, increased double support time (the period of time when both feet are in contact with the ground -this occurs twice in the gait cycle, at the beginning and end of the stance phase) as well as more flat foot contact (the point in time in the stance phase when the foot is plantar grade) during stance phase prior to toe off (Spirduso *et al*., 2005:149).

- **Balance deficits and the use of an assistive device**
- **Vestibular problems**

The peripheral and central vestibular systems exhibit an age-related structural deterioration which may be responsible for vestibular reflex deficits and dizziness in the elderly. An increasing number of people, particularly those aged 75 years and over, report experiencing frequent dizziness (Matheson *et al*., 1999).

- **Psychological status**

Psychological disorders, such as depression, are a biologically- based illness that affect a person's thoughts, feelings, behaviour, and even physical health. Depression is a risk factor for falls among older women.

Both depression and falls are known to be cross-sectionally related to the presence of chronic medical conditions such as functional disability, and to prospectively predict a decline in physical functioning (Biderman *et al*., 2002). A study done by Painter *et al*. (2012) found significant relationships between (1) fear of falling and depression, anxiety, and activity level; (2) depression and anxiety; and (3) activity restriction and depression. Both anxiety and depression predicted activity restriction because of fear of falling. Up to 70% of recent fallers and up to 40% of those not reporting recent falls acknowledge fear of falling. Reduced physical and functional activity is associated with fear and anxiety about falling. Up to 50% of people who are fearful of falling restrict or eliminate social and physical activities because of that fear. Strong relationships have been found between fear and poor postural performance, slower walking speed and muscle weakness, poor self-rated health and decreased quality of life.

- **Women with a history of a stroke**
- **Taking four or more types of medications**

Certain classes of prescription medications are associated with higher fall risk among the elderly. These include psychotropics, sedatives/hypnotics, and antidepressant medications (Rose, 2003:40). The relationship between antipsychotic drug use and the increased risk of falls in elderly persons may be related to the underlying medical condition for which the drug was prescribed or to the side effect of the drug on gait and postural stability.

Many studies have documented that patients taking antipsychotic medications have balance problems, gait instability, and impaired performance on reaction time and other sensorimotor functions. In particular, antipsychotic drugs are well known to produce rigidity and extrapyramidal symptoms (extreme restlessness and involuntary movements). These drugs were also associated with an increased risk for hip fracture (Lönnroos, 2009:37), dizziness, palpitations visual disturbances and an increase in orthostatic hypotension (Shuto *et al*., 2010). The use of benzodiazepines (sleep inducing medications) has been also identified as one of the most important risk factor for falls among elderly adults. Ataxia (poor co-ordination), drowsiness, dizziness, postural disturbances, and impaired motor coordination (common adverse effects of benzodiazepines) increase the risk of falling (Landi *et al.,* 2005).For each medication taken, risk of falling increases by 5% (Elwyn *et al*., 2003).

- **Nutritional deficiencies**

  A low body mass index suggesting malnutrition is associated with increased risk. Vitamin D deficiency is particularly common in older people in residential care facilities and may lead to abnormal gait, muscle weakness, osteopenia and osteoporosis.

- **Impaired cognition**

  Cognitive deficit is clearly associated with increased risk, even at a relatively modest level. Confusion and cognitive impairment are risk factors for falls (Vassallo *et al*., 2009). Two common cognitive disorders include deleruim and dementia. These conditions may exist separately or together. Delerium is an acute confusional state and one of the most common and important forms of psychopathology in later life (Lipowski, 1989). The other, more likely, explanation is that delirium is a marker of underlying mental impairment which may be relatively mild at first. Considerable proportions of patients with delirium (up to 55%) remain confused on follow-up and probably have underlying dementia (George *et al*., 1997). Individuals with these disorders have difficulty staying focused and are unable to maintain their attention (Jackson *et al*., 2004). Older adults with dementia are two to eight times more likely to fall than their cognitively intact peers. Dementia can show a gradual deterioration, even over a couple of months, and can have an effect on an individual's judgement or their ability to perform familiar tasks.

- **Visual impairments**

  Visual impairment is a risk factor for falls and on average approximately doubles fall risk in a wide variety of studies. Fall risk increases as visual impairment worsens and the relationship is almost certainly causal (Harwood, 2001). Visual acuity, contrast sensitivity, visual field, cataract, glaucoma and macular degeneration all contribute to risk of falls, as do bifocal or multifocal lenses. Multifocal glasses impair depth perception and edge-contrast sensitivity at critical distances for detecting obstacles in the environment. Older people may benefit from wearing non-multifocal glasses when negotiating stairs and in unfamiliar settings outside the home.
- **Foot problems**

  Bunions, toe deformities, ulcers, deformed nails and general pain in walking increase balance difficulties and risk of falls.

Extrinsic risk factors:

The size of the impact environmental factors have on the risk of falling among older people is uncertain. According to the report by Todd & Skelton (2004) some studies have reported that between 30% to 50% of falls among community dwelling older people are due to environmental causes and other studies report that 20% of falls are due to major external factors (those that would cause any healthy adult to fall). Older people often have problems slipping or tripping and lack good balance or righting mechanisms for preventing the fall.

Extrinsic risks include:

- Environmental hazards (poor lighting, slippery floors, uneven surfaces, etc.).
- Footwear and clothing.
- Inappropriate walking aids or assistive devices.

Exposure to risk:

According to the same report by Todd & Skelton (2004) some studies suggest a U-shaped association, that is, the most inactive and the most active people are at the highest risk of falls. This reveals the complex relationship between falls, activity and risk.

Although there are numerous risk factors that could lead to falling among the elderly, this study will focus on the most common, modifiable risk factors that have been shown, either individually or as a combination, to improve due to exercise intervention such as balance, gait, strength and endurance as well as the subjective rating of the fear of falling.

2.3.2.1 Balance

"We come into this world head first and go out feet first; in between it is all a matter of balance"- Paul Boese (Garcia, 2011)

The successful control of balance depends on a series of complex processes that are triggered by either a conscious or unconscious decision to act, involving multiple systems within the body. The motor system acts on internally and externally provided sensory information. The somatosensory system provides information about location and movements of the body relative to the support surface – this information is provided by important proprioceptors located in the muscles and joints throughout the body (e.g. muscle spindles and joint receptors), and the vestibular system(a delicate balance mechanism located in the inner ear and activated when we move our head), in conjunction with the visual system, helps determine whether the world or the body is moving (Rose, 2003:14).

Balance can be defined as the process by which we control the body's centre of mass (COM)/COG with respect to the base of support, whether it is stationary or dynamic (Toraman & Yildirim, 2010). When standing upright in space the COM must be maintained within the confines of the BOS, whereas when walking, the COM is continuously moving beyond the BOS and re-establishing a new BOS with each step taken (Rose, 2003:4). This dynamic balance is shown to be mostly relevant with falling risk (Toraman & Yildirim, 2010).

Good posture is essential to good balance and refers to the biomechanical alignment of each body part as well as the orientation of the body to the environment. Anticipatory postural control is used to avoid obstacles as well as adapting gait pattern due to different types of surfaces (e.g. firm to compliant or moving surfaces or wide to narrow surfaces). In contrast, reactive postural control allows a quick response to an unexpected event (e.g. stepping into a hole or being bumped in a crowd). Horak (1987) defines postural control as the ability to maintain equilibrium and orientation in a gravitational environment. According to Rose (2003:6), there are three distinct postural control strategies, referred to as the ankle, hip and step strategy. The ankle strategy is the movement of the body as a single entity about the ankle joints and is used to restore balance following a small nudge or push. This strategy requires adequate range of motion and strength in the ankle joints as well as an adequate level of sensation in the feet. The hip strategy allows the upper and lower body to move in opposite directions as a result of the hip muscles being activated to control balance. This strategy would be important if the speed and distance of sway increases and requires adequate range of motion and strength in the hip region. The final postural control strategy used to control balance is the step strategy and it occurs when the COG is displaced beyond the maximal stability limits and requires a new base of support. This strategy requires adequate lower body muscle strength, power and range of motion, adequate central processing speed and the ability to move the limb quickly during step initiation (Rose, 2003:7). The elderly often develop a forward head and kyphotic posture which greatly restricts their movement, and may affect postural control (Spirduso *et al*., 2005:140) and therefore the inability to use the correct postural control strategy to control balance and prevent a fall.

The structural and functional changes that occur within the central nervous system (CNS) with advancing age appear to have the most profound and observable effect on motor function as a whole. There is a significant decrease in the speed with which older adults initiate and execute movements, particularly when the complexity of the activity increases. At a behavioural level, these cumulative changes in the ageing CNS appear to manifest themselves in a reduced ability to perform a variety of complex movements that require speed and accuracy, balance, strength, and coordination (Rose, 2003:8).

The crucial factor in relation to fall risk is the redundancy of balance capacity against the balance demands of the individual's levels of fall-risky lifestyle and behaviour (Laessoe *et al*., 2007).

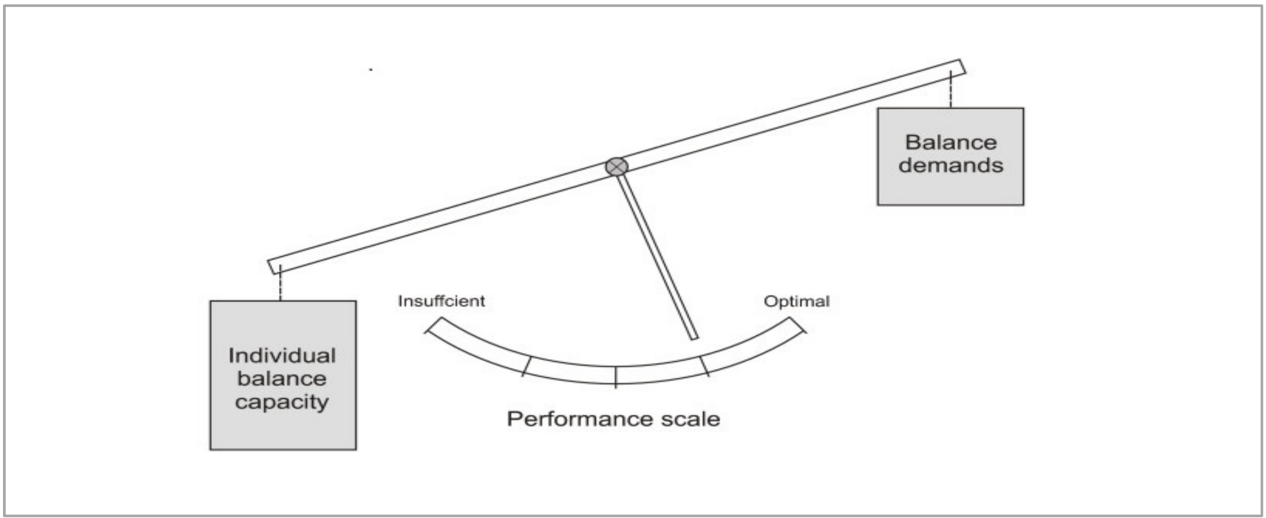

Figure 2.3: Balance performance model (Laessoe *et al*., 2007)

Balance performance model (as shown in Figure 2.3). This is a model which illustrates the interaction between balance capacity and balance demands. The interaction is reflected in an outcome which is measured on a given scale. A redundancy of balance capacity in relation to balance demands will ensure a good balance performance. On the contrary, an increase in the balance demand or loss of balance capacity results in insufficient performance (Laessoe *et al*., 2007), which may result in a fall.

2.3.2.2 Fear of falling

One of the most cited risk factors predisposing the elderly to recurrent falls, is the fear of falling (FOF), referred to by Niino & Nishita (2008) as post-fall syndrome, which comes with serious psychological symptoms associated with falls.

In the last decades, FOF has gained recognition as a health problem that may be as disabling as, and sometimes even more disabling than, the fall itself. Initially, FOF was believed to be a consequence of falling, a psychological trauma of the fall, resulting in reduced activity and consequent losses in physical abilities. However, since the early 1990s increased research attention has been dedicated to the phenomenon of FOF among the elderly. This focus might be explained by the growing awareness that FOF is frequent in older populations and can lead to excessive activity restriction and in that way affect seniors' health, well-being and quality of life. FOF is reported by up to 85% of the elderly, and this fear also showed to be prevalent in people who have not recently fallen. FOF can potentially lead to a variety of behavioral changes that may adversely affect future health, mobility and activity, including changes in posture and gait, avoidance of feared activities and environments as well as self-maintenance. This reduction in mobility and independence are often serious enough to result in admission to a hospital or nursing home and even premature death (Bicket *et al*., 2010).

In a study done by Oh-Park *et al*. (2011) it was found that the proportion of participants in their study with incident FOF increased linearly with an increasing number of risk factors and Yamagiwa *et al*. (2011) found that the incidence of fear of falling, particularly among women, increased with advancing age.

2.3.2.3 Gait

Walking is generally viewed as an automated, over-learned, rhythmic motor task and may even be considered the lower-limb analogue of rhythmic finger tapping, another automated motor task. Thus, one might hypothesize that walking would be associated with a simple rhythmic task like tapping rather than with a complex motor task like catching. Surprisingly, however for older adults, routine walking has more in common with complex motor tasks, like catching a moving object, than it does with tapping and therefore gait can be said to be a complex cognitive task in the elderly (Painter *et al*., 2010).

Three major tasks must be achieved during the gait cycle which are weight acceptance, single limb support and limb advancement. In order to achieve a normal gait pattern an individual must have four major attributes: an adequate range of joint mobility, appropriate timing of muscle activation across the gait cycle, sufficient muscle strength to meet the demands involved in each phase of the gait cycle and unimpaired sensory input from the visual, somatosensory and vestibular systems(Rose, 2003:179). Older adults have the tendency to load the limb more cautiously during the weight acceptance task, a flatter foot-to-floor contact pattern, less forward progression of the limb during single limb support, and reduced knee flexion during the pre-swing and swing phase of gait (Rose, 2003:182).

Rose (2003:182), a professor in the division of Kinesiology and health promotion and co-director of the Centre for Successful Ageing at California State University at Fullerton lists the following gait changes observed in older adults:

- Decreased velocity
- Decreased step frequency
- Increased stride width
- Increased time in double support
- Decreased stride length
- Increased stance phase
- Decreased time in swing phase

The most significant gait parameter affected by age is variable gait speed which is largely attributable to stride length, reduced arm swing, and reduced rotation of hips, knees and ankles, an increase in double support time, and more flat foot contact as well as a speed decrease during obstacle negotiation (Spirduso *et al*., 2005:149). It has been demonstrated that when approaching obstacles, older adults further reduce their gait speed and clear the obstacle using a much slower and shorter step. This reduction in step length decreases the likelihood of tripping, but it often causes the heel or sole of the foot to contact the obstacle before the fore-foot returns to the ground on the other side (Rose, 2003:182). Uemura *et al*. (2011) found that motor performance deterioration occurred in high-risk participants at the beginning of the pre-crossing phase of obstacle negotiation. A slow and inefficient anticipatory postural adjustment (APA) at the pre-crossing phase of obstacle negotiation might be one of the causes of accidental falls. Age has also been shown to effect the inter-joint coordination during obstacle-crossing. During the leading limb crossing, greater variability of the inter-joint coordination, correlated to the increased toe clearance, indicates that ageing increases the variability of the way the lower limb joints are controlled during obstacle crossing (Hsiao-Ching *et al*., 2009).

Findings by Liu-Ambrose *et al.* (2010) suggest that changes in step-width, step-time, and step-length with dual tasking may be related to future risk of falling. A study done by Priest *et al.* (2008) highlights that balance confidence is independently associated with dual-task gait performance. The gait changes observed in dual task walking characterise reduced gait stability and indicate that cognitively demanding tasks during walking have a destabilising effect on gait.

Slower gait speed, shorter stride length, increased stride width and prolonged double limb support time were all found to be associated with a pre-existing fear of falling (Chamberlin *et al*., 2005). A study done by Delbaere *et al*. (2009) suggests that walking performance is influenced by both physiological and psychological factors. Physiological falls risk appears to determine walking speed under optimal conditions, whereas concern about *falling* elicits greater (possibly excessive) gait adjustments under conditions of postural threat.

An abnormal gait mainly comes from structural changes in the musculoskeletal system and degeneration of the nervous system with age (Demura & Yamanda, 2007). Callisaya *et al.* (2009) suggest likely factors that may explain gait variability in the general older population are body sway, reaction time, quadriceps strength and proprioception (the scientific term for the physical feeling of your moving body-Batson, 2008). Figure 2.4 illustrates the gait pattern of an elderly man in his eighties compared to that of his younger self (age 20), demonstrating how gait changes with aging.

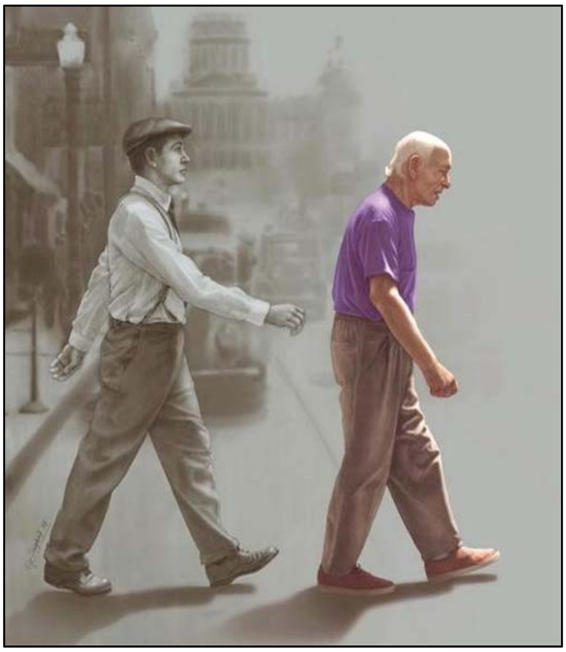

Figure 2.4: Gait pattern of the same man, 80 years of age versus 20 years of age (Daugherty, n.d.)

2.3.2.4 Muscular strength and endurance

The changes that occur in skeletal muscle with ageing, are defined by sarcopenia. The most apparent changes are decreases in muscle cross sectional area (maximum force which can be produced by a muscle is directly proportional to its cross-sectional area- Maughan, 1983) and the volume of contractile tissue within the cross sectional area. This is caused by the gradual disuse of the muscle fibres as elderly people become much less active. The preferential loss in area is principally seen in the fast twitch fibres (the latter recruited for higher intensity or more prolonged exercise - Foss & Keteyian, 1998:151), due to lack of explosive movements as the individual ages. Disuse also leads to muscle tissue atrophy and this tissue is replaced by connective tissue, fat and vacuous space. Whole-muscle mass decreases with age due to a decrease in fibre number (mainly fast twitch fibres) and a decrease in the size of individual fibres. It is reported that the major decrements in size occur between the ages of 60 and 80 years. The result is reduced strength caused by reduced muscle size and contractibility. A number of other noticeable changes occur to the muscle fibre with ageing such as a decrease in ATPase (an enzyme that facilitates the breakdown of ATP - Foss & Keteyian, 1998:596), ATP (a complex chemical compound formed with the energy released from food and stored in all cells, particularly muscles. Only by the energy released by the breakdown of this compound can the cell perform work - Foss & Keteyian, 1998:595) activity, motor neuron number, and in nerve conduction, an increase in length of contraction and twitch tension as well as a lower muscle excitation threshold. The underlying mechanisms appear to be due to inactivity and due to changes in functional demands for force, velocity and duration (Taylor & Johnson, 2007:34).

Muscles of the upper extremities, such as handgrip muscles or elbow extensors, tend to change less with age, when compared with muscles of the lower extremities (Spirduso *et al*., 2005:109). Among studies done by Rubenstein & Josephson (2006) leg weakness was identified as the most potent risk factor associated with falls and increased the odds of falling, on average, by more than four times. Strength losses have been shown to be most dramatic after the age of 70 years (Spirduso *et al*., 2005:109). Robbins *et al.* (1989) showed that poor quadricep strength has an effect on gait variability.

2.4 GETTING UP

The risk of falling increases with age and declining muscle function reduces the ability to get up (Fleming & Brayne, 2008). The risk factors for inability to get up are similar to those for falling (Tinetti *et al*., 1993). Lying on the floor for a long time after falling is more common among the "oldest old" than previously thought and is associated with serious consequences. Such consequences include hypothermia, dehydration, bronchopneumonia and the development of pressure sores (Fleming & Brayne, 2008). Time spent on the floor is also associated with fear of falling and half of those who lie on the floor for an hour or more die within six months, even if there is no direct injury from the floor (Lord *et al*., 2011:12). Lord *et al*. (2011:12), also state that only up to 47% of non-injured fallers are able to get up off the floor without assistance.

The inability to get up from lying on the floor is the strongest independent risk factor for serious fall- related injury (Bergland & Wyller, 2004). Injuries can be both a cause and a result of lying on the floor for a long time, which can be viewed not only as a possible outcome of falling, but also as a predictor of further sequelae such as admissions to hospital and or a care home (Fleming & Brayne, 2008).

In a study conducted by Fleming & Brayne (2008), two thirds (n=110) of all the falls reported, the person who fell was unable to get up without help. Their study also showed that many factors were associated with difficulty in rising from the floor; the important sociodemographic descriptors being age and sex. Women were six times more likely than men to have difficulty getting up and reported mobility was consistently associated with inability to get up. Severe cognitive impairment was significantly associated with lying on the floor for a long time. There were marked associations with other potential sequelae of falling for both being unable to get up and for lying on the floor for a long time. Any degree of injury was common, regardless of time on the floor. Serious injury, however, was consistently associated with lying on the floor for a long time (a 'long lie' - Lord *et al*., 2011:12), anything up to one hour.

After a fall, panic is often the first reaction. However, how one reacts after a fall can cause more injuries than the fall itself. If one tries to get up too quickly or in the wrong position, injuries incurred may become worse. Not surprisingly, therefore, many geriatric medicine texts recommend that old people at risk of falling should be taught how to get up from the floor. However, this is rarely done (Fleming *et al*., 2008).

Simpson & Salkin (1993) suggest that all old people at risk should be assessed with regard to their suitability for learning how to get up from the floor. Many older adults are unaware of the procedures for rising safely from the floor. This is an important skill should a fall occur especially when alone at home.

Rose (2003:134), divides the floor to standing progression into levels of difficulty from easiest to most difficult.

- Easiest progression

  Supine/prone to side lying position to side sitting to kneeling with hands on the floor, then crawling to an external support to pull up to standing.

- More difficult (emphasizes upper body strength)
  Supine/prone to side lying position to side sitting to kneeling with hands on the floor, then hand walking to standing.
- Still more difficult (emphasizes lower body strength)
  Supine/prone to side lying to side sitting to kneeling to half kneeling to standing.
- Most difficult
  Supine/prone to symmetrical sit up to squat to leg reliance to standing.

The most difficult floor to standing progression is very difficult for the majority of older adults to use successfully unless they are well conditioned and injury free.

2.5 ASSESSMENT

The identification of individuals at risk of falling is not a trivial matter, especially with regards to balance assessments which have changed and progressed over the years to one of the most objective state of the art balance assessment tools on the market and used within practice at the moment, namely the Biodex Balnce System. The progressions in balance assessments will be discussed further on in the text. Many different physiological performance tests are believed to be sensitive to fall risk. A major problem, when predicting fall risk, is the multi-factorial mechanisms of falls. The influence of environmental factors and the difficulty in daily tasks performed have to be considered as well as the individual physiological factors (Laessoe *et al*., 2007). Not only will assessment facilitate the early identification of older adults who are beginning to experience significant changes in multiple body systems resulting in observable changes in postural stability and mobility but it also aids in the development of an appropriate intervention programme that will target the identified system impairments (Rose, 2003:25), with the aim of potentially decreasing the risk of sustaining a fall.

The American and the British Geriatrics Society along with the American Academy of

Orthopaedic Surgeons Panel on Fall Prevention (n.d.) state that assessment measures should be based on the specific desired constructs one wishes to evaluate and influence. The justification for assessments to identify a specific risk factor is strongest when successful treatment or other risk reduction strategies have been explicitly based on this specific risk factor. A comprehensive review was carried out on a number of articles relating to 'falls' and the 'elderly' over the past five years, to ensure such a review is based on the most recent literature. The aim of the review was to gather as much information as possible relating to fall risk factors as well as assessment measures that have and are being used to assess the risk of falling among the elderly.

2.5.1 Assessment measures used

2.5.1.1 Assessment scales to evaluate fear of falling

Fear of falling is a major, specific health problem among older adults. A systematic review carried out by Scheffer *et al.* (2008) showed FOF leading to physical, functional, psychological and social changes in older adults. Balance and gait problems appeared to be strongly associated with FOF. Fear of falling also showed a substantial decrease in physical activity or physical health as well as functional dependence in activities of daily living. A reduction in social activity, as well as depression was also shown. A better understanding of FOF can contribute to the early identification of FOF and to provide more efficient interventions for primary (and secondary) prevention of falls in order to reduce some of the serious adverse health consequences of FOF.

Many studies incorporate questionnaires focusing on questions relating specifically to the individuals' current health status and medical history as well as their level of activity and concerns surrounding falls, leading to an actual 'fear of falling'.

2.5.1.2 Balance assessment instruments

Balance assessments made up the majority of the assessment measures used in this study due to the high risk value balance deterioration can have on falling among the elderly. Balance evaluation is one of the most common risk factors tested in the available literature. Field methods for measuring balance have included various balance stands (e.g., one-foot stand with eyes open and with eyes closed, standing on a narrow block) and balance walks on a narrow line or railsuch as the Wellnitz portable balance beam (Mathews, 1973:198; Campbell & Tucker, 1966:106). Another balance test used was the Bass test for dynamic balance (Corbin & Lindsey, 1970). In the laboratory, computer-based technology is now being used to evaluate balance measured on an electronic force platform or to analyze a videotape recording of the participant walking (Satcher *et al*., 1996: 35).

The Biodex Balance System was selected to provide an objective balance assessment for this study. It is one of the most modern assessment tools available, is versatile and is the only system that provides fast and accurate specific fall risk screening for older adults.

2.5.1.2.1 Biodex Balance System

The Biodex Balance System (BBS), as shown in Figure 2.5, is a devise with a circular balance platform that quantifies the ability to maintain dynamic bilateral and unilateral balance, as well as dynamic limits of stability (LOS) (Ishizuka, 2007)**.**

Figure 2.5: Biodex Balance System SD (Testerman & Vander Griend, 1999)

The BBS is globally an integral component of a fall risk assessment. The BBS is designed to evaluate postural balance and dynamic postural stability. The BBS has shown to provide valid, reliable and repeatable objective measures of an individual's ability to balance on stable and unstable surfaces and document this neuromuscular control in a safe environment (Biodex Balance System SD: Clinical Resource Manual, n.d.:1-5). Unlike the majority of balance evaluation tests, the BBS allows the measurement of not only static balance, but also dynamic balance. Dynamic balance can be defined as the body's maintenance of equilibrium under conditions causing the COG to move in response to muscular activity whereas static balance entails the maintenance of equilibrium standing in one spot. It is clear then that static balance measures do not resemble real life movement.

The BBS is a multiaxial device increasing the proprioceptive input to the spinal cord by increasing the responsiveness and sensitivity of the mechanoreceptors. Unlike force plate systems the BBS uses a circular platform that is free to move in the anterior-posterior – forward and back and medial-lateral – inwards and outwards axes simultaneously and it allows up to 20° of foot platform tilt which permits the ankle joint mechanoreceptors to be maximally stimulated. Although the movement of the BBS does not resemble all daily activities involving dynamic balance, it does involve angular perturbation of the ankle. Real life examples involving angular perturbations of the ankle include losing balance across an uneven surface or turning an ankle while stepping across a curb or sidewalk (Cachupe *et al*., 2001).

2.5.1.2.2 Balance Evaluation Systems Test (BESTest)

Current clinical balance assessment tools do not aim to help therapists identify the underlying postural control systems responsible for poor functional balance (Horak *et al*., 2009). The postural control system has two main functions: First, to build up posture against gravity and ensure that balance is maintained; and second, to fix the orientation and position of the segments that serve as a reference frame for perception and action with respect to the external world. This dual function of postural control is based on four components:

1. Reference values, such as orientation of body segments and position of the COG (an internal representation of the body or postural body scheme).
2. Multisensory inputs regulating orientation and stabilization of body segments.
3. Flexible postural reactions.
4. Anticipations for balance recovery after disturbance, or postural stabilization during voluntary movement (Massion, 1994).

Professor Fay Horak, Research Professor of Neurology and Adjunct of Physiology and Biomedical Engineering in the Department of Neurology at Oregan Health and Sciences University, along with Professor DM Wrisley, assistant Professor at the Department of Rehabilitation Science at the University of Buffalo in New York and Professor J Frank, Dean of Graduate Studies at the Department of Kinesiology at the University of Windsor in Canada (2008), developed a test called the Balance Evaluation-Systems Test (BESTest), a theory based, research driven, practical clinical tool. By organising clinical balance test items already in use, combined with new items not currently available, the BESTest is the most comprehensive clinical balance tool available (Horak *et al*., 2009).

After Horak and Frank developed the BESTest, thousands of experienced physical therapy clinicians contributed to the continued development of the BESTest by providing feedback around clarity, sensitivity and practicality of items across 38 continuing education workshops delivered by Horak between 1999 and 2005. Following two days of didactic and observational training in the test, therapists in the workshops practiced performance of the test on each other and provided critical feedback to improve the clarity and specificity of instructions to patients and therapists (Horak *et al*., 2009).

Balance deficits are one of the most common problems treated by biokineticists and physiotherapists. They need to identify who has a balance problem and then decide the best approach to rehabilitation. There are standardized clinical balance assessment tools directed at screening for balance problems and predicting fall risk, particularly in elderly people. These tools identify which patients may benefit from balance retraining, but they do not help therapists decide how to treat the underlying balance problems. The BESTest is a new balance assessment tool developed to help physical therapists identify the underlying postural control systems that may be responsible for poor functional balance so that treatments can be directed specifically at the abnormal underlying systems (Horak *et al*., 2009).

Although many clinical tests are designed to test a single "balance system", balance control is very complex and involves many different underlying systems. Previous motor control models assumed postural control consisted of hierarchical righting and equilibrium reflexes. Horak *et al*. (2009), wanted to develop a clinical test of balance control based on Bernstein's (Nikolai Bernstein viewed by many as father of contemporary motor control, was deeply involved in studies of the effects of learning on motor coordination in the 1940's– Latash & Lestienne, 2006: vii) concept that postural control results from a set of interacting systems.

<u>Figure 2.6</u> shows the 6 interacting systems underlying control of balance that are targeted in the BESTest. Each system consists of the neurophysiological mechanisms that control a particular aspect of postural control.

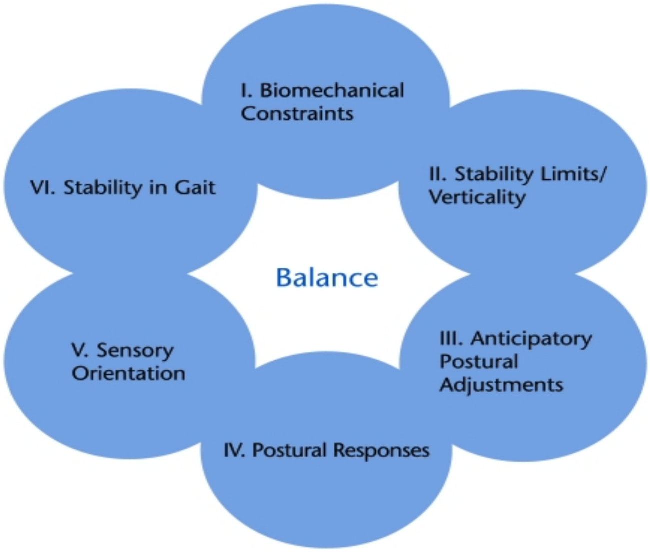

Figure 2.6: Model summarizing systems underlying postural control corresponding to sections of the Balance Evaluation- Systems Test (BESTest) (Horak *et al*., 2009)

Consistent with this "systems model of motor control," recent research has demonstrated how constraints, or deficits, in different underlying systems can impair balance:

I. Biomechanical system

Constraints on the biomechanical system, such as ankle or hip weakness and flexed postural alignment (Kyphosis), limit the ability of frail, elderly people to use an ankle strategy or compensatory steps for postural recovery. The most important biomechanical constraint on balance is the size and quality of the base of support: the feet. Any limitations in size, strength, range, pain or control of the feet will affect balance.

II. Limits of stability

Constraints on the limits of stability (that is, how far the body's COM can be moved over its BOS) and on *verticality* (that is, representation of gravitational upright), affected by sensory deficits, may result in inflexible postural alignment or precarious body tilt.

III. Anticipatory postural adjustments

Constraints on anticipatory postural adjustments prior to voluntary movements depend on interaction of supplementary motor areas (programming areas for motor subroutines and that these areas form a queue of time-ordered motor commands before voluntary movements are executed by way of the primary motor area -Roland *et al.*,1980) with the basal ganglia (a group of nuclei lying deep in the subcortical white matter of the frontal lobes that organize motor behaviour -Purves *et al.*, 2001) and brain-stem areas and result in instability during step initiation or during rapid arm movements while standing.

IV. Automatic postural responses

Constraints on short, medium, and long proprioceptive feedback loops responsible for automatic postural responses to slips, trips and pushes include late responses in patients with sensory neuropathy or multiple sclerosis, weak responses in patients with PD and hypermetric responses in patients with cerebellar ataxia.

V. Sensory integration

Constraints on sensory integration for spatial orientation result in disorientation and instability in patients with deficits in pathways involving the vestibular system and sensory integrative areas of the temporoparietal cortex when the support surface or visual environments are moving.

VI. Dynamic balance during gait

Constraints on dynamic balance during gait result from impaired coordination between spinal locomotor and brain-stem postural sensorimotor programs when the falling body's center of mass must be caught by a changing base of foot support. In addition, cognitive constraints on executive or attentional systems can compound constraints in the other systems because each underlying neural control system for balance control requires cortical attention (Horak *et al*., 2009).

2.5.1.3 Muscular strength evaluation

Muscle weakness and reduced physical fitness, particularly to the lower body, are one of the most common intrinsic risk factors for falling. A panel of the American Geriatrics Society, British Geriatrics Society and American Academy of Orthopaedic Surgeons, found it to be the most important risk factor, increasing risk of a fall by four to five times. Related balance and gait disorders have also been shown to be closely linked to falls, creating a three-fold increase in the risk of falling (Kronfol, n.d.)

Sarcopenia or muscle loss is thought to have direct effects on performance and leads to disabilities, increased risk for falls and increased vulnerability to injury. There is also an increased fracture risk due to greater impact. Loss of muscle mass also has metabolic effects, including accelerated bone loss. Overall, cross sectional data indicate a strength decline of 15% per decade in the sixth and seventh decades and 30% per decade thereafter. For 75-84 year olds, a large percentage have difficulty with minimal tasks of endurance or strength. Functional consequences of weakness include diminished gait performance, falls, and dependence in activities of daily living. Leg power has been correlated with functional performance. There is a negative correlation between strength and walking speed: Quadriceps strength and gait speed correlate in the very old. In older women, leg power is closely associated with walking speed and accounts for 86% of the variance in speed (Kronfol, n.d.). Therefore, measuring lower body strength is critical in evaluating the functional performance of older adults.

It is necessary that the likelihood of falling should be evaluated from the view point of both decreased physical function and FOF. Assessments should include measures that are reflective of both the functional capabilities and quality of postural strategies, are reliable and valid, as well as practical, i.e.; easy to use and inexpensive. Functional tests are helpful to document functional status and changes with intervention (Mutoh *et al*., 2008).

The first research article introducing the 30 Second Chair Stand Test was authored by Jones *et al*. (1999).The 30-second sit to stand was initially developed as an assessment tool to assess lower body strength. It has since been used to identify, predict and correlate with other areas of the International Classification of Functioning, Disability, and Health (ICF) model (Jones *et al*., 1999). One of the most common activities of daily living, and a precursor to walking, is rising from a seated to a standing position. The ability to perform the sit-to-stand (STS) movement is important to maintaining physical independence and may be one of the most important functional measures of physical capacity. Age-related decreases in lower limb strength, speed and power are considered major contributing factors to the diminishing capacity to perform basic activities of daily living (e.g., rising from a chair, walking unassisted and climbing stairs) and to increasing morbidity and ultimately leading to death (McCarthy *et al*., 2004).

2.6 PREVENTION

In ancient China as early as 3000 to 1000 B.C., the classic *Yellow Emperor's Book of Internal Medicine* first described the principle that human harmony with the world was key to prevention and that prevention was the key to long life. These principles grew into concepts that became central to the 6th century Chinese philosophy Taoism, where longevity through simple living attained the status of a philosophy that has guided Chinese culture through the present day. Tai chi chuan, an exercise system that teaches graceful movements, began as early as 200 B.C. with Hua To and has recently been shown to decrease the incidence of falls in elderly Americans (Satcher *et al*., 1996:12).

Falls and fall related injuries are common, potentially preventable causes of morbidity, functional decline and increased health-care use among elderly persons (Rizzo *et al*., 1996). Falls in the elderly can be prevented or at least become less frequent through an understanding of risk factors (Larson & Bergmann, 2008). Many of the modifiable risk factors involve physical function. Therefore physical activity plays a key role in both risk factor assessment and intervention. Todd and Skelton (2004) refer to a strategic approach to falls and fracture prevention in their report as having three specific stages. Firstly to identify high-risk groups of older people, secondly to carry out a detailed assessment in order to identify individual risk factors for falls or fracture and thirdly the introduction and implementation of an intervention programme aimed at reducing the identified risk factors.

Specific exercise programmes have been shown to work best within a multifactorial fall-prevention programme but there is evidence that they do work alone as well (Das & Joseph, 2005; Lehtola *et al.*, 2006). This conclusion is further supported by a recent study done by Nelson *et al.* (2007), where they conclude that physical activity should be one of the *highest priorities* for preventing disablement in older adults and that effective intervention to promote physical activity in older adults deserves wide implementation. The consistency of reported reductions in fall-related injuries across all programmes support the preliminary claim that the population-based approach – ("Population-based care involves a new way of seeing the masses of individuals seeking health care. It is a way of looking at patients not just as individuals but as members of groups with shared health care needs. This approach does not detract from individuality but rather adds another dimension, as individuals benefit from the guidelines developed for the populations to which they belong."-Halpern & Boulter, 2000) to the prevention of fall-related injury is effective and can form the basis of public health practice (McClure *et al.*, 2005).

In a study carried out by Hektoen *et al.* (2009) it was found that the reduction in healthcare costs per individual for treating fall-related injuries was 1.85 times higher than the cost of implementing a fall prevention programme. Their study concludes that the reduction in healthcare costs more than offset the cost of the prevention programme for women living at home, aged 80 years or older, which indicates that health authorities should increase their focus on prevention.

Exercise programmes have been proven to provide beneficial effects (Yasumura & Kanari, 2005), however it is necessary to consider exactly what and how much exercise one should prescribe to elderly individuals who are at high risk of falling.

The results from a study done by Kim *et al.* (2011) suggest that multidimensional exercise is an effective strategy for reducing geriatric syndromes in the elderly population and interventions aimed at reducing fear of falling may produce larger gains in health related quality of life (Iglesias *et al*., 2009). Schott (2007) concluded that the significant impact of functional and behavioral characteristics on activity-related fear of falling emphasizes the need for interventions enhancing fall-related self-efficacy to lessen activity-related FOF in older adults. Increased emphasis on mobility during rehabilitation leads to improved confidence to perform activities of daily living without falling (Bishop *et al*., 2010).

Todd & Skelton (2004) found that interventions with balance training at the core proved to be the most effective across a wide range of ages including people with mild to major functional limitations. A study by Vaillant *et al.* (2006) showed that balance was improved after the exercise sessions and the improvements were clinically significant and increased over time. This finding is supported by Sherrington *et al*. (2008) who claim greater relative effects are seen in programmes that include exercises that challenge balance. Halvarsson *et al.* (2011) found that a balance training programme is feasible and leads to decreased FOF, decreased time for step execution during dual-task performance and increased velocity during fast walking. Proprioceptive exercise (exercises challenging balance and postural control in space) appears to have the best impact on balance regulation and precision (Gauchard *et al*., 2006).

Strengthening the lower body is especially important as it has been found that lower body strength diminishes at a faster rate than upper body strength (Gardner *et al*., 2001). Data from a study done by LaStayo *et al.* (2003), demonstrated that lower extremity resistance exercise can improve muscle structure and function in those with limited exercise tolerance. A report on the prevention of falling by Todd & Skelton (2004) also highlights the need for adequate strength training before more challenging balancing exercises are introduced. The association of progressive strength training for the quadriceps and the proprioceptive training is effective for the prevention of falls, increasing the muscle power, the static and dynamic balance and increasing the speed of the motor responses, therefore improving the performance of daily activities (Teixeira *et al*., (2010); Satcher *et al*., 1996:7 &44). Recovery of balance after a trip is limited in the elderly probably because forward placement of the recovery leg is slower, likely due to neural factors. Furthermore, balance recovery is impaired in the elderly because joint movements in the stance leg are generated more slowly and reach lower peak values, likely due to a combination of muscular and neural factors. These results suggest that coordination and strength training can contribute to fall prevention among the elderly (van Dieën *et al*., 2005). Gu *et al.* (2006) found the most desirable type of exercise intervention to prevent falling is lower limb strength and balance exercise together.

Enhancement of lower extremity strength contributed to improvements in balance stability, demonstrated by greater ankle force production in response to balance threats (Hess *et al*., 2006). Findings from a study carried out by de Bruin(2007) suggest that twice-weekly lower extremity strength training of 12 weeks' duration in hostel-dwelling elderly people only improves task-specific balance performance and lower extremity physical function when additional functional exercises are added . Pavol & Pai (2006) support that the improvement of proactive and reactive limb support should be a focus of fall prevention efforts. Chaimoff *et al.* (2006) found that a progressive programme of balance and gait training and muscle strengthening seems to induce compensation for sensory deficits.

Iwamoto *et al.* (2009) stress the importance of a safe and well tolerated exercise programme appropriate for elderly with a high risk of falling. Due to the fact that many older people reject the idea that they are at risk of falling, the uptake of strength and balance training programmes may be promoted more effectively by maximizing and emphasizing their multiple positive benefits for health and well-being. A personal invitation from a health professional to participate is important (Yardley *et al*., 2006). The motives for continuation of exercises depend on the understanding of the patients and the physical, psychological and social effect of the exercise at the earlier period of the therapy. In order to increase the motives for the exercise, the necessity and effect of exercise should be explained repeatedly to the patients (Bonkohara & Kajihara 2002).

An effective duration of exercise is necessary to see physiological training changes to match improvements in confidence. Successful exercise programmes have consistently been longer than 10 weeks of duration. Exercise needs to be specific (dynamic balance, strength, endurance and gait training), progressive and sustained to have continuing benefit. Strategies for coping on the floor after a fall are essential and should also be practised safely in a group environment (Skelton, 2004).

There has been extensive literature over the past six years investigating the effects of exercise intervention on the risk of falling among the elderly, however, only a few studies have incorporated the combination of balance, gait and strength training (Chaimoff *et al*. (2006); Kim (2008); Iwamoto *et al*. (2009)) and no studies were found to include any sort of coping or getting up strategies should a fall occur. The study done by Chaimoff *et al.* (2006) is the only one that also takes fear of falling into account.

From cost efficiency and public health perspectives, exercise-alone interventions can be considered valuable, as they are more likely to be implemented in countries with fewer resources (Petridou, 2009). However, few studies have reported the effect of exercise intervention on falls in residential care facilities (Kim, 2008).

CHAPTER 3: RESEARCH METHODS AND PROCEDURES

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3.3 RESEARCH DESIGN AND ENVIRONMENT

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3.1 INTRODUCTION

Falls among the elderly, particularly women (Trembley & Barber, 2005), are prevalent, dangerous and costly. Even falls that do not result in injury can have serious consequences. Psychological trauma and fear of falling produce a downward spiral of self-imposed activity reduction which leads to loss of strength, flexibility and mobility, thereby increasing the risk of future falls. The number of older persons with fall induced injuries is increasing at a rate that cannot be explained by demographic changes alone and strong preventative measures should be adopted to control the increasing burden of injury. As falls are not a normal part of ageing, they may be preventable to a large degree. Risk factors for falls have been identified and there are many screening tools available to determine the presence of balance and mobility disorders (Rose & Allison, 2012). Exercise has been shown to be effective in lowering fall risk among the elderly (Gardner *et al*., 2000) and the development of a specific exercise intervention programme focussed on reducing the main modifiable risk factors is proposed (using information from results of this study) to advise elderly women at risk of falling on the correct choice of specific exercises in order to decrease this risk.

The research design, subject group, methods and instruments used to capture the data, as well as the research intervention programme will now be discussed, as well as, the safety measures put in place for this study.

3.2 ETHICAL APPROVAL

The researcher was required to present a research proposal for approval by the Research Ethical Committee: Human Research (Non-Health) of Stellenbosch University. The study gained ratification by the Ethics Committee for its commencement, reference number 378/2010.

3.3 RESEARCH DESIGN AND ENVIRONMENT

The study was conducted as a quantitative experimental study at Stellenbosch in the Western Cape, South Africa. The initial introduction of the study was conducted at three randomly selected retirement homes within the Stellenbosch area close to the Stellenbosch University (SU) Campus. The managers of the three randomly selected retirement homes were then approached by the researcher for permission to organise a presentation for the female residents of the home, 65 years and older. The retirement homes addressed were Azaleahof, Langverwag and Utopia. A powerpoint presentation was conducted by the researcher outlining the study in detail, as well as information on risk factors leading to falls in the elderly, and the importance of prevention in order to motivate their participation in the study. Initially a total of 30 subjects signed up for the study and their contact details were collected. These individuals were then contacted individually by the researcher and a time was arranged in order to complete the Health Activity Questionnaire (APPENDIX B). The study was then also explained in more detail and the subjects had the opportunity to ask any questions they had regarding the study. The subjects were then asked to sign a formal consent form compiled through Stellenbosch University (APPENDIX A) which again outlined:

1. The purpose of the study
2. The procedures of the study
3. The potential risks and discomforts
4. The potential benefits to the subject and/or society
5. That there will be no payment remuneration for involvement in the study
6. Confidentiality
7. Participation and withdrawal procedures
8. The identification of the study investigators
9. The rights of the research subjects
10. A section for the signature of the subject or legal representative
11. The signature of the investigator

There was no control group selected for this study and each individual served as her own control. It was unethical to have a control group when most elderly women were likely to benefit from such an intervention. Likewise, it was unethical to accommodate only one group of female subjects while others who were available and willing to participate in the intervention were excluded from the study. According to a statistician, Professor Martin Kidd, Head of the Centre for statistical support at Stellenbosch University, the results of such a study without a control group is valid.

The testing and assessment procedures both pre- and post- intervention were conducted at the Biokinetics Centre located at the Department of Sport Science at Stellenbosch University. These procedures will be discussed in detail. The intervention programme was conducted at each of the subject's specific place of residence for their convenience. The subjects were split into four small groups with a maximum of eight subjects per group to ensure precise exercise execution as well as the safety of each individual.

3.4 EXCLUSION AND INCLUSION CRITERIA

3.4.1 Exclusion criteria

The below list of criteria was set in place in order to set the standards to determine whether potential research participants may or may not be allowed to participate in this research project. These criteria enabled the exclusion of any potential research participant to ensure the safety of each participant as well as the production of reliable results.

See exclusion criteria below:

1. **Cardiovascular and Pulmonary disease**

   Participants were excluded if they presented with any one of the following major signs or symptoms suggestive of Cardiovascular and Pulmonary Disease:

- Pain, discomfort (or other angina equivalent) in the chest, neck, jaw, arms, or other areas that may be due to ischemia
- Shortness of breath at rest or with mild exertion
- Dizziness or syncope(loss of consciousness with interruption of awareness of oneself and ones surroundings)
- Orthopnea or paroxysmal dyspnea (difficulty breathing when lying flat)
- Ankle edema (swollen ankles)
- Palpitations or tachycardia (heart rate over 100 beats per minute)
- Intermittent claudication (muscle pain in legs)
- Known heart murmur
- Unusual fatigue or shortness of breath with usual activities

(Thompson *et al*., 2010:26-27)

Any participant with one or more signs/symptoms listed above or known cardiovascular, pulmonary, or metabolic disease would be classified as a high risk individual according to the American College of Sports Medicine (ACSM) (2000). These individuals would require physician supervision throughout the pre- and post- testing procedures as well as exercise intervention should there be an emergent need. Unfortunately there was no physician present during the research procedures of this study and therefore any high risk participants were excluded from this study.

2. Serious illnesses or comorbidities

Comorbidity refers to the existence of two or more diseases or conditions in the same individual at the same time (Gijsen *et al*., 2001). Individuals presenting with a serious illness such as cancer, diabetes, dementia, Parkinson's disease, osteoarthritis or a combination thereof, were excluded from the study due to the consequences of many of these diseases or specific disease combinations. Such consequences may have included mortality or a substantial decrease in functional status which would have prevented adequate participation in the intervention programme or affected post intervention evaluations due to a possible exacerbation of one of these diseases. There would also be the possibility of increased risk to these individuals should any of the assessments or intervention activities jeopardise their safety or wellbeing.

3. Major musculoskeletal disorders

Major musculoskeletal disorders would include any major joint replacements, pain or injuries that have left an individual incapacitated and unable to carry out normal activities of daily living due to extremely limited mobility and functional capacity or the reliance on an assistive device. These conditions would likely interfere with pre- and post-assessment measures and exercise training by limiting certain movements and exercises that formed an essential and vital part of the assessment or intervention programme. These individuals would unlikely be able to gain the desired benefits the prescribed exercise intervention programme provided in order to attempt to lower particular risk factors leading to falls among the elderly.

4. Uncorrected visual problems

Visual impairments would likely interfere with exercise training, firstly by putting these individuals at increased risk of falling due to their poor visual acuity (clarity), contrast sensitivity (the lowest contrast at which a pattern can be seen) and depth perception (the distance of an object) and their potential inability to execute specific balancing, transfer or depth perception exercises safely and correctly.

5. Vestibular problems

Dizziness would affect these individual's sense of balance and may put these individuals at increased risk of falling during certain of the assessment measures and exercises. It would also affect their ability to gain any noticeable or measurable improvements in balance post-exercise intervention.

6. Significant cognitive impairment

Putting these individuals through the research process would have implications on their mental state due to confusion and fluctuating emotions. This would have implications on the safely of such an individual during assessment and intervention procedures.

7. Psychological disorders

Emotional disturbances such as depression may have also limited motivation to be consistent in attending the required amount of exercise intervention sessions or interfered with the ability to perform all of the exercises correctly in order to gain a measurable improvement. For these reasons, the study outcomes would possibly have been adversely affected.

8. Taking psychotropic medications or Benzodiazepines

Taking psychotropic medication Benzodiazepines can have many negative side effects on gait and postural stability. Poor co-ordination, drowsiness and dizziness may also exist which would put these individuals at a much higher risk of sustaining injury during certain more demanding exercise activities. The side effects of the medication may also prevent any positive measurable effects the exercise intervention may have.

The above exclusion criteria were addressed by means of the Health Activity Questionnaire and research consent form (APPENDIX A & B).

3.4.2 Inclusion criteria

1. **Female and aged 65 years and older**

   Subjects were homogenised by age and gender and only female subjects of 65 years and older were allowed to participate in the study.

2. **No major Cardiovascular and Pulmonary disease signs or symptoms as recognized by the American College of Sports Medicine** (Thompson *et al*., 2010:26-27)

   These signs and symptoms are listed in point one of the exclusion criteria.

3. **No serious illnesses or comorbidities**

   Any illness or disease that would limit full participation or may result in further physical deterioration over the time of the study, therefore influencing post intervention results and study outcome.

4. **Subjects were mobile with no significant musculoskeletal disorders**

   Subjects had to be able to walk unaided (without the use of a cane or external support) in order to be able to carry out all intervention exercises. Subjects also had to be relatively pain-free, to ensure full intervention participation.

5. **Subjects had to be willing to follow a 12-week exercise intervention programme**

   Subjects were asked to sign a consent form prior to commencement of study (APPENDIX A), which informed the subjects of the necessity to attend all exercise sessions over a 12-week period.

6. **Subjects had to sign an informed consent document(APPENDIX A)prior to the commencement of the study**

If all the above inclusion criteria were met by each participant, they were formally invited to participate in the study and informed when and where the intervention programme would commence.

3.5 FINAL SELECTION OF SUBJECTS

A group of elderly women aged 65 years and older were randomly recruited for this study. The study population was from a selection of retirement homes within the Stellenbosch area in the Western Cape, South Africa. The study population consisted of female volunteers who were interested in taking part in this programme to address the probability of their potential risk of falling, as well as improve their functional capacity, and potentially improve their quality of life. The final group of research participants were selected based on the discussed inclusion and exclusion criteria. Initially two retirement homes namely Utopia and Azaleahof were approached where a total of 20 (n=20) subjects volunteered to participate in the study. In order to further increase the sample size another retirement home, namely Langverwag, was approached where an additional eight subjects volunteered to participate in the study (n=28). The final total number of participants that successfully completed the study including pre-intervention assessment, an exercise intervention programme and post-intervention assessment was a total of 22 participants (n=22). A total of six subjects were unable to complete the full study due to unforeseen circumstances preventing these subjects from attending an adequate amount of exercise sessions, if any at all.

Of these six subjects, one developed a gastrointestinal complication and was advised by the specialist physician to stop all physical activity. Two of the subjects had to stop the intervention due to orthopaedic complications and pain. One of the subjects came down with influenza just before the exercise intervention was scheduled to begin and unfortunately remained unwell for over three weeks with remnants of the flu virus. Another two of the subjects missed more than six sessions of the intervention programme due to travel commitments. The four research groups attended a total of 24 exercise sessions which consisted of two 30-minute exercise sessions a week for a total of 12 weeks. Each subject's attendance was carefully recorded to ensure each subject attended the required total of exercise sessions necessary to achieve valid research results. If any subject was unable to attend a minimum of 19 exercise sessions over the 12 week research period, their results would be excluded from the study.

Results for 22 (n=22) research participants are reported. These 22 female research participants presented with an average age of 79.5 (±6.8) years, an average weight of 64 (±9.4) kg, and an average height of 159cm (±7.6), an average body mass index (BMI) of 25.5 (±4.8) kg/m^2, and an average blood pressure (BP) of 131/77mmHg (±15/11). Nine of the subjects were on some sort of chronic medication either to control BP or cholesterol predominantly.

3.6 SAFETY MEASURES

A number of safety measures were put into place before commencement of this study and these safety measures were ensured throughout the duration of the study. All assessment measures pre- and post- intervention were carried out by the researcher, a Biokineticist registered with the Health Professions Council of South Africa (HPCSA) (APPENDIX E). The researcher is also certified in cardiopulmonary resuscitation (CPR) procedures (APPENDIX F). Before commencement of the study each participant was required to complete an extensive Health Activity Questionnaire (APPENDIX B), which was then carefully screened according to the exclusion and inclusion criteria in order to ensure that no high risk individuals were included in the study, so as to avoid placing them at any unnecessary risk.

Each participant was also required to read and sign a consent form before participating in the study (APPENDIX A). The consent form ensured each participant was informed about the exact procedure the study would follow, which will be discussed, as well as potential risks and discomforts and their rights as a research subject and the process that one would follow should any participant wish to withdraw from the study. This consent form also included a clause on the confidentially procedures that would be followed regarding all data collection.

All assessment procedures were conducted at the Biokinetics Centre at the Department of Sport Science at Stellenbosch University. The majority of personnel working at the Biokinetics Centre are either qualified Biokineticists, intern Biokineticists or Biokinetics honours students, all registered with the HPCSA and CPR certified. There was also an Automatic External Defibrillator available in the centre should an emergency arise.

Prior to commencement of the pre-assessment measures, each subject's blood pressure was measured, using the postural orthostatic hypotention measurement shown in Figure 3.1, to ensure no subject was suffering from uncontrolled hypertension or possible orthostatic hypotension.

POSTURAL ORTHOSTATIC HYPOTENSION

Take blood pressure (BP) and heart rate (HR) supine (lying down on their back). Wait 3 minutes, retake BP and HR standing.

SUPINE				STANDING			
HR		BP		HR		BP	

A positive test will be indicated by:

A pressure decline of ≥ 20mmHg systolic/ <90mmHg diastolic

Figure 3.1: Postural orthostatic hypotension measurement section (Deegan *et al.*, 2007)

If a positive test was indicated the subject would not have been allowed to undergo the rest of the assessment protocol for safety reasons.

The exercise intervention programme was carried out at the retirement homes of the individuals for their convenience and practical reasons regarding transport issues, should some of the subjects not have had their own means of transport. Each of the retirement homes also had a nurse's station with a qualified nurse present and an emergency trolley should a medical emergency occur. The nurse as well as any other personnel on duty, such as the manager or the retirement home receptionist, were informed of the exercise session times, and so were aware and ready to respond or help should an emergency occur, or contact emergency services if necessary via their emergency plan.

All exercise sessions were carried out by the researcher. The subjects were split into four small groups with a maximum of eight subjects in each group so as to ensure that the groups were small enough to maintain control and ensure safety. The subjects were told to wear appropriate clothing and footwear to ensure safety during the exercise sessions. Tracksuits were recommended and long flowing clothing that may induce a trip was discouraged. Flat soled non-slip shoes were also advised for their safety and comfort. Subjects were asked prior to each session if they had possibly sustained an injury since the last session or were in any pain that may be aggravated by the exercise. If this was the case, the subject was advised to miss that particular session and recover entirely before commencing with any further intervention. Subjects were also asked if they were sick or had any symptoms indicating that they may be getting sick and if this was the case, to miss that particular session and recover entirely before commencing with any further intervention.

The exercise sessions that involved pieces of equipment were attended by an intern Biokineticist, also registered with the HPCSA and certified in CPR. This was to ensure that each subject was carefully monitored and assisted if necessary with any exercise on the equipment that may have been more challenging, specifically some of the balancing exercises. Every exercise session was planned around an adequate and suitable warm-up and cool-down to ensure the prevention of any unnecessary injury or stiffness.

Each exercise or activity was demonstrated to ensure safe and correct execution and if a subject felt uncomfortable at any stage, with any one of the activities, they were given a more suitable or modified alternative. The exercises were kept simple and functional and the exercise intervention programme also ensured a slow and safe progression of the exercises and, again, was modified for individuals that perhaps were progressing slower than others due to individual factors such as a higher age, more muscle weakness or lower balancing ability. Sufficient rest periods were also taken into account between each section of the exercise session ensuring adequate recovery between each exercise in order to maintain correct and safe execution and to gain maximum benefit of each prescribed exercise. It was also ensured that equipment that was not being used for certain of the exercises was packed away in order to prevent any subject potentially tripping and falling over this equipment.

3.7 PRE-INTERVENTION ASSESSMENT

Persons who were interested in participating in the study were contacted individually and times were set up to discuss the study further in detail. Subjects were again given the opportunity to ask any questions they had with regards to the study. It was explained, in detail, what would be expected of them as a participant. Each potential participant then had to complete a Health Activity Questionnaire (APPENDIX B), which served as a selection tool and addressed all criteria that would make them unsuitable for the study. If an individual did not meet the necessary requirements to be involved in the study, they were told they would unfortunately not be able to take part due to certain health risks. If the individual met all the requirements with regards to the relevant inclusion and exclusion criteria, they were formally invited to be part of the study and were required to sign a letter of consent (APPENDIX A).
By appointment each subject was collected from their respective retirement home and taken to the Biokinetics Centre at the Department of Sport Science at Stellenbosch University. The pre-intervention assessment began at the beginning of May 2011.

All pre-assessment tests were carried out in the morning between 09:00 and 12:00. It was requested that each subject have breakfast prior to assessment. On arrival at the Biokinetics Centre, the subject was taken to the blood pressure measurement station where they were again briefed on the assessment procedure. The subject was then instructed to lie down in the supine position (on their back) on a plinth and to relax for five minutes to allow their blood pressure to settle to their normal supine pressure. The subject's blood pressure was then measured using a standard mercurial sphygmanometer in conjunction with a stethoscope, and recorded. The subject was then asked to stand and again their blood pressure was measured and recorded. If the subjects blood pressure showed a decline of ≥ 20mmHg systolic or below 90mmHg diastolic, this would have indicated orthostatic hypotension and the subject would not have been allowed to carry on with the assessment and possibly excluded from the study.

After their blood pressure had been measured their height and weight were recorded in order to establish the average BMI of the research group. Height of the subject was measured in standing position. The subject was instructed to stand barefooted on the board of a standard standiometer with both feet in close contact with each other, trunk braced along the vertical board, and the head adjusted in Frankfurt plane. The measurement was taken in centimetres, by bringing the horizontal sliding bar to the vertex. Subjects were then asked to confirm the level of their 'Fear of Falling' (1-5) via a questionnaire shown in Figure 3.2.

The subjects then underwent a number of assessments including the 'Fall Risk Assessment' on the Biodex Balance system, The Balance Evaluations Systems Test (BESTest), as well as the 30-Second Chair Stand Test to evaluate lower body strength and endurance. Each test was explained in detail to each subject and demonstrated clearly to ensure correct execution and safety. These tests, their validity and reliability will be discussed in detail. After all the assessments had been carried out and all scores recorded, the subject was taken back to their place of residence and informed when and where the exercise intervention programme would commence, as well as what clothing and shoes to wear.

3.8 RESEARCH MEASUREMENTS

3.8.1 Fear of falling evaluation scale

Aim

The aim of getting a score or rating for the research subject's level of FOF was to establish whether participation in an exercise intervention programme would perhaps encourage participants to become more functionally independent, and would promote them to become more involved in physical activity and improve physical health, as well as social activity, thereby preventing symptoms of depression. It was also to establish whether the exercise intervention programme would result in any improvements in balance and gait, as subjects may potentially become less fearful and more confident in their daily life activities.

Description

FOF was addressed by means of a subjective question in the Health Activity Questionnaire (APPENDIX B),question 11 shown in Figure 3.2. This subjective question/measure required the subjects to rate their fear/concern about falling on a scale of one to five. (1 – no, 2 – a little, 3 – moderately, 4 – very, 5 – extremely)

PLEASE CIRCLE THE APPROPRIATE NUMBER: e.g. 1

1. Are you worried/concerned about falling?

1	2	3	4	5
no	**a little**	**moderately**	**very**	**extremely**

Figure 3.2: Research questionnaire content: Question 11. Fear of Falling

Reliability and Validity

During an extensive literature review from 2005 to present, it was noted that the question of FOF was widely used, especially in a questionnaire format, and FOF has been shown to be one of the main and most important indicators in evaluating the risk of falling among the elderly. A review article carried out by Scheffer *et al*. (2008) showed that there is great variation in the reported prevalence of FOF in older people and that there are multiple associated factors. Knowledge of risk factors of FOF may be useful in developing multidimensional strategies to decrease FOF and improve quality of life. However, the only identified modifiable risk factor of FOF is a previous fall. In order to measure the impact of interventions, a uniform measurement strategy for FOF should be adopted, and follow-up studies should be conducted. (The way the question of rating of fear of falling has been addressed in this particular study is closely related to the Falls Efficacy Scale–International (FES-I). The level of concern is measured on a four point Likert scale (1=not at all concerned to 4=very concerned. The FES-I was developed in a collaborative effort with members of the Prevention of Falls Network Europe (ProFaNE), European Committee focused on fall prevention and the psychology of falling. The FES-I has been found to have excellent internal validity (Cronbach's alpha=0.96) as well as test-retest reliability (intraclass correlation coefficient-measure of relationship between variables –Howell, 1999) (ICC) =0.96) (Boltz & Greenberg, 2011).

3.8.2 Biodex Balance System: Stability Index: Fall risk assessment

The Biodex Balance System is effective in the assessment of the somatosensory and neuromuscular control aspects of balance, as it challenges the mechanoreceptors (sensory receptors) found around the joints of the lower extremity in a safe environment. The ability of the subject to maintain dynamic postural balance on this unstable, tilting platform is assessed.

Aim

The aim of the Biodex fall risk assessment is to assess overall balance and forms an integral component of the Fall Risk Assessment Evaluation, in addition to being used as an objective balance performance baseline, in conjunction with a balance intervention programme. The test provides an objective score, 'stability index', that, if higher than the predicted value, may indicate a strength, proprioception and vestibular or visual impairment. It was also used to establish whether the exercise intervention programme would result in any objective improvements in balance and strength, and therefore neuromuscular control, which would decrease the risk of sustaining a fall.

Description

It is a simple, efficient and reproducible dynamic balance assessment tool. This testing machine consists of a multiaxial standing platform which can be adjusted to provide varying degrees of platform tilt or platform instability. A maximum of 20 degrees of platform surface tilt can be selected. With this degree of surface tilt, a dynamic situation is created, similar to actual functional activities that result in instability. The subject is challenged to maintain their COG over their BOS by trying to keep the platform level. The performance of this task is dependent upon neuromuscular mechanisms of proprioception, strength and power.

The Falls Risk Assessment Evaluation programme was used during this study. The falls risk assessment consists of 3 x 20 second trials at level 8 (out of 12 levels) on both feet. Subjects were tested with footwear on (non-slip, flat shoes).

The subject's details (including name, age and height) were first entered into the system. They were then positioned on the Biodex Balance System platform, which was locked in a static position to ensure their safety. They were then asked to stand in a comfortable position and their foot position coordinates were recorded for consistency between trial tests.

The test was explained to the subjects and they were instructed to maintain a level platform for the duration of 20 seconds for all 3 trials, by keeping the screen cursor in the middle of the circle on the screen in front of them. This allowed for visual biofeedback of a subject's ability to control their COG as well as LOS. Figure 3.3 shows and example of a fall risk test results screen.

The stability index is the average position from the centre

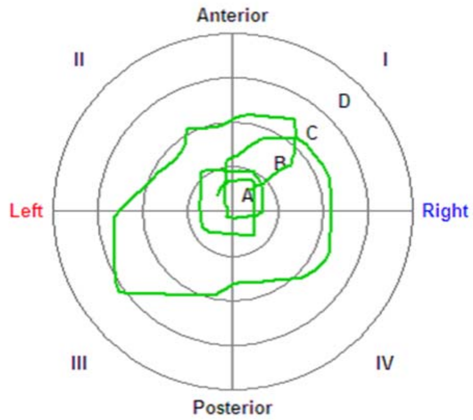

Figure 3.3: Example of fall risk test results screen (Biodex Balance System SD: Clinical Resource Manual, n.d.:2-3)

They were asked to refrain from using the side bars as an aiding device, but were informed that the side bars were there as support should they feel that they may lose their balance.

Test results are compared to age dependent normative values. The test provides an objective score, 'stability index', that, if higher than the predicted value, indicates a strength, proprioception, and vestibular or visual impairment. Objective data confirms presence or absence of a balance problem (Biodex Balance System SD: Clinical Resource Manual, n.d.:1-5).

Reliability and Validity

The Biodex Balance System provides valid, reliable and repeatable objective measures of a subject's ability of balance on stable and unstable surfaces (Biodex Balance System SD: Clinical Resource Manual, n.d.:1-5). Lephart *et al.* (1995) showed the Biodex Balance System to be a highly reliable assessment device across multiple test trials. A study conducted by Hinman (n.d.) found test-retest reliability of the stability index produced by the Biodex Balance System is acceptable for clinical testing and is comparable to other balance measures currently in use.

3.8.3 Balance Evaluation Systems Test: BESTest (APPENDIX C)

Aim

The aim of the BESTest is to identify the disordered systems underlying balance control. This test enables the selection of specific types of intervention exercises to address different types of balance problems. The aim of the test is not to limit intervention exercises to specific tasks within the test but to rather focus on the underlying system deficits contributing to the difficulty of certain tasks.

Description

The BESTest consists of 36 items, grouped into 6 systems: Biomechanical Constraints; Stability Limits/Verticality; Anticipatory Postural Adjustments; Postural Responses; Sensory Orientation; and Stability in Gait.

Although several separate neural systems underlie balance control, each task may involve more than one system that interacts with others. Thus, each patient with balance problems is likely to fall because of deficits in different underlying systems and may consequently fall in different environments and while performing different tasks.

The test is simple and easy to administer and uses exercise evaluation modes relevant to everyday activities. It is a safe and inexpensive measure to assess the risk of falling among the elderly.

The BESTest consists of 27 tasks, with some items consisting of two- or four sub items (e.g., for left and right sides), for a total of 36 items. Each item is scored on a 4-level, ordinal scale from 0 (worst performance) to 3 (best performance). Scores for the total test, as well as for each section are provided as a percentage of total points as shown in Figure 3.4.

SUMMARY OF PERFORMANCE: CALCULATE PERCENT SCORE

Section I: ________/15 x100 = _______ Biomechanical Constraints

Section II: ________/21 x 100 = _______ Stability Limits/Verticality

Section III: ________/18 x 100 = _______Transitions/Anticipatory

Section IV ________/18 x 100 = _______ Reactive

Section V: ________/15 x 100 = _______ Sensory Orientation

Section VI: ________/21 x 100 = _______ Stability in Gait

TOTAL: ________/108 points =________ Percent Total Score

Figure 3.4: BESTest content: Summary of performance to calculate overall percent score (Horak, 2008)

All subjects were tested with flat heeled shoes.

An overview of the six interacting systems (Figure 2.6) underlying control of balance that are targeted in the BESTes is as follows:

I: Biomechanical Constraints

Biomechanical constraints for standing balance include the quality of the BOS (item 1), geometric postural (COM) alignment (item 2), functional ankle and hip strength (force-generating capacity) for standing (items 3 and 4), and ability to rise from the floor to a standing position (item 5).

II: Stability Limits/Verticality

This system includes items for an internal representation of how far the body can move over its BOS before changing the support or losing balance, as well as an internal perception of postural vertical (the ability to lean as far as possible in a sitting position with eyes closed)-(item 6) providing a measure of lateral limits of stability in a sitting posture, and the ability to realign the trunk and head back to perceived vertical (item 6) provides a measure of internal representation of gravity. The ability to reach maximally forward and laterally while standing (items 7 and 8) represents the functional limits of stability, although this may not necessarily be correlated with how far a person can lean the body's COM when not reaching.

III: Transitions-Anticipatory Postural Adjustment

This system includes tasks that require an active movement of the body's center of mass in anticipation of a postural transition from one body position to another. For example, the transitions from a sitting to a standing position (item 9), from normal stance to stance on toes (item 10), and from 2-legged- to 1-legged stance (item 11) are included. Item 12 involves repetitive weight shifting from leg to leg in anticipation of tapping a forefoot on a stool, and item 13 involves anticipatory postural adjustments prior to rapid, bilateral arm raises with a weight.

IV: Reactive Postural Response

Reactive postural responses include both in-place and compensatory stepping responses to an external perturbation induced by the examiner's hands using the unique “push and release” technique. To induce an automatic postural response with the patient's feet in place (ankle or hip strategy), the tester pushes isometrically against either the front (item 14) or back (item 15) of the patient's shoulders until either the toes or the heels just begin to raise without changing the initial position of the body's center of mass over the feet before suddenly letting go of the push.

To induce compensatory stepping responses, the tester requires a forward (item 16) or backward (item 17) or lateral (item 18) lean of the patient's COM over the base of foot support prior to release of pressure, requiring a fast, automatic step to recover equilibrium.

V: Sensory Orientation

This system identifies any increase in body sway during stance associated with altering visual or surface somatosensory information for control of standing balance. Item 19 is the modified Clinical Test of Sensory Integration and Balance (CTSIB), and item 20 involves standing on a 10-degree, toes-up incline with eyes closed.

VI: Stability in Gait

This system includes evaluation of balance during gait (item 21) and when balance is challenged during gait by changing gait speed (item 22), by head rotations (item 23), by pivot turns (item 24), and by stepping over obstacles (item 25). This section also includes the Timed "Get Up & Go" Test, which evaluates how fast a patient can sequence rising from a chair, walking three meters, turning, and sitting back down again without (item 26) and with (item 27) a secondary cognitive task to challenge the patient's attention.

Reliability and Validity

The BESTest shows excellent reliability and very good validity. Specific patient and rating instructions and stopwatch and ruler values are used to improve reliability. With an ICCof .91 for BESTest total scores, the interrater reliability for the BESTest is excellent and just as good, or better than the current, shorter balance assessment batteries such as the Berg Balance Scale (BBS) with poor to moderate sensitivity and an of ICC of .98 and the Tinetti Mobility Assessment which has poor specificity and an ICC of .75. Subsections of the BESTest adapted from established tests also show reliability similar to or better than that previously reported: Functional Reach Test (FRT) ICC=.98 compared with BESTest section (II) ICC=.79; Clinical Test of Sensory Organization and Balance (CTSIB) ICC=.74 compared with BESTest section

(V) ICC=.96; Dynamic Gait Index kappa ICC =.64 and timed "Get Up & Go" Test ICC=.99 compared with BESTest section (VI) ICC=.88. The interrater reliability of each section of the BESTest is sufficiently strong to allow therapists to use an individual section if they are short on time or want to direct a balance test at a specific postural system (Horak *et al*., 2009).

3.8.4 The 30-Second Chair Stand Test

Aim

The aim of using the 30-Second Chair Stand Test as part of the pre assessment was to provide a measurement of a person's lower body (particularly leg) strength. This could be associated with the ability to perform lifestyle tasks such as climbing stairs, as well as transfer skills such as getting into and out of a car or the bath, sitting to standing etc.

Description:

The subject is given specific instructions to sit in the middle of a chair with a straight back and a seat at 43 cm from the ground. The subject then places each hand on their opposite shoulder, crossed at the wrists, feet are flat on the floor and their back is straight. On the researcher's signal they rise to a full stand and then sit back down again. This is repeated for 30 seconds and the total number of full stands is recorded. If the subject is over halfway to a standing position when the 30 seconds have elapsed, this is counted as a stand. If a subject is unable to stand at least once, their hands are allowed to be placed on their legs or a cane or frame may be used. This score is then recorded as zero, but the number of stands is recorded as an adapted test score and adaptions are indicated. Another person should always be present to catch the participant should they lose balance and the participant should be able to stop and rest should they become tired, however, should this be the case, the time is kept going.

Reliability and Validity

A study done by Jones *et al.* (1999) on76 community-dwelling older adults (mean age = 70.5 years) involved performing two 30-Second Chair Stand tests and two maximum leg-press tests, each conducted on separate days two to five days apart. Test-retest intraclass correlations of .84 for men and .92 for women, utilizing one-way analysis of variance procedures appropriate for a single trial, together with a nonsignificant change in scores from Day 1 testing to Day 2, indicates that the 30-Second Chair Stand Test has good stability reliability. A moderately high correlation between chair-stand performance and maximum weight-adjusted leg-press performance for both men and women (r = .78 and .71, respectively) supports the criterion-related validity of the chair stand as a measure of lower body strength.

3.9 INTERVENTION PROGRAMME

A total number of 22 subjects completed the 12-week exercise intervention programme (APPENDIX D) consisting of two 30 minute exercise sessions per week. Subjects were split up into four small groups and the exercise sessions took place at their place of residence in an allocated area under the instruction and supervision of the study researcher. Participant compliance was carefully recorded over the 12-week period and subjects could accumulate no more than five sessions of absence in total. The exercise sessions were held at the same time of day on the same days of the week, namely a Monday and Friday morning. The exercise sessions took place in the mornings between 09:00 and 12:00. Subjects were required to be on time in order to participate in the full 30 minutes of exercise and instructed to wear comfortable, practical clothing and flat soled, non-slip shoes. They were also instructed to make sure they had an adequate breakfast and had taken all necessary medication as was part of their daily routine in the mornings.

Every exercise session was preceded by a five minute dynamic warm up routine which included simple, conservative dynamic arm and leg movements to ensure an adequate warm up, important as a prerequisite, to any exercise session, according to Thompson *et al*.; 2010:153.

The equipment used during the intervention included exercise mats, small 45cm Pilates balls, steps, Airex mats – stability pads, 65cm big balls, 2kg ankle weights (AW), pieces of 1 meter theraband (TB) and 1kg dumbbells (DB). On the intervention days that involved more of the complicated and challenging exercises the same intern Biokineticist was present to assist and ensure safe execution of all activity.

Exercises were specifically designed with the aim of lowering the subjects' fall risk status and improving their functional capacity to ensure an independent lifestyle. The exercise intervention also had the aim of lowering the subjects' FOF.

The exercise programme consisted of the following components:

- Balance (COG control) training
- Gait pattern enhancement training
- Stability (postural strategy) training
- Reaction time/anticipatory type (multisensory) training
- Dual task training
- Strength and endurance training for the upper and lower body
- Getting up strategies should a fall occur

Although each of the exercises/tasks used in the intervention programme are targeted to one exercise component, such as balance or strength, each task may involve more than one of these components, as these components may need to interact with each other for the effective execution of the task.

Balance (COG control) training

The exercises in this section of the programme are designed to improve the subjects' ability to:

- Maintain a better upright position in space, whether seated or standing
- Lean away from, and return to, the midline with improved postural control

- Move body through space more quickly and confidently

In order to accomplish these movement goals, participants were first educated as to where their COG is relative to their BOS (i.e. feet and buttocks when sitting and feet when standing), and how to move it relative to that base (e.g. rising from a chair, walking up a flight of stairs).

The exercises that form part of this section progress from seated to standing to moving task situations.

Getting up strategies

All participants are required to practice floor-to-standing transfers many times throughout the intervention programme.

Many older adults are unaware of the procedures for rising safely from the floor. This is an important skill to learn in case a fall is sustained when alone at home. It has been well documented that morbidity and mortality rates associated with falls increase the longer the person lies after falling to the ground (Rose, 2003:133).

Rose (2003:133), divides the floor-to-standing progression into four levels of difficulty, described in chapter two, from easiest to most difficult. Every three weeks the next strategy was practiced.

Only a few of the participants were able to execute the 'still more difficult' and the 'most difficult' strategy, and participants were encouraged to only attempt the strategy that they were comfortable with and to attempt this in their own time, with guidance from the researcher.

Multisensory training

Balance training designed to improve intersensory interaction could effectively improve balance performance in healthy older adults (Hu & Woollacott, 1994).

The ability to perceive where the body is in space and how to respond to changing sensory conditions during our daily lives is heavily dependent on; a) the amount and quality of information received from the peripheral sensory receptors and, b) how the information is organized and integrated from the different sensory receptors once it has reached the CNS. It has been well documented that each of the three sensory systems (visual, vestibular, and somatosensory) that contribute to balance and mobility experience significant changes as a function of the ageing process (Rose, 2003:11).

The exercises within this section of the intervention programme are intended to optimize the functioning of the sensory systems that are not impaired, while compensating for the system or systems that may be permanently impaired.

More specifically, the goals of this component of the programme are to:

- Improve the functioning of the somatosensory system by compromising or removing vision.
- Improve the use of visual inputs for balance by compromising the somatosensory system.
- Enhance the interaction between all three systems.

Postural strategy training

The ankle strategy

The body moves as a single entity about the ankle joints as force is exerted against the surface (i.e. the upper and lower body sway in the same direction or in phase). As the amount of force that can be generated by the muscles surrounding the ankle joint is relatively small, this strategy is generally used to control sway when we are standing upright in space. The ankle strategy is also used at a subconscious level to restore balance following a small nudge or push. An effective ankle strategy requires:

- Adequate range of motion and strength in the ankle joints
- A firm, broad surface below the feet
- An adequate level of sensation in the feet and ankles

The hip strategy

This strategy involves activation of the larger hip muscles and is used when the COG must be moved more quickly back over the BOS as the speed or distance of the sway increases. The upper and lower body move in opposite directions (out of phase) as a result of the hip muscles being activated to control balance. This strategy becomes increasingly important when standing on a surface that is narrower than the length of the feet. An effective hip strategy requires:

- Adequate range of motion and strength in the hip region

The step strategy

This strategy comes into play when the COG is displaced beyond the maximum limits of stability, or the speed of sway is too great for the hip strategy to be effective. In this situation a new BOS must be established to prevent a fall. When executing a step strategy, at least one or more steps will be taken in the direction of the loss of balance. An effective step strategy requires:

- Adequate lower body muscle strength, power and range of motion
- Adequate ventral processing speed
- The ability to move the limb rapidly during step initiation

It has been shown that various combinations of the above strategies are used to control forward and backward sway in a standing position (Rose, 2003:7).

Each strategy was practice separately and progressed accordingly.

Again participants were encouraged to only attempt the strategy they were comfortable with and to attempt this in their own time, with guidance from the researcher.

Gait pattern enhancement training

The ability to move about successfully and safely in a variety of environmental contexts that impose different timing (e.g. stepping onto and off of surfaces) or spatial demands (e.g. stepping over obstacles) requires a gait pattern that is both flexible and adaptable. Initiating gait, walking, stopping and turning are all movements that require constant changes in our postural orientation.

Three major tasks must be achieved during the gait cycle:

- Weight acceptance
- Single-limb support
- Limb advancement

  (Rose, 2003:179)

Four major attributes are needed for normal gait:

- Adequate range of joint mobility
- Appropriate timing of joint mobility
- Sufficient muscle strength
- Unimpaired sensory input

  (Rose, 2003:180)

The age associated changes in gait include:

- Decreased velocity
- Decreased step frequency

- Increased stride width
- Increased time in double support
- Decreased step length
- Increased stance phase
- Decreased time in swing phase

  (Rose, 2003:182)

The gait pattern enhancement and gait variation activities of the intervention programme are intended to help the older adult develop a gait pattern that is more efficient, flexible and adaptable. The activities are also intended to improve the subjects' confidence and their ability to adapt their gait pattern to changing environmental demands.

The activities included tasks such as requiring participants to start and stop quickly, walk with longer, shorter, or wider stride patterns, and turn in different directions, which required them to vary the spatial and temporal characteristics of the gait pattern, making it more flexible long-term. Other varying activities included walking on the toes or heels, stopping, starting, and turning on command, stepping over obstacles and onto and off different surface types. As the participants became more confident in their balance abilities and began to demonstrate better overall performance, secondary tasks were added to force a more subconscious control of balance due to the need to divide attention between multiple tasks. Activities such as counting backwards, catching objects, or head turns while walking, were incorporated into the programme. Activities such as these were intended to be task specific and mimic the participant's everyday performance environment.

Strength and endurance training

Strength training is considered a promising intervention for reversing the loss of muscle function and the deterioration of muscle structure that is associated with advanced age. This reversal is thought to result in improvements in functional abilities and health status in the elderly by increasing muscle mass, strength and power and by increasing bone mineral density (Hurley & Roth, 2000).

The strength retraining component of the programme was carried out at a moderate intensity. Hip extensors, hip abductors and ankle muscles were targeted, as these muscles are especially important for transferring, standing up from a chair, as well as walking. The ankle plantar and dorsi flexors, responsible for ankle flexion and extension respectively, were specifically targeted as these muscle are important for recovery of balance (Gardner *et al*., 2001) and come into play during the ankle strategy as discussed. Ankle weights were used to provide resistance for lower body exercises involving the hip abductors, knee flexors and extensors. Ankle muscles were strengthened by using only body weight (Gardner *et al*., 2001).

Upper body strength is also considered an important element in the training programme and becomes increasingly important in assisting "getting up techniques" when crawling to external support is necessary to assist in getting up to a standing position. Upper body strength and retraining is also important to counteract the effects of a rounded and stooped over posture evident in many elderly women.

Exercises targeted to upper-back strengthening and spinal support were incorporated into the exercise programme with the aim of trying to correct posture abnormalities, specifically hyperkyphotic postures, as well as the possible prevention of spinal fractures should a fall occur. Shoulder and chest exercises were also done to assist with getting up, as well as certain transfer skills, such as getting out of a bath or rising from a chair.

Evidence from a variety of sources indicates that exercise can increase the mineral content of bone, raising the expectation that exercise programs may be effective therapy for the treatment of osteoporosis, and the prevention of hip and spinal fractures (Birge & Dalsky, 1989).

Following a report by Gardner *et al.* (2001) on the practical implementation of an exercise-based falls prevention programme, if any muscle pain or discomfort was experienced, the exercise technique used by the subject was assessed and, if necessary, revised or modified. Minimal substitution of other muscle groups was ensured, as well as the correct breathing technique, i.e. breathing out during exertion or movement. Exercises were carried out slowly (two to three seconds to lift a weight and four to six seconds to lower the weight), through the full functional range of active joint movement. Rest periods were also incorporated into the programme between each exercise set. Upper and lower body exercises were alternated to ensure adequate muscle recovery and correct form. Standing exercises were focused on as they are thought to aid balance and strength.

The exercises that form part of this section use equipment such as resistance bands, ankle weights and 1kg dumbbells.

3.10 POST–INTERVENTION ASSESSMENT

The exercise intervention programme was directly followed by the post-intervention assessment. The post intervention assessment was again carried out by the researcher at the Biokinetics centre, situated at the department of Sports Science, Stellenbosch University. The post-intervention assessment proceeded at the beginning of September 2011, directly after the 12-week intervention programme. Times were arranged for the collection of participants from their residence to the Biokinetics centre as close to pre-assessment times as possible. All tests were carried out between 09:00 and 12:00, after an adequate breakfast and all necessary routine morning medication had been taken. The subjects were instructed to again wear comfortable, practical clothing and the same flat heeled, non-slip shoes as used in the pre-assessment.

On arrival at the Biokinetics centre, the subject was taken to the blood pressure measurement section where they were again briefed on the assessment procedure. They were first asked if there had been any changes to their health status and if so, these changes were recorded on their Activity Health Questionnaire. From then on, the assessment procedure followed the exact same procedure as the pre assessment:

- Blood pressure was measured supine and standing to measure for any possible signs of orthostatic hypotension, which would have excluded them from further assessment
- Height and weight was assessed

- Their FOF status was rated on the same scale of 1 to 5, one being ‘no fear at all’ and five being ‘extremely fearful’
- The fall risk assessment was carried out on the Biodex Balance System following the same protocol as was used for pre-assessment
- The BESTest was then carried out and all sections therein completed
- Followed by the 30-Second Chair Stand Test

After all the assessments had been carried out and all scores recorded, the subject was taken back to their place of residence. They were all sincerely thanked for participating in the study and were informed that they would be contacted on completion of the study and briefed on the results thereof.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 INTRODUCTION

Population ageing or demographic ageing refers, in simplistic terms, to the process by which the older population (65 years or older) become a proportionally larger component of the total population. Population ageing is an outcome of a population's demographic transition from higher to lower levels of fertility and mortality. During this process the age-structure of the population changes from a broad-based pyramid shape with high proportions of children to a more columnar shape with increased proportions of middle-age and older persons. Population ageing has been described as a key demographic feature of the 20th century. The United Nations termed it "one of the most distinctive demographic events" of the previous century and stated that it will remain an important population issue throughout the 21st century. In 1950, the world housed an estimated 205 million older persons. This figure increased to 606 million in 2000, and is projected to increase to 2000 million in 2050. This reflects a tripling of the older population over each of two consecutive 50-year periods. Although initially experienced by the more developed countries, population ageing is now a global phenomenon, experienced in virtually all countries of the world. Population ageing has become a well-publicised phenomenon and public concern in the more developed nations, but is commonly less publicised and less of a public concern in the less developed regions. This relative lack of concern observed in much of the less developed world is ironic for two reasons: first, in the year 2000, that part of the world was home to 62% of the world's older persons, and, secondly, the world's older population is growing at a much faster rate in the less, compared to the more developed regions, which means that the older population will be increasingly concentrated in the less developed regions (Joubert & Bradshaw, 2006).

Every year, one-third to one-half of the population aged 65 years and older experience falls and half of the elderly people who fall, do so repeatedly. Falls are the leading cause of injury in older adults and the leading cause of accidental death in those over age 85. 5% of falls lead to a fracture and falls cause approximately 300 000 hip fractures annually (Rose & Allison, 2012).

The number of older persons with fall-induced injuries is increasing at a rate that cannot be explained by demographic changes alone and strong preventative measures should be adopted to control the increasing burden of these injuries (Rose & Allison, 2012).

Results from a study conducted by Stevens *et al.* (2006), show that fall-related injuries among older adults, especially among older women, are associated with substantial economic costs that are borne by individuals, society and the medical care system. Although research has identified interventions that can reduce fall-related injuries, implementation remains limited. Additional efforts are needed to successfully disseminate cost-effective fall prevention programmes and to promote widespread adoption at the local level.

From cost efficiency and public health perspectives, exercise-alone interventions can be considered valuable, as they are more likely to be implemented in countries with fewer resources (Petridou, 2009).However, few studies have reported the effect of exercise intervention on falls in residential care facilities (Kim, 2008).

With the above-mentioned research in mind, this study was aimed at the establishment of a specific intervention programme using exercises to focus on the improvement or reduction of the main physical risk factors related to the risk of falling, such as balance, gait and strength. Teaching getting up strategies, should a fall occur, as well as the reduction of the FOF were also key elements of this study.

4.2 DATA ANALYSIS

The data analysis was determined and guided by the primary research questions of the study. All research measures were depicted on a specially designed Microsoft Excel spreadsheet. The data for each measure was then extrapolated and captured by the researcher. This was done directly after the respective pre- and post-assessment measures had been concluded.

The data analysis for the research had the aim of investigating whether a specific 12 week exercise intervention programme of two 30 minute exercise sessions a week had a significant effect on the following fall risk variables:

- Fear of falling
- Muscular strength
- Balance
- Gait
- Getting up strategies

A Bio-Statistician from the Centre of Statistical Consultation at Stellenbosch University, Professor Martin Kidd, was responsible for the design of the Microsoft Excel spreadsheet, where the data for each pre- and post-assessment was captured. Professor Kidd also assisted with the final analyses of the collected and processed data for this study.

The Statistica 10 programme on the Stellenbosch University Campus network was used to analyse the data. Data was analysed to assess any significant improvements/changes that the exercise intervention had on each fall risk variable tested.

For descriptive purposes, corresponding units and percentages of each variable post-intervention were calculated and reported and descriptive statistic methods were used to summarise and present the data which will be discussed.

4.3 RESULTS AND DISCUSSION POST-INTERVENTION

The results represent a total of 22 subjects (n=22) that were involved in the research. The sample population were elderly women with an average age of 79.5 (±6.8) years. The youngest subject was 67 years old and the oldest subject was 90 years old. The subjects were randomly selected from three retirement homes in the Stellenbosch area, Western Cape, South Africa.

4.3.1 Effects on the level of fear of falling

Table 4.1 represents the effects on the subjective rating of the fear of falling post-intervention and standard deviation (±) and the figure below (figure 4.1) shows a graphic representation of the results pre- and post- intervention.

Table 4.1: The mean ± SD changes in the subjective rating of FOF of 22 elderly women pre- and post a 12-week exercise intervention programme

VARIABLE	PRE	POST	P-VALUE
Fear of falling:	2.5 (±1.8)	1.4 (±0.5)	< 0.001

Values are mean and ± standard deviation

1=No 2=A little 3=Moderately 4=Very 5=Extremely

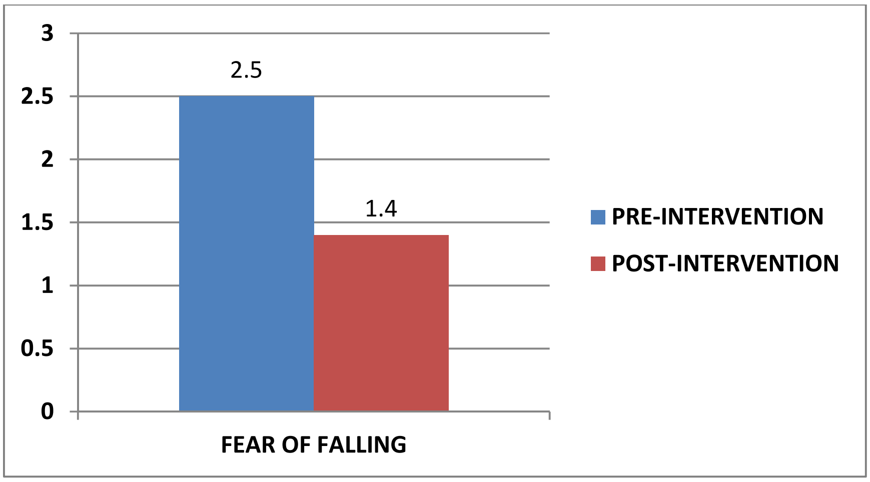

Figure 4.1: Graph representing the level of fear of falling pre- and post-intervention.

FOF is a major health problem among the elderly living in communities, present in older people who have fallen, but also in older people who have never experienced a fall (Scheffer *et al*., 2008). Several studies have indicated that people who are afraid of falling appear to enter a debilitating spiral of loss of confidence, restriction of physical activities and social participation, physical frailty, falls and loss of independence (Zijlstra *et al*., 2007). Individuals who fear falling may restrict themselves from performing certain activities which may increase their risk of falling (McCormack *et al*., 2004) due to physical decline from lack of activity. In addition to the adverse consequences of fear of falling for those suffering from it, there are consequences for the public expenditure, because healthcare utilization increases (Zijlstra *et al*., 2007).

It is therefore important to reduce fear of falling by reversing the downward spiral by intervening in factors in the spiral, such as increasing physical functioning (Zijlstra *et al*., 2007). A systematic review conducted by Zijlstra *et al*. (2007) to assess the methodological quality of trials evaluating interventions that could reduce fear of falling in community-living older people found consistent findings in trials of higher methodological quality which showed that exercise programmes have been effective in reducing fear of falling in community-living older people. Similar results were found in a study by Li *et al.* (2005), suggesting that exercise interventions designed to improve self-efficacy in relation to falls are likely to reduce the FOF in older adults. A study done by Yoo *et al*. (2010) also found that walking exercises in particular can have positive effects on fall-related psychological factors. This could be due to an improved walking efficiency due to increased confidence.

The results of this study indicate that the exercise intervention programme did have a statistically significant positive impact on participants' subjective rating of their FOF, indicating that the programme was successful in its intention of decreasing the research groups' overall FOF, supported bythe available literature.

A subjective rating of each participant's FOF was recorded pre- and post-intervention. The initial average rating was (mean±SD) 2.5±1.8, which correlated to a subjective assessment of 'a little' to 'moderately' worried/concerned about falling. After the 12-week intervention programme the post average rating was 1.4±0.5, which correlated to a subjective rating of 'not worried at all' to 'a little' worried/concerned about falling.

From the results of this study, it can therefore be said that the exercise intervention programme has the potential to decrease elderly women's FOF, which will lead to an increase in their quality of life and enable them to be confident in carrying out activities of daily living, improving quality of life and an independent living status, minimizing this population segments burden on society.

4.3.2 Biodex Balance System: Stability Index comparison

Table 4.2 depicts the changes in the research subjects' stability index score post-intervention, Figure 4.2 depicts the decrease in stability index post-intervention and Table 4.3 the age dependent normal ranges for stability index.

Table 4.2: The change in the research subjects' stability index score pre- and post- 12 week exercise intervention programme

VARIABLE	PRE	POST	P-VALUE
BIODEX: Stability Index	2.5 (±1.1)	1.7 (±0.9)	0.043

Values are mean ± standard deviation

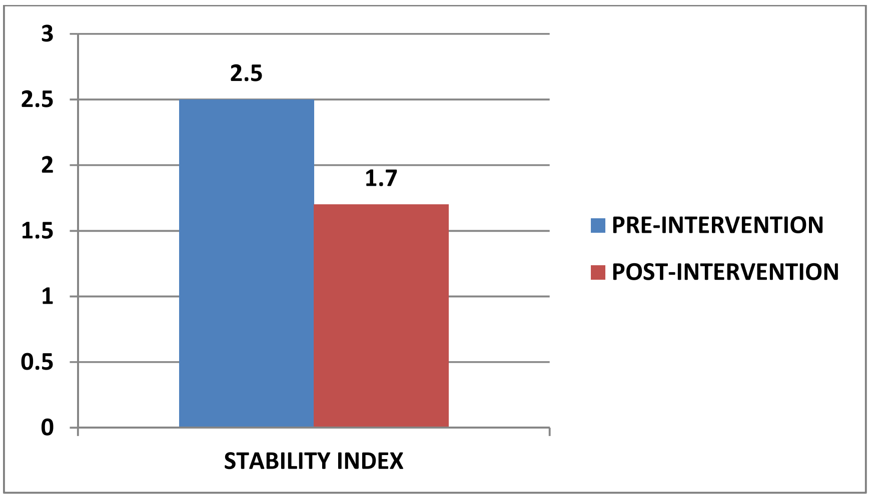

Figure 4.2: Graph representing the decrease in the stability index pre- and post-intervention.

Table 4.3: Age dependent normal ranges for stability index (Biodex Balance System SD: Clinical Resource Manual, n.d:1-12)

Age	Stability Index Range
54-71	**1.79 – 3.35**
72-89	**1.90 – 3.50**

The Biodex Balance System was the most objective and reproducible assessment tool used in the study. It was used to assess the overall balance performance of each subject. Test results were compared to age dependent normative values. The high stability index pre intervention of the research group with an average age of 79.5 (±6.8) years compared to age dependent normal ranges represents poor neuromuscular control among the research group being tested.

Zech *et al.* (2010), defines neuromuscular training as multi-intervention programmes with a combination of balance and strength exercises and showed that balance training is an effective intervention to improve neuromuscular control.

The results from this study support the above study by Zech *et al.* (2010) and indicate a small, but significant training effect on the subjects stability index ($p = 0.043$). Therefore, the exercise programme which included both balance and strength training did improve the subjects' overall stability indexes, indicating improved functional status and a lowered overall risk of sustaining a fall. The improvement could also be due to the intersensory balance training, which has previously been shown to improve balance and stability control in older adults by Hu & Woollacott (1994). A possible explanation for the minor improvement could be supported by a study done by Shumway-Cook *et al.* (1997), where a visual cognitive task was introduced to investigate the effects on stability, similar to the Biodex visual task, where subjects are instructed to keep the screen cursor in a particular area. The results from this study suggested that when postural stability is impaired in anyway, even relatively simple cognitive tasks can further impact balance and that the allocation of attention during the performance of concurrent tasks is complex; depending on many factors including the nature of both the cognitive and postural task, the goal of the subject and the instructions. The Biodex Balance System presents an unfamiliar task which could have also had an impact on the results of this specific section of the assessment and resulted in only minimal improvements.

4.3.3 Effects on specific components within the Balance Evaluation-Systems Test (BESTest)

The BESTest was used to identify specific disordered postural control systems underlying balance control. It assessed all six interacting systems underlying balance control, described in chapter three under 3.8.3.Some of the tasks within the assessment involved more than one system interacting with others.

Table 4.4 provides a summary of the items evaluated as part of the BESTest.

Table 4.4: Summary of Balance-Evaluation Systems Test (BESTest) items under each system category (Horak *et al*., 2009)

Summary of Balance Evaluation Systems Test (BESTest) Items Under Each System Category[a]

I. Biomechanical Constraints	II. Stability Limits/Verticality	III. Anticipatory Postural Adjustments	IV. Postural Responses	V. Sensory Orientation	VI. Stability in Gait
1. Base of support	6. Sitting verticality (left and right) and lateral lean (left and right)	9. Sit to stand	14. In-place response, forward	19. Sensory integration for balance (modified CTSIB) Stance on firm surface, EO Stance on firm surface,EC Stance on foam, EO Stance on foam, EC	21. Gait, level surface
2. CoM alignment	7. Functional reach forward	10. Rise to toes	15. In-place response, backward		22. Change in gait speed
3. Ankle strength and ROM	8. Functional reach lateral (left and right)	11. Stand on one leg (left and right)	16. Compensatory stepping correction, forward		23. Walk with head turns, horizontal
4. Hip/trunk lateral strength		12. Alternate stair touching	17. Compensatory stepping correction, backward	20. Incline, EC	24. Walk with pivot turns
5. Sit on floor and stand up		13. Standing arm raise	18. Compensatory stepping correction, lateral (left and right)		25. Step over obstacles
					26. Timed "Get Up & Go" Test
					27. Timed "Get Up & Go" Test with dual task

[a] CoM=center of mass, ROM=range of motion, CTSIB=Clinical Test of Sensory Integration for Balance, EO=eyes open, EC=eyes closed.

Scores for the total test, as well as for each section, are provided as a percentage of total points and Table 4.5 shows the final results of each section of the BESTest post-intervention as well as the total overall BESTest score.

Table 4.5: Changes in subjects' scores within sections of the BESTest pre- and post- the 12-week exercise intervention programme as well as total BESTest score.

VARIABLES	PRE	POST	P-VALUE	% improvement
SECTIONS WITHIN BESTest:				
Biomechanical constraints	55.8% (±18.9)	80.7% (±19.7)	< 0.001	24.9%
Stability limits/verticality	69.6% (±20.2)	80.0% (±10.4)	0.021	10.4%
Transitions/anticipatory	52.8% (±18.5)	83.9% (±11.5)	< 0.001	**31.1%**
Reactive	94.2% (±8.4)	100% (±0.0)	0.006	**5.8%**
Sensory orientation	62.5% (±17.8)	87.9% (±13.1)	< 0.001	25.4%
Stability in gait	62.2% (±21.0)	90.5% (±13.5)	< 0.001	28.3%
BESTest TOTAL	**65.9% (±15.6)**	**87.4 (±8.7)**	**< 0.001**	**21.5%**

Values are mean ± standard deviation

Most improvement

Least improvement

The graph below Figure 4.2 shows a graphic representation between the pre- and post-intervention test results.

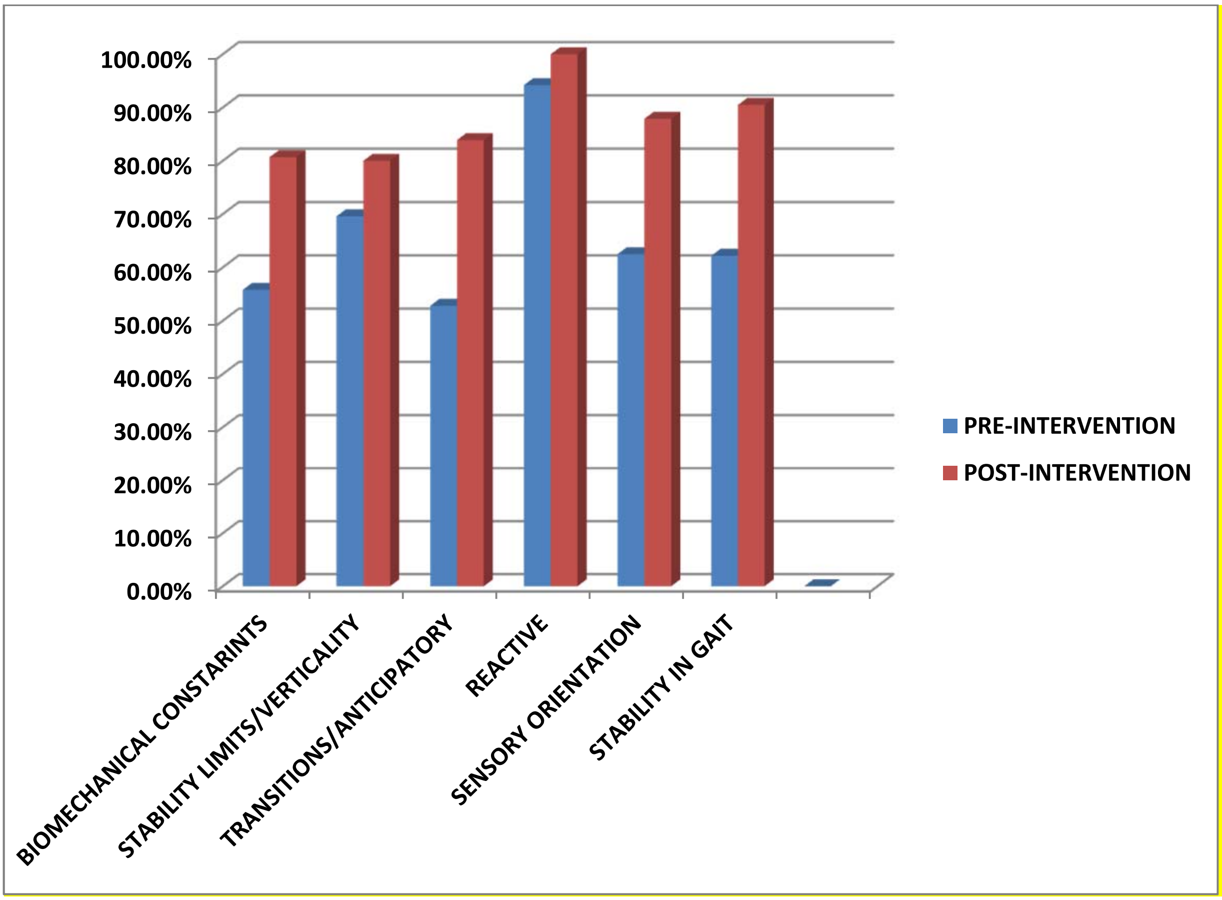

Figure 4.3: Graph representing the improvements in the BESTest systems pre- and post-intervention.

For each section post-training values are significantly better than pre-training values with an overall test score improvement of 21.5% ($p<0.001$) as shown in Figure 4.2 and Figure 4.3.

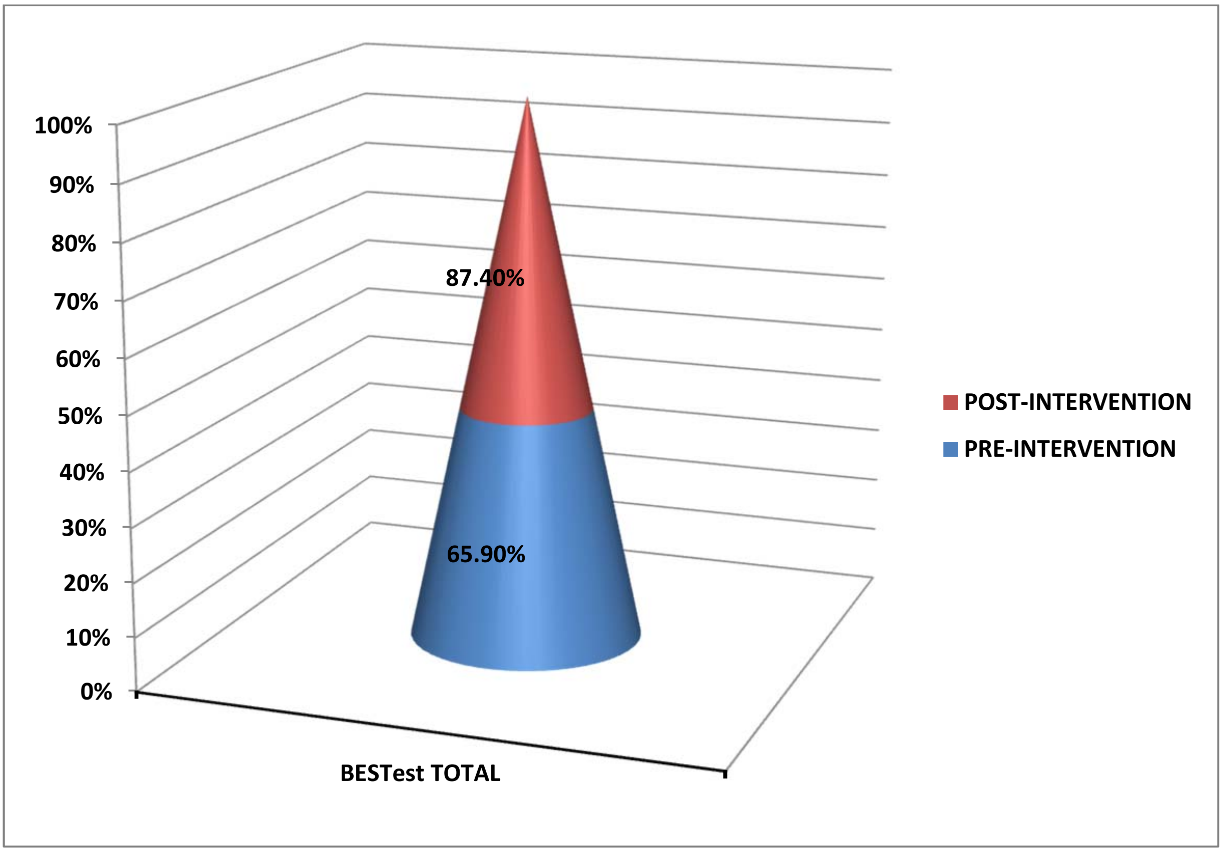

Figure 4.4: Graph representing the improvements in the overall score of the BESTest pre- and post-intervention.

Results from each system, as shown in Table 4.5 and Figure 4.3, will be discussed individually below:

4.3.3.1 Biomechanical constraints

An overall statistically significant ($p<0.001$) improvement of 24.9% was shown in Table 4.5, indicating that intervention strategies to improve functional ankle and hip strength, as well the ability to get up from the floor were effective. This gain in functional ankle and hip strength has a direct positive effect on the individuals' force generating capacity and the ability to use the ankle strategy or compensatory steps for postural recovery.

The most significant biomechanical constraint on balance is the size and quality of the base of support: the feet. Any limitations in size, strength, range, pain or control of the feet will affect balance. An improvement in this system overall score could also be particularly due to exercises throughout the intervention programme focusing on ankle functions (Nagai *et al*., 2011) such as ankle mobility, strength and exercises aimed at practicing the ankle strategy. The ability to get up is also assessed in this section and the improvement in the subject's ability to get up post exercise intervention could be attributed to improvements in both balance and gait which Tinetti *et al.* (1993) found to be marginally associated with inability to get up. The ability to be able to get up should a fall occur would also contribute to increased confidence in physical capability and an increase in participants' quality of life.

4.3.3.2 Stability limits/verticality

The ability to orient the body parts with respect to gravity, the support surface, visual surround and internal references is a critical component of postural control (Horak, 2006).

The measure of how far the body can move over its BOS before losing balance (limits of stability) as well as verticality (gravitational upright) showed a small but significant improvement of 10.8%, (p=0.021).

Healthy nervous systems automatically alter how the body is orientated in space, depending on the context and the task. For example, a person may orient the body perpendicular to the support surface until the support surface tilts, and then they orient their posture to gravity, evident during the lateral lean, as shown in Figure 4.1, and the functional lateral reach test. The ability to return to vertical smoothly, without over or undershooting, is dependent on lateral trunk stability as well as the coordination of sensorimotor strategies to stabilise the body's COM during both self-initiated and externally triggered disturbances in postural stability (Horak, 2006). The subjects' ability to lean and how far they are able to lean (maximum lean involves subject moving upper shoulders beyond the midline of the body – Horak, 2006) is affected by sensory deficits resulting in inflexible postural alignment or precarious body tilt. LOS predict the size of the postural response (Horak, 2006). Posture and body alignment are intimately related to function with what we can and cannot physically do. This is greatly affected by the ageing process due to joint-pain and disability.

Figure 4.5: Sitting verticality and lateral lean test

Since falls occur not only in the forward direction, but also to the side (Newton, 2001), the significant improvement in this system (Table 4.5) will be beneficial in contributing to the lowering of this populations' fall risk.

The Functional Reach Test (FRT) is also part of this section/system and is defined as the maximal distance one can reach forward beyond arm's length, while maintaining a fixed base of support in the standing position (Smith *et al*., 2004).

Reaching is a ubiquitous function that constantly imposes a stress to our balance. Analysis of this activity in elderly individuals has demonstrated decreased efficiency of movement, delayed anticipatory preparation for movement, and impaired coordination of postural adjustments for upper extremity movement. The boundary of stability lies within a more limited area, which may reflect an effort to compensate for impaired postural control mechanisms. Ankle plantar-flexor force has also shown to contribute to the prediction of FRT scores. The FRT, however, uses complex upper-body as well as lower-body strategies and thus, may be more related to upper-body flexibility and force measures rather than to lower-extremity muscle force measures (Daubney & Culham, 1999).

Morioka *et al*. (2011) found results that suggested that plantar perception exercises might efficiently stabilize standing postural balance as these exercises resulted in improvements in FRT scores, indicating proprioceptive exercises included in this exercise intervention may have resulted in a similar outcome.

However the results from research done by Jonsson *et al*. (2003) suggest that the FRT is a weak measure of the stability limits. Movement of the trunk seems to influence the test more than the displacement of the centre of pressure and that when using the FRT for assessing balance, compensatory mechanisms should be taken into account.

4.3.3.3 Transitions-anticipatory postural adjustment

It has been reported that anticipatory postural adjustments are attenuated and even disappear if postural stability is compromised. It is quite likely that, in such cases, anticipatory postural adjustments themselves are regarded as a perturbation to postural balance and the CNS may be "unwilling" to generate strong anticipatory postural adjustments in order to avoid subjecting a fragile equilibrium to another source of perturbations (Aruin, 2002).

The results for this measure (Table 4.5) indicated a ***main effect for training*** with a 31.1% ($p<0.001$) improvement between pre- and post-test scores.

This substantial improvement could be supported by a number of studies using task-specific training and exercise activities which have shown to enhance feed-forward control that improved movement stability (Pai *et al*.; 2003). As was done in this intervention, Nitz & Choy (2004) also used specific balance strategy training workstations which proved to be more superior to average traditional exercise classes.

4.3.3.4 Reactive postural response

Postural disturbances can be introduced externally or internally in daily living and frequently impose threats to standing balance. To maintain standing balance, the ability to detect postural disturbances and generate proper postural responses is required. This ability has long been noted to deteriorate with increasing age and could possibly lead to imbalance and increased risk of falling. In addition to maintaining balance while performing daily activities, the ability to counteract unexpected externally induced unbalancing forces, i.e. reactive postural control, is also essential for independent living. The control of reactive balance is also under the influence of the function of the sensorimotor systems (Lin & Woollacott, 2005).

The subjects' automated postural response did show improvements with a pre-training score of 94.2±8.4 and a post-training score of 100±0.0 (Table 4.5) which indicates a statistically significant improvement of p=0.006. This increased capability for rapidly planning and executing an appropriate postural response to an external disturbance shows the potential for being able to decrease the risk of falling among the elderly (Tseng *et al.*, 2009).Recent evidence shows that a faster and/or more anteriorly positioned COM is more stable against backward balance loss, and that compensatory stepping is the key to recovering stability upon balance loss (Bhatt *et al.*, 2005). All postural strategies practiced and progressed as part of the intervention programme certainly had to play a part in achieving these results.

4.3.3.5 Sensory orientation

Postural control is no longer considered simply a summation of static reflexes but rather a complex skill based on the interaction of dynamic sensorimotor processes. The two main functional goals of postural behaviour are postural orientation and postural equilibrium. Postural orientation involves the active alignment of the trunk and head with respect to gravity, support surfaces, the visual surround and internal references. Sensory information from somatosensory, vestibular and visual systems is integrated, and the relative weights placed on each of these inputs are dependent on the goals of the movement task and the environmental context. The amount of cognitive processing required for postural control depends both on the complexity of the postural task and on the capability of the subject's postural control system (Horak, 2006).

Older adults have difficulty with high level sensory integration of the vestibular, visual and proprioceptive information used for balance. They have been shown to have a slow muscle response when balance is challenged, decreased muscle strength, limited range of movement and change in sensory integration (including a decrease in sensitivity to proprioceptive information). Vision has been shown to play a highly significant role in balance for elderly people and they place a great reliance on vision for balance (Wiener *et al*., 2010).

A post-training score of 87.9% shows a 25.4% (p=<0.001) improvement (Table 4.5) in the ability of the sensory orientation system to identify any increase in body sway due to somatosensory information. This improvement is due to the rehabilitation of balance, which formed a big focus of the intervention programme and was continuously challenged and progressed throughout the programme. An interesting study done by Anacker & Di Fabio (1992) showed that the orientation input from the ankle appears to have greater importance for preventing falls compared with a visual reference. This could indicate why, even though some tasks excluded vision, vast improvements were still seen even on unstable and altered surfaces.

4.3.3.6 Stability in gait

Gait is the normal manner of walking. One's gait pattern is one's collection of specific gait characteristics. When standing, the body strives to maintain the COG over the BOS. In walking, however, the COG is repeatedly moved outside of the BOS, and the body moves in that direction to realign the COG with the BOS. In this sense, walking is an on-going process of repeatedly losing and regaining balance (Horak, 2006).

Stability is a critical component of walking – it can be defined as the ability to maintain functional locomotion despite the presence of small kinematic disturbances of control errors (England & Granata, 2007).

The elderly show a great variability in gait patterns such as a shortened stride length, wider BOS, slower speed, flatter steps with a decreased heel strike and an increase in knee and hip flexion as well as an increase in double support stance, attributed to adaptation to a safer, less destabilizing gait pattern. Suggested reasons for this change in elderly gait patterns generally imply loss of muscle strength and a degeneration in balance (Horak, 2006).

Slower gaits have been shown to be directly associated with an increased fall risk and are correlated with lower scores on clinical balance scales. Several lines of research have proposed that a more quickly moving COM, due to faster gait, may travel forward more effectively to "catch up" with the slipping BOS. It has also been shown that faster gaits have higher stability (Bhatt *et al*., 2005). Hardy *et al*. (2007) note that gait speed has been recommended as a possible "vital sign" in older adults. They also note that gait speed has known relationships with overall functional status, so it can be linked to the capacity to perform daily activities.

These test results (Table 4.5) showed vast improvements in subjects' gait stability ($p<0.001$) with a 28.3% improvement being measured. Individual improvements were seen in all aspects of gait such as balance during gait, gait speed, obstacle negotiation as well as dual task activities. These finding suggest that exercise can improve these gait parameters in older adults. A number of studies have shown and suggest that this increase may be mediated by improved lower limb muscle strength (Manini *et al*., 2007; Pijnappels *et al*., 2008; Kang & Dingwell, 2008; Persch *et al*., 2009; Katsura *et al*., 2010).

Impaired walking performance can also be associated with impaired cognitive performance in dual-task walking. The gait changes observed in dual-task walking characterise decreased gait stability and indicate that cognitively demanding tasks during walking have a destabilising effect on gait and may place older people at a greater risk of falling (Hollman *et al*., 2006). It can also be concluded that the training intervention was effective in remediating cognitive decline and in improving the performance of gait during dual-task activities. This finding is supported by Li *et al., 2010.*

BESTest TOTAL

Overall significant improvements were seen in each system. The greatest improvements were seen in the 'transitions/anticipatory section', followed by the 'stability in gait' section (Table 4.5).

The most difficult system for the subjects seemed to be the items in the 'stability limits/verticality' section. Post intervention also did not result in particularly substantial improvements and only a 10.4% improvement was noted. The 'transitions/anticipatory' system which showed the lowest overall score pre-intervention, proved to have the highest % increase post-intervention with a 31.1% total overall improvement. The 'reactive postural control' system had the highest score pre- and post-intervention, and achieved a full score of 100% post-intervention. Stability in gait, with the second lowest score pre-intervention, showed the second highest improvement post-intervention with a 28.3% improvement.

Because the six systems being tested are all interacting systems underlying the control of balance and each task mayhave involve more than one system that interacts with others, it is difficult to pin-point or conclude the exact underlying reasons for the above and the fact that some systems improved more than others or why some of the improvements were on a minimal level. For example, the task of tapping alternate feet onto a stair (item 12) is placed in the "Anticipatory Postural Adjustments" system because it requires adequate anticipatory postural weight shifting from one leg to the other. However, it also requires an adequate base of support and strength in the hip abductors ("Biomechanical Constraints" system). Interactions among systems can be seen by how a single pathology, such as abnormal vestibular function, will likely affect several tasks, such as the ability to stand on foam with eyes closed (item 19 in the "Sensory Orientation" system) and the ability to rotate the head while walking (item 23 in the "Stability in Gait" system).

4.3.4 The 30-Second Chair Stand Test

One of the most common activities of daily living, and a precursor to walking, is rising from a seated to a standing position (McCarthy *et al.*, 2004). The 30-Second Chair Stand Test provides a measurement of a person's lower body (particularly legs) strength. This is associated with the ability to perform lifestyle tasks such as climbing stairs, and transfer skills, such as getting into and out of a car, standing from a seated position, getting into and out of a bath etc.

Muscle weakness and reduced physical fitness, particularly with regards to the lower body, are one of the most common intrinsic risk factors for falling and measuring lower body strength is critical in evaluating the functional performance of older adults. Construct (or discriminant) validity of the chair-stand was demonstrated by the test's ability to detect differences between various age and physical activity level groups. As expected, chair-stand performance decreased significantly across age groups in decades-from the 60s to the 70s to the 80s ($p < .01$) and was significantly lower for low-active participants than for high-active participants ($p < .0001$). It was concluded that the 30-Second Chair Stand Test provides a reasonably reliable and valid indicator of lower body strength in generally active, community-dwelling older adults (Jones *et al.*, 1999) and Skelton (2004) highlights the importance of preparatory strength training before balance-challenging exercises are attempted.Khalil *et al.* (2010) also showed the 30-Second Chair Stand Test to have excellent reliability and concurrent validity with other measures of gait and balance.

Table 4.6, shows the improvement measured for the 30-Second Chair Stand Test post-intervention and Table 4.7 the norms for females. Figure 4.5 shows a graph depicting this improvement,

Table 4.6: Table showing the improvement in subjects' scores for the 30-Second Chair Stand Test pre- and post- the 12-week exercise intervention programme

VARIABLE	PRE	POST	P-VALUE
30 Second chair stand test	10.1 (±6.0)	14.3 (±4.7)	< 0.001

Values are mean ± standard deviation

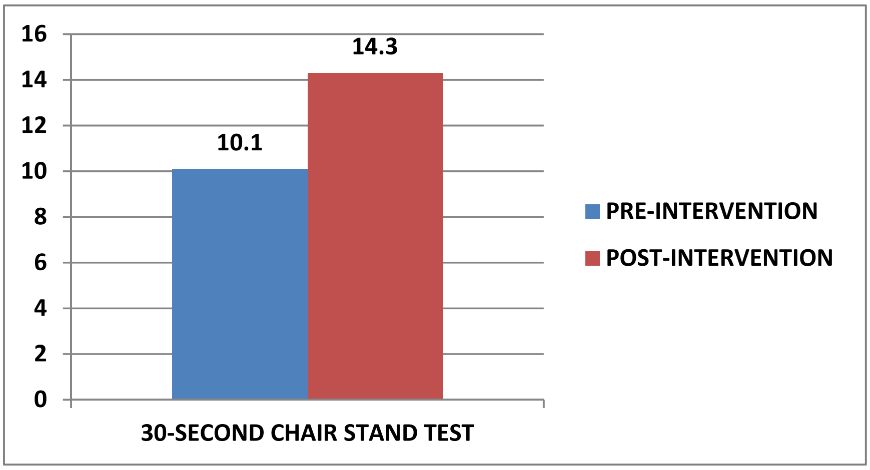

Figure 4.6: Graph representing the increase in the total number of full sit to stands in the 30-second chair stand test pre- and post-intervention.

Table 4.7: The 30- Second Senior Chair Stand Test Norms for females- SENIOR FITNESS TEST MANUAL (Rickli & Jones, n.d.)

AGE	65-69	70-74	75-79	80-84	85-89	90-94
% Rank						
Excellent	16	16	16	15	14	12
Good	14	14	13	12	11	9
Average	13	12	12	10	9	7
Below Average	11	10	9	8	7	4
Poor	8	7	6	4	4	0

The results (Table 4.6) indicate a statistically significant improvement ($p<0.001$) with an average increase of 4.2 full sit-to- stands. This test score would rank the average research age group as relatively below average pre-intervention to 'good' post-intervention, indicating a substantial rank improvement.

Although ankle plantar flexor, hip flexor, and knee extensor strength play essential roles in performing the sit-to- stand (STS) test, McCarthy *et al*. (2004) showed that ankle plantar flexor strength contributed the most to predicting sit to stand test performance, followed by hip flexor and knee extensor strength. In addition, the ankle plantar flexors undoubtedly contribute to successful STS performance in ways not measured by strength alone. For example, because each STS test involves repeated sitting and standing, where each successive STS repetition requires an adequate level of static balance, the essential role the ankle plantar flexors contribute in stabilizing the body in the upright standing position after each chair rise becomes apparent. Psychological factors and the enhancement of mood and confidence levels could also have contributed to this improvement.

CHAPTER 5: SUMMARY AND RECOMMENDATIONS

5.1 SUMMARY INTRODUCTION

The research was conducted as a quantitative experimental study, involving a specific 12-week exercise intervention programme to assess whether a cause and effect relationship exists between the risk of falling and exercise intervention.

The independent variable consisted of a 12-week exercise intervention programme involving two 30 minute exercise sessions a week, and the dependent variables assessed, pre- and post-intervention, consisted of 'FOF' status, balance, gait, strength and endurance as well as *getting up* capability. The research process involved the collection and translation of data into a numerical form so as to perform statistical calculations, assess results and draw conclusions there from.

The main aim of the study was to assess the effect of an exercise intervention programme on the fall risk of geriatric women and whether exercise intervention alone could have a positive effect on the main physical risk factors leading to falling among the elderly and improve their overall functional status.

The overall sample size consisted of 22 female subjects, aged 65 years and older. The sample was randomly selected to ensure that it was representative of the population of the research focus (Black, 2005).

The effect of the exercise intervention programme was evaluated by means of various instruments and assessments shown to be valid and reliable, such as the Biodex Balance System fall risk assessment, the BESTest as well as the 30-Second Chair Stand Test.

A summary of the results, followed by brief, but specific recommendations and a critical examination are provided in the next section.

5.2 RESULTS AND RELATED SPECIFIC RECOMMENDATIONS

The average age of the study cohort was 79.5 (±6.8) years, indicating a normal distribution of typical elderly females, as reported in literature. In 2012, 'old age' was considered and defined by the *World Health Organization* (WHO) (2012)and most developed world countries have accepted the chronological age of 65 years as a definition of 'elderly' or older person.

The results from the study of the variables tested were all found to be statistically significant, indicating that the intervention programme had indeed resulted in observable changes. These included 'Fear of Falling' rating, balance, gait, muscular strength and endurance as well as getting up capabilities.

Through exercise, FOF was decreased, and an increased quality of life is directly associated with this decrease in 'fear'. This stems from the multifactorial causes of falls, and it is recommended that the psychological status of this population is just as important, if not more important, than the physical status, due to the fact that a decrease in independent living, and activity-restriction as a result of being fearful, will have a direct result on physical deterioration.

The Biodex Balance System, assessing overall stability index and dynamic postural control, showed a small but significant training effect ($p=0.043$) post-exercise intervention. Through exercises designed to challenge subjects' stability and dynamic-anticipatory as well as reactive postural control, the subjects became far better equipped to maintain their COG over their BOS during such tasks. This is directly associated with the enhancement of neuromuscular mechanisms of proprioception, response time, as well as improvements in strength and power. These results stress the importance of the inclusion of such exercises as part of a fall prevention strategy, enhancing this population's adaptability to our ever changing environmental surroundings.

The overall result of the BESTest, involving numerous interacting balance control systems, showed a highly statistically significant improvement post-intervention ($p<0.001$). One of the main outcome measures, the ability to get up should a fall occur, fell within the 'Biomechanical

Constraints' system and showed a substantial overall improvement of 24.9% ($p<0.001$), only 19.3% away from a full score of 100%. These results strongly suggest the importance of the incorporation and prioritisation of the practicing of mentioned 'getting up' strategies to prevent the negative consequences of a long lie on the floor after a fall.

Another subsection of particular importance within the BEStest was the 'Stability in Gait' system which included the main parameters of gait stability that are directly associated to the ageing process, such as gait speed, obstacle negotiation and dual task activity performance. With a statistically significant improvement ($p<0.001$) of 28.3% post-intervention and an overall post-intervention score of 90.5%, exercise intervention involving such task specific activities is highly effective and an extremely beneficial part of overall fall risk prevention.

Improvements in strength and endurance were measured by means of the 30 Second Chair Stand Test and showed the specific lower body strength exercises included in the exercise intervention programme were effective and resulted in statistically significant improvements ($p<0.001$) in this important fall risk variable.

5.3 GENERAL RECOMMENDATIONS

This study was designed to examine the outcome of a specific exercise intervention programme on the overall fall risk of elderly women.

Procedures and programmes should be put in place in old age homes to support and encourage the participation of elderly women in specifically designed exercise programmes to decrease the risk of falling by focusing on specific physical risk factors that have shown to be strong determinants to the probability of sustaining a fall, and then having to deal with the negative consequences thereof.

This majority population needs to be targeted and informed of the risk factors leading to falls and the negative consequences thereof, such as the possibility of sustaining a serious injury or injuries and the impact this would then have on their life which would possibly force them to no longer be independent, thereby affecting their quality of life, as well as the costs that would be incurred should long-term care and treatment be necessary.

Falling among the elderly remains a pressing and important public health issue in both developed and developing societies and needs to be seriously considered. This population needs to be specifically targeted and programmes and support structures need to be put in place to allow this population to have access to such a preventative strategy.

Social support is also a highly influential component to the adoption of such a programme among this population. Specific suggestions and strategies need to be put into place to ensure participation rather than just the provision of general information.

5.4 LIMITATIONS

This study has several possible limitations that need to be noted:

- Research with a larger sample size could be investigated to verify the results. There were eight subjects that were unable to complete the study due to unforeseen circumstances, therefore diminishing the sample size.
- There is a limit to the generalizability of the effects of training as the focus of this study was on elderly female subjects. The question of whether elderly males would benefit equally from such a training programme remains.
- It is assumed that the improvements in risk factors seen following the 12-week intervention programme persist. However, this study is unable to determine whether the changes seen post-intervention persist, or if they deteriorate over time given that no repeat training and reassessment was done after an extended period had lapsed since the completion of the intervention and post-assessment.

- It proved difficult to ensure the same level of activity intensity with all the subjects due to different levels of capability. Some of subjects were unable to execute and practice certain of the more challenging exercises either due to lack of strength or endurance, extremely poor balance or lack of confidence.

5.5 RESEARCH CONTRIBUTION

"Population ageing is a triumph of humanity but also a challenge to society" (WHO, 2002)

Fall prevention is a challenge to population ageing. The number of falls increases in magnitude as the numbers of older adults increase in many nations throughout the world. Falls exponentially increase with age-related biological change. In fact, incidence of some fall injuries such as fractures and spinal cord injury, have markedly increased by 131% during the last three decades. If preventive measures are not taken in the immediate future, the number of injuries caused by falls is projected to be 100% higher by the year 2030 .This applies to many developing countries where currently close to 70% of the elderly population lives and where population ageing is occurring rapidly. "Unlike the developed world that became richer before getting older, developing countries are getting older before becoming richer". This is reflected in the fact that health in older age is neglected in some developing countries and fall prevention is one of the issues that has not been given sufficient attention (WHO, 2007).

Regular participation in moderate physical activity is integral to good health and maintaining independence, contributing to lowering risk of falls and fall-related injuries. Many older adults harbour an intrinsic FOF that leads to a decline in their overall quality of life and an increased risk of falling due to a reduction in activities needed to maintain self- esteem, independence, confidence, strength and balance. This FOF also leads to a lack of confidence in their ability to prevent or manage falls, such as how to get up should a fall occur (WHO, 2007).

Then there is the significant issue around the economic impact of falls, critical to family, community and society. Healthcare impacts and costs of falls in older age are significantly increasing all over the world (WHO, 2007).

People's attitudes influence their behaviours. Attitudes affect how people interpret and cope with falls in older age. Awareness should be raised in the general population of a number of interventions that could prevent falls. To make choices, people need to have at least basic information about the benefits of taking part in activities aimed at prevention. However, information alone is not enough; it needs to be framed so that it promotes realistic positive beliefs about the possibilities for preventive action if any change is likely to follow. Many older people seem to assume that fall prevention consists of activity restriction or the use of aids and home modifications. Research suggests that many older people are ignorant that fall risks can be reduced as there is a fatalistic acceptance of falling and this may contribute to low uptake of falls prevention interventions. Awareness should not only be aimed at older people, the opinions of others, including health professionals and family, can influence older peoples' decisions (WHO, 2007).

Informing the general population about the benefits of easy-to-provide interventions, such as strength and balance training activities, should influence older people's views and counteract fatalistic views that falling is a consequence of ageing. Exercise may be generally recognized as important for maintaining fitness and strength, but its importance in maintaining good balance and function needs to be better publicised (WHO, 2007).

Due to the fact that the effectiveness of less intensive interventions at a population level is currently unknown (WHO, 2007), it was the aim of this research to develop a standardized specific exercise programme focusing on the main physical risk factors leading to falling among the elderly. Exercises that improve strength, balance and gait, as well as decreasing the FOF and coping mechanisms, should a fall occur, are included.

Emphasis must be on the positive advantages of undertaking interventions, such as balance and exercise training, rather than on the reduction of risk of falls, since the latter is generally viewed negatively by many older people. Uptake of exercise intervention programmes may be encouraged through promoting greater awareness among older people, their families and health professionals, of how undertaking specific physical activities may contribute to improving balance and reducing falls risk and the effect this has on one's potential to maintain functional capabilities and thus avoid disability and dependence. General health, mobility and appearance should also be promoted and exercise intervention should be encouraged through being interesting, enjoyable and sociable. Intervention must also be promoted as being specifically designed to meet the specific needs, preferences and capabilities of the target population (WHO, 2007).

Uptake may be encouraged by the use of personal invitations to participate (from a health professional or other authority figures) and positive media images and peer role models to illustrate the social acceptability, safety and multiple benefits of taking part. Uptake and adherence may be encouraged through on-going support from family, peers, professionals and social organizations as well as medical organizations (WHO, 2007), such as medical aid schemes.

The evidence from this specific research project could contribute to the proof that intervention has been shown to be a tried and tested application to prevent the risk of falling, improve confidence and therefore, quality of life and long-lasting independence and coping mechanisms.

5.6 CONCLUSION AND REMAINING CHALLENGES

The research theory motivating this study was that the population is ageing rapidly and is becoming a grave issue for our health care systems (Taylor & Johnson, 2007:ix), resulting in substantial economic costs. Falling is the most serious problem in geriatrics (Levencron & Kimyagarov, 2007), with about a third of community-dwelling people aged 65 years and older who fall each year (Scheffer, 2011:13). A solution that is not based on increased fees and medical costs must be found (Taylor & Johnson, 2007:ix) in order to prevent falling among the elderly and the negative consequences thereof, such as fall induced injuries which is one of the most common causes of longstanding pain, functional impairment, disability, loss of independence and institutionalisation in the older population (Scheffer, 2011:13). The risk factors associated with ageing and the increased risk of falling among the elderly highlight the importance of research aimed at decreasing the incidence and severity of falls in the elderly.

After an extensive review of the literature with reference to falling among the elderly and the risk factors thereof, it was found that many of the intrinsic risk factors are physical and have been shown to be modifiable such as balance impairment, impairment in gait, as well as impairment in strength and endurance. Declining muscle function can also reduce the ability to get up should a fall occur, which can have devastating consequences such as hypothermia, dehydration, bronchopneumonia and the development of pressure sores. Fleming & Brayne (2008), state that the inability to get up from lying on the floor is the strongest independent risk factor for serious fall related injury (Bergland & Wyller, 2004). Another one of the most cited risk factors predisposing the elderly to recurrent falls is their subjective rating of the FOF, and in the last decades, fear of falling has gained recognition as a health problem that may be as disabling as, and sometimes even more disabling, than the fall itself (Bicket *et al*., 2010).

From cost efficiency and public health perspectives, exercise-alone interventions can be considered valuable, as they are more likely to be implemented in countries with fewer resources (Petridou, 2009).However, few studies have reported the effect of exercise intervention on falls in residential care facilities (Kim, 2008), and not one study was found to incorporate and target all of the above potentially modifiable risk factors through one exercise intervention programme.

The results from this study indicate that the 12-week exercise intervention programme, consisting of two 30-minute exercise sessions a week, proved to be successful in its aim to decrease the overall risk of falling among elderly women by decreasing or improving the cited individual risk factors that could potentially lead to falls among the elderly or increase the risk of serious fall-related injury. The intervention programme also proved to be successful in its attempt to lower the overall subjective rating of the subjects' FOF and thereby contributing to an improved quality of life and independent living status.

However, the challenges remain substantial, in that, despite the high prevalence and adverse effects of falls among older adults prevention still receives little attention in practice. This neglect reflects, in part, a health care system focused on the episodic diagnosis and treatment of individual diseases rather than on on-going evaluation and management of the multiple simultaneous conditions experienced by many older adults (Tinetti, 2003).

The results of this research emphasise the importance of further research involving a larger sample size, as well as whether the effects of such an intervention programme show the same improvements on a sample of the elderly male population. It would also be of interest as to whether the improvements following a 12-week intervention programme persist for an extended period of time, and a follow up study is recommended in this regard.

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APPENDICES

APPENDIX **pg.**

APPENDIX A

CONSENT FORM

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

STELLENBOSCH UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

THE DEVELOPMENT OF A FALL RISK ASSESSMENT AND EXERCISE INTERVENTION PROGRAMME FOR ELDERLY WOMEN

You are asked to participate in a research study conducted by Ghabrielle Anne Dekenah: BA Hons (Biokinetics) and Professor JG Barnard: (D.Phill.), from the Department of Sport Science at Stellenbosch University. The results from this study will be contributed to a research dissertation. You were selected as a possible participant in this study because you have met the necessary inclusion criteria of being a 65 + years, apparently healthy female.

1. PURPOSE OF THE STUDY

The aim of the research is to determine the effect of a specific exercise intervention programme on the risk of falling among elderly women.

2. PROCEDURES

If you volunteer to participate in this study, we would ask you to do the following:

- Be willing and able to undergo an extensive battery of subjective and objective assessments, which will include:

** All tests will be introduced by means of a demonstration**

-Filling in of a health/physical questionnaire, please note assistance will be provided if necessary.
-Orthostatic blood pressure readings.
-Height and weight measurements in order to determine your body mass index (BMI)
-A Biodex balance assessment, which involves standing on both a stable and unstable surface. You will complete a total of 3 x 20 second trials standing on both feet. The data collected will confirm either the presence or absence of a balance problem.
-Carrying out a battery of objective tests, known as the BESTest. Due to the fact that balance control is very complex and involves many different underlying systems, the BESTest is aimed to assess these systems in a very practical, safe and functional way.
-Finally a 30-second chair stand test will be carried out, where you will be asked to stand up and sit down as many times as you can in a period of 30-seconds. The aim of this test is to determine each individuals overall lower body strength.

These tests will be conducted at the Biokinetics Centre, at the Sport Science Department, part of Stellenbosch University.

- Once the pre-test assessment has been completed and all the necessary data has been collected, you will be asked to attend a 12 week exercise intervention programme, consisting of 2 x 30 minute low to moderate intensity exercise sessions per week.

**These exercises sessions will be conducted at your specific place of*

- On completion of the 12 week exercise intervention programme you will be retested in order to note any improvements obtained due to the specific exercise intervention programme.

3. POTENTIAL RISKS AND DISCOMFORTS

Safety will be ensured during all tests and activities carried out, by means of comprehensive demonstrations and addressing any potential risks that may occur. Potential discomforts may include muscular and joint stiffness due to new movements and exercises introduced in the exercise intervention programme, especially if you have been sedentary prior to involvement in this study. Exercises will be progressed accordingly and modified if need be in order to suit each individual's level of experience or capability. If under any unforeseen and unfortunate circumstances, a participant becomes injured the researcher may feel it is necessary for this participant to withdraw from the study. The participant will also not be allowed to continue with the study if they are unable to attend more than fiveof the exercise sessions.

4. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The potential benefits include subjects being made aware of all their potential risks that may lead to an injurious fall. This will be achieved both through particular assessment measures that will be carried out as well as information, education and advice offered relating to falling and the prevention thereof. The exercise intervention programme will provide numerous benefits to each individual such as improvements in general functional ability, improvements in strength, flexibility, mobility, gait, balance as well as improvements in reaction time and getting up strategies. This all, in turn, will lead to a marked reduction to each participants fall risk status, as well as improvements in psychological well-being; confidence levels and will effectively contribute to an independent lifestyle. After the study participants will also be debriefed and given any appropriate feedback as well as future recommendations.

This study will also prove to be beneficial to health and medical science as it will positively contribute to our understanding of this relevant topic, and implementation thereof.

5. PAYMENT FOR PARTICIPATION

Please note you will not receive any remuneration for your involvement in this study.

6. CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of coding procedures, and all collected hard data will be kept in a secure location within the Sport Science Department at the University of Stellenbosch. Electronic data will be kept in a file only accessible by means of a secure password. Only the researcher responsible for this study as well as Professor Barnard (research supervisor) will have access to this information.

Eventually this information will need to be released to the relevant statistician assigned to this project in order to assess relevant trends and outcomes. The information will be released as part of the pre-determined coding procedure. Published results will also ensure subject confidentially and anonymity.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you don't want to answer and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so, such as, if a subject is unable to attend more than five exercise intervention sessions, as mentioned previously. This will be done without regard to the subjects consent.

8. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact either the:

Principal Investigator:
Gabi Dekenah
Contact number: 0829758025
Address: 124 Myburgh Road, Diep River, Cape Town, 7800

OR

Research Supervisor:
Professor JG Barnard
Contact number: 021 8084718
Address: Sport Science Department, Stellenbosch, 7780.

9. RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

10. SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to me/the subject/the participant: (Name) ______________________ by Gabi Dekenah (principal researcher), in English.
OR it was satisfactorily translated to me in Afrikaans by Professor JG Barnard (research supervisor).

I was given the opportunity to ask questions and these questions were answered to my satisfaction.
I hereby consent voluntarily to participate in this study/I hereby consent that the subject/participant may participate in this study. I have been given a copy of this form.

____
Name of Subject/Participant

____
Name of Legal Representative (if applicable)

____ ____________________
Signature of Subject/Participant or Legal Representative Date

11. SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to (name of subject/participant] ____________________________ and/or (his/her) representative (name of representative) ___________ ____________________________. The participant was encouraged and given ample time to ask me any questions.

This conversation was conducted to me in English by the principal research investigator (Gabi Dekenah) and was translated to me in Afrikaans by the research supervisor (Professor JG Barnard).

____ ______________
Signature of Investigator Date

APPENDIX B

HEALTH ACTIVITY QUESTIONAIRRE

(Rose, 2003)

HEALTH/ACTIVITY QUESTIONNAIRE

Date ______________________________

Name _____________________________

Address

____

__________________________________ City ______________________________ Code _________

Home phone number ____________________

Mobile Phone number ___________________

Year of birth ____________________________

Age _________

Height _____________ Weight _____________

Ethnicity ________________

Who to contact in case of emergency ____________________ Phone number ____________________

Name of your physician _________________________________ Phone number ____________________

PLEASE CHECK THE APPROPRIATE BOX: e.g. [X]

Do you live alone? [YES] [NO]

Do you feel that you have support, e.g. familial/social? [YES] [NO]

Do you smoke? [YES] [NO] [QUIT IN LAST 6 MONTHS]

Have you ever been diagnosed as having any of the following conditions?

YES (**X**) Year of onset (approximate)/details

Heart attack [ ] ___________________________

Angina (chest pain) [ ] ___________________________

Syncope /dizziness [ ] ___________________________

FEQUENCY: [DAILY] [WEEKLY] HOW MANY TIMES/WEEK _________________

High blood pressure [ ] ___________________________

[ ]

Stroke		______________________
Diabetes	☐	______________________
Neuropathies (problems with sensations)	☐	______________________
Intermittent claudication	☐	______________________
Respiratory disease/COPD	☐	______________________
Parkinson's disease	☐	______________________
Multiple sclerosis	☐	______________________
Polio/post polio syndrome	☐	______________________
Epilepsy/seizures	☐	______________________
Other neurological conditions	☐	______________________
Osteoporosis	☐	______________________
Rheumatoid arthritis	☐	______________________
Other arthritic conditions	☐	______________________
Visual/depth perception problems	☐	______________________
Inner ear problems/recurrent infections	☐	______________________
Dizziness/vertigo	☐	______________________
Urinary incontienence	☐	______________________
Cerebellar problems (ataxia)	☐	______________________
Other movement disorders	☐	______________________
Musculoskeletal/movement disorders	☐	______________________
Spinal cord injury	☐	______________________
Sleep disturbances	☐	______________________
Chemical dependency (alcohol &/drugs)	☐	______________________
Depression/anxiety disorders	☐	______________________
Malnourishment	☐	______________________
Vitamin D deficiency	☐	______________________

Anaemia ☐ ______________________________

Dementia ☐ ______________________________

1. Have you ever been diagnosed as having any of the following conditions? **If YES: indicate with cross**

Yes (**X**) Year of onset (approximate)/detail

Cancer ☐ ______________________________

If YES describe what kind____

Joint replacement ☐ ______________________________

If YES, which joint (e.g. knee, hip) and side (left or right) ____

Cognitive disorder(i.e. Problems with memory/language) ☐ ______________________________

If YES, describe condition____

Uncorrected visual problems ☐ ______________________________

Last tested (approximate date) ____________________________

If YES, describe type____

Any other type of health problem ☐ ______________________________

If YES, describe condition____ _

2. Do you currently suffer any of the following symptoms in your legs or feet?

Numbness___________________________ Arthritis_________________________________

Tingling _____________________________ Swelling _________________________________

3. Do you currently have any medical conditions for which you see a physician regularly? YES NO

If YES, please describe the condition(s).

____

4. Do you wear eye glasses? YES NO

5. Do you wear hearing aids? YES NO

6. Do you use an assistive device for walking? YES NO SOMETIMES

7. List all medications that you currently take (including over-the-counter medications)

Type of medication	For what condition
________________________________	________________________________
________________________________	________________________________
________________________________	________________________________
________________________________	________________________________
________________________________	________________________________
________________________________	________________________________

8. Have you required emergency medical care or hospitalization in the last three years?

   YES NO

   If YES, please list when this occurred and briefly explain why.

   ____

9. Have you ever had any condition or suffered any injury that has affected your balance or ability to walk without assistance? YES NO

If YES, please list when this occurred and briefly explain condition or injury.

____

10. How many times have you fallen within the past year? 0 1-2 X 3-4 X >4 X

Did you require medical treatment? YES NO

If you answered YES to either question, please list the approximate date of the fall, the medical treatment required, and the reason you fell in each case (e.g. uneven surface, going down stairs)

____

____

PLEASE CIRCLE THE APPROPRIATE NUMBER: e.g. (1)

11. Are you worried/concerned about falling?

1	2	3	4	5
No	**a little**	**moderately**	**very**	**extremely**

12. How would you describe your health?

1	2	3	4	5
Excellent	**Very good**	**Good**	**Fair**	**Poor**

13. In the past 4 weeks, to what extent did health problems limit your everyday physical activities (such as walking and household chores)?

1	2	3	4	5
Not at all	**slightly**	**Moderately**	**Quite a bit**	**Extremely**

14. How much "bodily pain" have you generally had during the past 4 weeks (while doing normal activities of daily living)?

1	2	3	4	5
None	**Very little**	**Moderate**	**Quite a bit**	**Severe**

15. In general, how much depression have you experienced in the past 4 weeks?

1	2	3	4	5
None	**Very little**	**Moderate**	**Quite a bit**	**Severe**

16. In general, how would you rate the quality of your life? (circle appropriate number)

1	2	3	4	5
Very low	**Low**	**Moderate**	**High**	**Very high**

17. Please indicate your ability to do each of the following:

	Can do	**Can do with Difficulty/help**	**Cannot do**
a. Take care of your own personal needs (E.g. dressing yourself)	2	1	0
b. Bathe yourself using a tub/shower	2	1	0
c. Climb up and down a flight of stairs	2	1	0
d. Walk outside one or two blocks	2	1	0
e. Do light household activities-cooking, dusting, sweeping etc	2	1	0

f. Do own shopping for groceries and clothes	2	1	0
g. Walk 10-15 minutes	2	1	0
h. Walk 15-30 minutes	2	1	0
i. Lift and carry a full bag of groceries	2	1	0
j. Lift and carry medium to large suitcase	2	1	0
k. Do most heavy household chores-vacuuming etc	2	1	0
l. Do strenuous activities-hiking, digging in garden moving heavy objects, bicycling etc	2	1	0

18. In general do you require household or nursing assistance to carry out daily activities?

[YES] [NO]

If YES, please check (X) the reason(s).

[ ] Pain
[ ] Strength or endurance
[ ] Lack of flexibility or balance
[ ] Health problems
[ ] Other reasons

____

____

____

19. In a typical week, how often do you leave your house (to run errands, go to work, go to meetings, classes, church, social functions, etc.)?

_______ Less than once/week _______ 3-4 times/week

_______ 1-2 times/week _______ almost every day

20. Do you currently participate in regular physical exercise (such as walking, sports, exercise classes, housework, and yard work) that is strenuous enough to cause a noticeable increase in breathing, heart rate, or perspiration? [YES] [NO]

If YES, how many days per week? (Please circle appropriate number)

1x **2x** **3x** **4x** **5x** **6x** **7x**

21. When you go for walks (if you do), which of the following best describes your walking pace? **(Tick √)**

___________ Strolling

___________ Average

___________ Fairly brisk

___________Do not go for walks on a regular basis

22. Did you require assistance in completing this form? **(Circle appropriate answer)**

None (or very little)   Needed quite a bit of help

If needed help please provide a reason/s: ____

APPENDIX C

BALANCE EVALUATION-SYSTEMS TEST (BESTest)

(Fay Horak PhD 2008)

BESTest
BALANCE EVALUATION – SYSTEMS TEST

ALL TESTS WILL BE CONDUCTED BY THE PRINCIPAL RESEARCHER: GABI DEKENAH, AS WELL AS ALL INFORMATION COLLECTED

TEST NUMBER/SUBJECT CODE___________________ **DATE**____________________

EXAMINER NAME______________________________

EXAMINAR instructions for BESTest:

1. Subjects should be tested with flat heeled shoes or with shoes and socks off
2. If subject must use an assistive device for an item, score that item one category lower
3. If subject requires physical assistance to perform an item score the lowest category (0) for that item.

TOOLS REQUIRED:

- Stop watch
- Measuring tape mounted on wall for Functional Reach test
- Approximately 60 cm x 60 (2 x2 ft) cm block of 4-inch, medium-density, foam/aerex mat
- 10 degree incline ramp (at least 2 x 2 ft) to stand on
- Stair step, 15cm (6 inches) in height for alternate stair tap
- 2 stacked shoe boxes for obstacle during gait
- 2.5kg free weight for rapid arm raise
- Firm chair with arms with 3 metres in front marked with tape for Get Up and Go test
- Masking tape to mark 3 m and 6 m lengths on the floor for Get Up and Go

SUMMARY OF PERFORMANCE: CALCULATE PERCENT SCORE

Section I:	________	**/15 x 100 =**	________	**Biomechanical constraints**
Section II:	________	**/21 x 100 =**	________	**Stability Limits/Verticality**
Section III:	________	**/18 x 100 =**	________	**Transitions/Anticipatory**
Section IV:	________	**/18 x 100 =**	________	**Reactive**
Section V:	________	**/15 x 100 =**	________	**Sensory Orientation**
Section VI:	________	**/21 x 100 =**	________	**Stability in Gait**
TOTAL:	________	**/108 points =**	________	**Percent Total Score**

BESTest

BALANCE EVALUATION – SYSTEMS TEST

I. BIOMECHANICAL CONSTRAINTS **SECTION I: _________/15 POINTS**

1. BASE OF SUPPORT
   - (3) Normal: Both feet have normal base of support with no deformities or pain
   - (2) One foot has deformities and/or pain
   - (1) Both feet has deformities OR pain
   - (0) Both feet have deformities AND pain

2. CoM ALIGNMENT
   - (3) Normal AP and ML CoM alignment and normal segmental postural alignment
   - (2) Abnormal AP OR ML CoM alignment OR abnormal segmental postural alignment
   - (1) Abnormal AP OR ML CoM alignment AND abnormal segmental postural alignment
   - (0) Abnormal AP AND ML CoM alignment

3. ANKLE STRENGTH AND RANGE
   - (3) Normal: Able to stand on toes with maximal height and to stand on heels with front of feet up
   - (2) Impairment in either foot of either ankle flexors or extensors (i.e. less than maximum height)
   - (1) Impairment in two ankle groups (e.g.; bilateral flexors or both ankle flexors and extensors in 1 foot)
   - (0) Both flexors and extensors in both left and right ankles impaired (i.e. less than maximum height)
4. HIP/TRUNK LATERAL STRENGTH
   - (3) Normal: Abducts both hips to lift the foot off the floor for 10 s while keeping trunk vertical
   - (2) Mild: Abducts both hips to lift the foot off the floor for 10 s but without keeping trunk vertical
   - (1) Moderate: Abducts only one hip off the floor for 10 s with vertical trunk
   - (0) Severe: Cannot abduct either hip to lift a foot off the floor for 10 s with trunk vertical or without vertical

5. SIT ON FLOOR AND STAND UP Time___________secs
   - (3) Normal: Independently sits on the floor and stands up
   - (2) Mild: Uses a chair to sit on floor OR to stand up
   - (1) Moderate: Uses a chair to sit on floor AND to stand up
   - (0) Severe: Cannot sit on floor or stand up, even with a chair, or refuses

II. STABILITY LIMITS **SECTION II: __________/21 POINTS**

6. SITTING VERTICAL AND LATERAL LEAN

Lean			Verticality		
Left	Right		Left	Right	
(3)	(3)	Maximum lean, subject moves Upper shoulders beyond body Midline, very stable	(3)	(3)	Realigns to vertical with very small or no overshoot
(2)	(2)	Moderate lean, subject's upper Shoulder approaches body midline Or some instability	(2)	(2)	Significantly over-or under-shoots but eventually realigns To vertical
(1)	(1)	Very little lean, or significant Instability	(1)	(1)	Failure to realign to vertical
(0)	(0)	No lean or falls (exceeds limit)	(0)	(0)	Falls with the eyes Closed

7. FUNCTIONAL REACH FORWARD *Distance reached:______ cm*

(3) Maximum to limits: >32 cm
(2) Moderate: 16.5 cm -32 cm
(1) Poor: < 15.5 cm
(0) No measurable lean – or must be caught

8. FUNCTIONAL REACH LATERAL *Distance reached: Left_____ cm , Right_____ cm*

Left	Right	
(3)	(3)	Maximum to limit: > 25.5 cm
(2)	(2)	Moderate: 10-25.5 cm
(1)	(1)	Poor: < 10 cm
(0)	(0)	No measurable lean, or must be caught

III. TANSITIONS-ANTICIPATORY POSTURAL ADJUSTMENT SECTION III. ____/18 POINTS

9. SIT TO STAND

(3) Normal: Comes to stand without the use of hands and stabilizes independently
(2) Comes to stand on the first attempt with the use of hands
(1) Comes to stand after several attempts or requires minimal assist to stand or stabilize or requires touch of back of leg or chair
(0) Requires moderate or maximal assist to stand

10. RISE TO TOES

(3) Normal: Stable for 3 sec with good height
(2) Heels up, but not full range (smaller than when holding hands so no balance requirement) – OR – slight instability & holds for 3 sec
(1) Holds for less than 3 sec
(0) Unable

11. STAND ON ONE LEG

Left *Time in Sec:*_______
(3) Normal: Stable > 20 s
(2) Trunk motion, OR 10-20 s
(1) Stands 2 – 10 s
(0) Unable

Right *Time inSec:*_______
(3) Normal: Stable for >20s
(2) Trunk motion, OR 10-20 s
(1) Stands 2 – 10 s
(0) Unable

12. ALTERNATE STAIR TOUCHING *# of successful steps:* ________ *Time in Sec*_______

(3) Normal: Stands independently and safely and completes 8 steps in < 10 seconds
(2) Completes 8 steps (10-20 seconds) AND/OR show instability such as inconsistent foot placement, excessive trunk motion, hesitation or arrythmical
(1) Completes < 8 steps – without minimal assistance (i.e. assistive device) OR > 20 sec for 8 steps
(0) Completes < 8 steps, even with assistive devise

13. STANDING ARM RAISE

(3) Normal: Remains stable
(2) Visible sway
(1) Steps to regain equilibrium/unable to move quickly without losing balance
(0) Unable, or needs assistance for stability

IV. REACTIVE POSTURAL RESPONSE **SECTION IV: ________/18 POINTS**

14. IN PLACE RESPONSE-FORWARD

(3) Recovers stability with ankles, no added arms or hips motion
(2) Recovers stability with arm or hip motion
(1) Takes a step to recover stability
(0) Would fall if not caught OR requires assist OR will not attempt

15. IN PLACE RESPONSE-BACKWARD

(3) Recovers stability at ankles, no added arm/hip motion
(2) Recovers stability with some arm or hip motion
(1) Takes a step to recover stability
(0) Would fall if not caught OR requires assistance OR will not attempt

16. COMPENSATORY STEPPING CORRECTION-FORWARD

(3) Recovers independently, with a single, large step (second realignment step is allowed)
(2)More than one step used to recover equilibrium, but recovers stability independently OR 1 step with imbalance
(1) Takes multiple steps to recover equilibrium, or needs minimum assistance
(0) No step, OR would fall if not caught, OR falls spontaneously

17. COMPENSATORY STEPPING CORRECTION-BACKWARD

(3) Recovers independently, with a single large step
(2) More than one step used, but stable and recovers independently OR 1 step with imbalance
(1) Takes several steps to recover equilibrium, or needs minimum assistance
(0) No step, OR would fall if not caught, OR falls spontaneously

18. COMPENSATORY STEPPING CORRECTION-LATERAL

Left	Right
(3) Recovers independently with 1 step of Normal length/width (crossover or lateral OK)	(3) Recovers independently with 1 step of normal length/width (crossover or lateral OK)
(2)Several steps used, but recovers independently	(2) Several steps used but recovers Independently
(1) Steps, but needs to be assisted to prevent A fall	(1) Steps, but needs assistance to prevent a fall
(0) Falls, or cannot stop	(0) Falls, or cannot stop

V.SENSORY ORIENTATION **SECTION V: _________/15 POINTS**

19. SENSORY INTEGRATION FOR BALANCE (MODIFIED CTSIB)

A –EYES OPEN,FIRM SURFACE	**B –EYES CLOSED,FIRM SURFACE**	**C -EYES OPEN,FOAM SURFACE**	**D –EYES CLOSED,FOAM SURFACE**
Trial 1 ______ sec	Trial 1 ______ sec	Trial 1 ______ sec	Trial 1 ______ sec
Trial 2 ______ sec	Trial 2 ______ sec	Trial 2 ______ sec	Trial 2 ______ sec
(3)30 s stable	(3)30 s stable	(3)30 s stable	(3)30 s stable
(2)30s unstable	(2)30s unstable	(2)30s unstable	(2)30s unstable
(1)< 30s	(1)< 30s	(1)< 30s	(1)< 30s
(0) Unable	(0) Unable	(0) Unable	(0) Unable

20. INCLINE-EYES CLOSED

Toes up

(3)Stands independently, steady without excessive sway, hold 30 sec, and align with gravity
(2) Stands independently 30 sec with greater swat than in item 19B OR aligns with surface
(1) Requires touch assist OR stands without assist for 10-20 sec
(0) Unable to stand >10 sec OR will not attempt independent stance

VI.STABILITY IN GAIT **SECTION VI: ________/21 POINTS**

21. GAIT-LEVEL SURFACE *Time________secs.*
(3) Normal: walks 20 ft., good speed (</= 5.5 sec), no evidence of imbalance
(2) Mild: 20 ft., slower speed (>5.5 sec), no evidence of imbalance
(1) Moderate: Walks 20 ft., evidence of imbalance (wide-base, lateral trunk motion, inconsistent step path) – at any preferred speed
(0) Severe: cannot walk 20ft. Without assistance, or severe gait deviations OR severe imbalance

22. CHANGE IN GAIT SPEED
(3) Normal: Significantly changes walking speed without imbalance
(2) Mild: Unable to change walking speed without imbalance
(1) Moderate: Changes walking speed but with signs of imbalance
(0) Severe: Unable to achieve significant change in speed AND signs of imbalance

23. WALK WITH HEAD TURNS – HORIZONTAL
(3) Normal: Performs head turns with no change in gait speed and good balance
(2) Mild: Performs head turns smoothly with reduction in gait speed
(1) Moderate: Performs head turns with imbalance
(0) Severe: performs head turns with reduced speed AND imbalance AND/OR will not move head within available range while walking

24. WALK WITH PIVOT TURNS
(3) Normal: Turns with feet close, FAST (</= 3 steps) with good balance
(2) Mild: Turns with feet SLOW (>/= 4 steps) with good balance
(1) Moderate: Turns with feet close at any speed with mild signs of imbalance
(0) Severe: Cannot turn with feet close at any speed and significant imbalance

25. STEP OVER OBSTACLES *Time_________sec*
(3) Normal: Able to step over 2 stacked shoe boxes without changing speed and with good balance
(2) Mild: Steps over 2 stacked shoe boxes but slows down, with good balance
(1) Moderate: steps over shoe boxes with imbalance or touches box
(0) Severe: cannot step over shoe boxes AND slows down with imbalance or cannot perform without assistance

26. TIMED "GET UP & GO" *Get Up and Go: Time____________sec*
(3) Normal: Fast (<11 sec) with good balance
(2) Mild: Slow (>11 sec) with good balance
(1) Moderate: Fast (< 11 sec) with imbalance
(0) Severe: Slow (>11 sec) AND imbalance

27. TIMED "GET UP & GO" WITH DUAL TASK *Dual task: Time_________________sec*
(3) Normal: No noticeable change between sitting and standing in the rate or accuracy of backward counting and no change in gait speed
(2) Mild: Noticeable slowing, hesitation or errors in counting backwards OR slow walking (10%) in dual task
(1) Moderate: Affects on BOTH the cognitive task AND slow walking (>10%) in dual task
(0) Severe: Can't count backward while walking or stops talking while walking

(Fay Horak PhD 2008)

INSTRUCTIONS FOR BESTEST

BIOMECHANICAL CONSTRAINTS

1. BASE OF SUPPORT

Examiner Instructions: Closely examine both feet to look for deformities or complaints of pain such as abnormal pronation/supination, abnormal or missing toes, pain from plantar fascitis, bursitis, etc).

Patient: Stand up in your bare feet and tell me if you currently have any pain in your feet or ankles or legs.

2. COM ALIGNMENT

Examiner Instructions: Look at the patient from the side and imagine a vertical line through their center of body mass (CoM) to their feet. (The CoM is the imaginary point inside or outside the body about which the body would rotate if floating in outer-space.) In an adult, standing erect, a vertical line through the CoM to the support surface is aligned in front of the vertebrae at the umbilicus and passes about 2 cm in front of the lateral malleolus, centered between the two feet. Abnormal segmental postural alignment such as scoliosis or kyphosis or asymmetries may or may not affect CoM alignment.

Patient: Stand relaxed, looking straight ahead

3. ANKLE STRENGTH & RANGE

Examiner Instructions: Ask the patient rest their fingertips in your hands for support while they stand on their toes has high as possible and then stand on their heels. Watch for height of heel and toe lift.

Patient*:* Rest your fingers in my hands for support while you stand on your toes**.** Now stand on your heels by lifting up your toes. Maintain each position for 3 sec.

4. HIP/TRUNK LATERAL STRENGTH

Examiner Instructions: Ask the patient to rest their fingertips in your hands while they lift their leg to the side off the floor and hold. Count for 10 sec while their foot is off the floor with a straight knee. If they must use moderate force on your hands to keep their trunk upright, score as without keeping trunk vertical.

Patient: Lightly rest your fingertips in my hands while you lift your leg out to the side and hold until I tell you to stop. Try to keep your trunk vertical while you hold your leg out.

5. SIT ON FLOOR AND STANDUP

Examiner Instructions: Start with the patient standing near a sturdy chair. The patient can be considered to be sitting when both buttocks are on the floor. If the task takes more than 2 minutes to complete the task, with or without a chair, score 0. If the patient requires any physical assistance, score 0.

Patient: Are you able to sit on the floor and then stand up, in less than 2 minutes? If you need to use a chair to help you go onto the floor or to stand up, go ahead but your score will be affected. Let me know if you cannot sit on the floor or stand up without my help.

SITTING STABILITY LIMITS

6. VERTICALITY AND LATERAL LEAN

Examiner Instructions: Patient is sitting comfortably on a firm, level, armless surface (bench or chair) with feet flat on floor. It is okay to lift ischium or feet when leaning. Watch to see if the patient returns to vertical smoothly without over or undershooting. Score the worst performance to each side.

Patient: Cross your arms over your chest. Place feet shoulder width apart. I'll be asking you to close your eyes and lean to one side as far as you can. You'll keep your spine straight, and lean sideways as far as you can without losing your balance OR using your hands. Keeping your eyes closed, return to your starting position when you've leaned as far as you can. It's okay to lift your buttocks and feet. Close your eyes Lean now. (REPEAT other side)

7. FUNCTIONAL REACH FORWARD

Examiner Instructions: Examiner places the ruler at the end of the fingertips when the arms are out at 90 degrees. The patient may not lift heels, rotate trunk, or protract scapula excessively. Patient must keep their arms parallel to ruler and may use less involved arm. The recorded measure is the maximum horizontal distance reached by the patient. Record best reach.

Patient: Stand normally. Please lift both arms straight in front of you, with fingertips held even. Stretch your fingers and reach forward as far as you can. Don't lift your heels. Don't touch the ruler or the wall. Once you've reached as far forward as you can, please return to a normal standing position. I will ask you to do this two times. Reach as far as you can.

8. FUNCTIONAL REACH LATERAL

Examiner Instructions: Have subject align feet evenly so that the fingertips, when the arm is out at 90 degrees is at the start of the ruler. The recorded measure is the maximum horizontal distance reached by the patient. Record the best reach. Make sure the subject starts in neutral. The patient is allowed to lift one heel off the floor but not the entire foot.

Patient: Stand normally with feet shoulder width apart. Arms at your sides. Lift your arm out to the side. Your fingers should not touch the ruler. Stretch your fingers and reach out as far as you can. Do not lift your toes off the floor. Reach as far as you can. (REPEAT other side)

TRANSITIONS – ANTICIPATORY POSTURAL ADJUSTMENT

9. SIT TO STAND

Examiner Instructions: Note the initiation of the movement, and the use of hands on the arms of the chair or their thighs or thrusts arms forward

Patient: Cross arms across your chest. Try not to use your hands unless you must. Don't let your legs lean against the back of the chair when you stand. Please stand up now.

10. RISE TO TOES

Examiner Instructions: Allow the patient to try it twice. Record the best score. (If you suspect that subject is using less than their full height, ask them to rise up while holding the examiners' hands.) Make sure subjects look at a target 4-12 feet away.

Patient: Place your feet shoulder width apart. Place your hands on your hips. Try to rise as high as you can onto your toes. I'll count out loud to 3 seconds. Try to hold this pose for at least 3 seconds. Look straight ahead. Rise now.

11. STAND ON ONE LEG

Examiner Instructions: Allow the patient two attempts and record the best. Record the sec they can hold posture, up to a maximum of 30 sec. Stop timing when subject moves their hand off hips or puts a foot down.

Patient: Look straight ahead. Keep your hands on your hips. Bend one leg behind you. Don't touch your raised leg on your other leg. Stay standing on one leg as long as you can. Look straight ahead. Lift now. **(**REPEAT other side**)**

12. ALTERNATE STAIR TOUCHING

Examiner Instructions: Use standard stair height of 6 inches. Count the number of successful touches and the total time to complete the 8 touches. It's permissible for subjects to look at their feet.

Patient: Place your hands on your hips. Touch the ball of each foot alternately on the top of the stair. Continue until each foot touches the stair four times (8 total taps). I'll be timing how quickly you can do this. Begin now.

13. STANDING ARM RAISE

Examiner Instructions: Use 2.5 Kg (5 lb) weight. Have subjects stand and lift weight with both hands to shoulder height. Subjects should perform this as fast as they can. Lower score by 1 category if weight must be less than 2.5 Kg (5 lb) +/or lifts < 75 deg.

Patient: Lift this weight with both hands from a position in front of you to shoulder level. Please do this as fast as you can. Keep your elbows straight when you lift and hold. Hold for my count of 3. Begin now.

REACTIVE POSTURAL RESPONSES

14. IN PLACE RESPONSE- FORWARD

Examiner Instructions: Stand in front of the patient, place one hand on each shoulder and lightly push the patient backward until their anterior ankle muscles contract, (and toes just start to extend) then suddenly release. Do not allow any pre-leaning by patient. Score only the best of 2 responses if the patient is unprepared or you pushed too hard.

Patient: For the next few tests, I'm going to push against you to test your balance reaction. Stand in your normal posture with your feet shoulder width apart, arms at your sides. Do not allow my hands to push you backward. When I let go, keep your balance without taking a step.

15. IN PLACE RESPONSE- BACKWARD

Examiner Instructions: Stand behind patient, place one hand on each scapula and isometrically hold against patient's backward push, until heels are about to be lifted, not allowing trunk motion. Suddenly release. Do not allow any pre-leaning by patient. Score the better of 2 responses if patient is unprepared, or you pushed too hard.

Patient*:* Stand with your feet shoulder width apart, arms at your sides. Do not allow my hands to push you forward. When I let go, keep your balance without taking a step

16. COMPENSATORY STEPPING CORRECTION-FORWARD

Examiner Instructions: Stand in front to the side of patient with one hand on each shoulder and ask them to push forward. (Make sure there is room for them to step forward). Require them to lean until their shoulders and hips are in front of their toes. Suddenly release your support when the subject is in place. The test must elicit a step. Be prepared to catch patient.

Patient: Stand with your feet shoulder width apart, arms at your sides. Lean forward against my hands beyond your forward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall.

17. COMPENSATORY STEPPING CORRECTION - BACKWARD

Examiner Instructions: Stand in back and to the side of the patient with one hand on each scapula and ask them to lean backward. (Make sure there is room for them to step backward.) Require them to lean until their shoulders and hips are in back of their heels. Release your support when the subject is in place.

Patient: Stand with your feet shoulder width apart, arms down at your sides. Lean backward against my hands beyond your backward limits. When I let go, do whatever is necessary, including taking a step, to avoid a fall. Test must elicit a step. NOTE: Be prepared to catch patient.

18. COMPENSATORY STEPPING CORRECTION- LATERAL

Examiner Instructions: Stand behind the patient, place one hand on either the right (or left) side of the pelvis, and ask them to lean their whole vertical body into your hand. Require them to lean until the midline of pelvis is over the right (or left) foot and then suddenly release your support.

Patient: Stand with your feet together, arms down at your sides. Lean into my hand beyond your sideways limit. When I let go, step if you need to, to avoid a fall. NOTE: Be prepared to catch patient.

SENSORY ORIENTATION

19. SENSORY INTEGRATION FOR BALANCE (MODIFIED CTSIB)

Examiner Instructions: Do the tests in order. Record the time the patient was able to stand in each condition to a maximum of 30 seconds. Repeat condition if not able to stand for 30 s and record both trials (average for category). Use medium density Temper® foam, 4 inches thick. Assist subject in stepping onto foam. Have the subject step off the foam between trials. Include leaning or hip strategy during a trial as "instability."

Patient*:* For the next 4 assessments, you'll either be standing on this foam or on the normal ground, with your eyes open or closed. Place your hands on your hips. Place your feet together until almost touching. Look straight ahead. Each time, stay as stable as possible until I say stop.

20. INCLINE EYES CLOSED

Examiner Instructions: Aid the patient onto the ramp. Once the patient closes their eyes, begin timing. Repeat condition if not able to stand for 30 s and average both trials/ Note if sway is greater than when standing on level surface with eyes closed (Item 15B) or if poor alignment to vertical. Assist includes use of a cane or light touch any time during the trial.

Patient*:* Please stand on the incline ramp with your toes toward the top. Place your feet shoulder width apart. Place your hands on your hips. I will start timing when you close your eyes.

STABILITY IN GAIT

21. GAIT – LEVEL SURFACE

Examiner Instructions: Place two markers 20 feet (6 meters) apart and visible to the patient on a level walkway. Use a stopwatch to time gait duration. Have subjects start with their toes on the mark. Start timing with the stopwatch when the first foot leaves the ground and stop timing when both feet stop beyond the next mark.

Patient: Walk at your normal speed from here past the next mark and stop.

22. CHANGE IN SPEED

Examiner Instructions: Allow the patient to take 2-3 steps at their normal speed, and then say "fast", after 2-3 fast steps, say "slow". Allow 2-3 slow steps before they stop walking.

Patient: Begin walking at your normal speed, when I tell you "fast" walk as fast as you can. When I say "slow", walk very slowly.

23. WALK WITH HEAD TURNS – HORIZONTAL

Examiner Instructions: Ask the patient to turn their head and hold it so they are looking over their shoulder until you tell them to look over the opposite shoulder every 2-3 steps. If the patient has cervical restrictions allow combined head and trunk movements.

Patient: Begin walking at your normal speed, when I say "right", turn your head and look to the right. When I say "left" turn your head and look to the left. Try to keep yourself walking in a straight line.

24. WALK WITH PIVOT TURNS

Examiner Instructions: Demonstrate a pivot turn. Once the patient is walking at normal speed, say "turn and stop." Count the steps from turn until the subject is stable. Instability is indicated by wide stance width, extra stepping or trunk and arm motion.

Patient: Begin walking at your normal speed. When I tell you to "turn and stop", turn as quickly as you can to face the opposite direction and stop. After the turn, your feet should be close together.

25. STEP OVER OBSTACLE

Examiner Instructions: Place the 2 stacked boxes (9" or 22.9 cm height) 10 ft. away from where the patient will begin walking. Use a stopwatch to time gait duration to calculate average velocity by dividing the number of seconds into 20 feet. Look for hesitation, short steps and touch on obstacle.

Patient: Begin walking at your normal speed. When you come to the shoe boxes, step over them, not around them and keep walking.

26. TIMED "GET UP & GO"

Examiner Instructions: Have the patient sit with their backs against the chair. Time the patient from the time you say "go" until they return to sitting in chair. Stop timing when the patient's buttocks hit the chair bottom. The chair should be firm with arms to push from if necessary. TOOLS: TAPE ON FLOOR 3 METERS FROM THE FRONT OF THE CHAIR LEGS**.**

Patient: When I say "GO," stand up from the chair, walk at your normal speed across the tape on the floor, turn around, and come back to sit in the chair. I will time how long it takes.

27. TIMED "GET UP & GO" WITH DUAL TASK

Examiner Instructions*:* Before beginning, practice with the patient how to count backward from a number between 90 and 100 by 3s, to make sure they can do the cognitive task. Then ask them to count backwards from a different number and after a few numbers say GO for the GET UP AND GO TASK. Time the patient from when you say "go" until they return to sitting. Stop timing when the patient's buttocks touch the chair bottom. The chair should be firm with arms to push from if necessary.

Patient: a) Count backwards by 3's starting at 100 OR b) List random numbers and when I say "GO," stand up from the chair, walk at your normal speed across the tape on the floor, turn around, and come back to sit in the chair but continue listing numbers**.**

APPENDIX D

12 WEEK EXERCISE INTERVENTION PROGRAMME

EXERCISE INTERVENTION PROGRAMME: 12 WEEKS: 2X30MINUTE EXERCISE SESSIONS/WEEK

CENTRE OF GRAVITY CONTROL TRAINING

WEEK 1	EXERCISE	SETS AND REPS
	Seated on chair, ankle rotations	x10 in each direction
	Seated on chair, forward trunk leans and return back to upright position +Seated on chair, lateral trunk leans and return back to upright position	2x5
	Seated alternating heel and toe lifts	
	Standing on 1 leg, holding onto chair	1x15

WEEK 2	EXERCISE	SETS AND REPS
	Seated on chair, ankle rotations	x10 each direction
	Seated on ball Seated on ball-arms across chest	x20 seconds
	Standing on Airex mat, both legs, holding onto chair	x20 seconds
	Marching in place	x20 seconds

WEEK 3	EXERCISE	SETS AND REPS
	Seated on chair, ankle rotations	x10 each direction
	Seated on ball with knee lifts	
	Seated on ball, forward trunk leans and return back to upright position +Seated on ball, lateral trunk leans and return back to upright position	2x5
	Standing on Airex mat, 1 leg, holding onto chair	2x15 seconds

WEEK 4	EXERCISE	SETS AND REPS
	Seated on chair, ankle rotations	x10 each direction
	Seated on ball forward, back, lateral and diagonal trunk leans	2x5 each direction
	Standing square stepping	1x5 each direction
	Standing on 1 leg, eyes closed holding onto chair	1x15 seconds

WEEK 5	EXERCISE	SETS AND REPS
	Seated on ball, ankle rotations	x10 each direction
	Seated on ball, forward, backward, lateral and diagonal trunk leans with eyes closed	x 5 each direction
	Stepping on and off Airex mat	2x5 each leg
	Standing on one leg	15 seconds

WEEK 6	EXERCISE	SETS AND REPS
	Seated on ball, ankle rotations	x10 each direction
	Standing alt step touches	1x10
	Marching in place with head turns	
	Standing on one leg	20 seconds

WEEK 7	EXERCISE	SETS AND REPS
	Seated on ball, ankle rotations	x10 each direction
	Seated on ball with pelvic tilts, lateral, anterior and posterior	1x5 each direction
	Kicking ball to partner	
	Standing on one leg with eyes closed	10 seconds

WEEK 8	EXERCISE	SETS AND REPS
	Seated on ball, ankle rotations	x10 each direction
	Seated on ball, arms across chest and knee lifts	1x10 alt
	Marching while counting backwards	20 seconds
	Standing on Airex mat with eyes closed	15 seconds

WEEK 9	EXERCISE	SETS AND REPS
	Seated on ball, ankle rotations	x10 each direction
	Standing with foot on ball and alt	1x10
	Side stepping onto Airex mat	1x10
	Standing on one leg, eyes closed	15 seconds

WEEK 10	EXERCISE	SETS AND REPS
	Seated on ball, ankle rotations	x10 each direction
	Marching in place with head turns while counting backwards	1x20 seconds
	Seated on ball with pelvic tilts with eyes closed	1x5 each direction
	Standing on 1 leg on Airex mat	15 seconds

WEEK 11	EXERCISE	SETS AND REPS
	Seated on ball, ankle rotations	x10 each direction
	Forward step ups and step downs	1x10 each leg
	Side step ups and step downs	1x10 each leg
	Standing on one leg	30 seconds

WEEK 12	EXERCISE	SETS AND REPS
	Seated on ball, ankle rotations	x10 each direction
	Seated on ball heel and toe raises with eyes closed and arms across chest	1x10
	Seated on ball with front and lateral raises 1kg DB	1x10
	Standing on 1 leg	30 seconds

GETTING UP STRATEGIES

-EASIEST: *week 1 to 3*

Supine/prone to side-lying to side-sitting to kneeling with hand on floor to crawling to external support and then pull up to standing.

-MORE DIFFICULT (emphasize upper body strength): *week 4-6*

Supine/prone to side-lying to side-sitting with hands on floor to hand walk to standing

-STILL MORE DIFFICULT (emphasize lower body strength):*week 7-9*

Supine/prone to side-lying to side-sitting to kneeling to half-kneeling to standing

-MOST DIFFICULT: *week 10-12*

Supine/prone to symmetrical sit- up to squat to leg reliance and standing

MULTISENSORY TRAINING

WEEK 1	EXERCISE	SETS AND REPS
	Standing on Airex mat while focusing on stationary visual object	1x30 seconds
	Walking while counting forwards	1x30 seconds
	Seated on ball, Airex mat under feet	1x30 seconds

WEEK 2	EXERCISE	SETS AND REPS
	Seated on big ball, eyes closed and counting backwards	1x30 seconds
	Walking while counting forwards, high knees	1x30 seconds
	Seated on big ball, Airex mat under feet, eyes closed	1x30 seconds

WEEK 3	EXERCISE	SETS AND REPS
	Seated on ball while reading aloud	1x30 seconds
	Walking while counting forwards, heels to bum	1x30 seconds
	Seated on big ball, Airex mat under feet and alt knee lifts	1x20

WEEK 4	EXERCISE	SETS AND REPS
	Seated on big ball and ball throws to partner	1x30 seconds
	Walking while counting backwards	1x30 seconds
	Seated on big ball, alt knee lifts with eyes closed	1x30 seconds

WEEK 5	EXERCISE	SETS AND REPS
	Seated on big ball throwing ball to partner with alt knee lifts	1x30 seconds
	Walking with head turns	
	Seated on big ball with Airex mat under feet, alt knee lifts with head turns	1x30 seconds

WEEK 6	EXERCISE	SETS AND REPS
	Seated on big ball, foot off floor and focus on moving object	1x30 seconds
	Walking with high knees counting backwards	1x30 seconds
	Seated on big ball, alt knee lifts with eyes closed	1x20

WEEK 7	EXERCISE	SETS AND REPS
	Seated on big throw, throwing ball sideways to partner	1x30 seconds
	Walking with bum kicks counting backwards	1x30 seconds
	Seated on big ball, feet on Airex mat, alt knee lifts while raising arms up and down	1x20

WEEK 8	EXERCISE	SETS AND REPS
	Seated on big ball, eyes closed, with alt front and lateral raises, 1kg DB's	1x30 seconds
	Walking and stepping over objects	1x30 seconds
	Seated on big ball, feet on Airex mat , lift one foot and throwing ball to partner	1x30 seconds

WEEK 9	EXERCISE	SETS AND REPS
	Seated on big ball, eyes closed, hands above head and counting backwards	1x30 seconds
	Walking and stepping over obstacles	1x30 seconds
	Seated on big ball, feet on Airex mat , lift one foot and throwing ball sideways to partner	1x30 seconds

WEEK 10	EXERCISE	SETS AND REPS
	Seated on big ball, eyes closed, hands above head , lift one foot and counting backwards	1x30 seconds
	Walking with pivot turns	1x30 seconds
	Seated on big ball, feet on Airex mat , lift one foot, lateral rotations with ball out in front	1x30 seconds

WEEK 11	EXERCISE	SETS AND REPS
	Seated on big ball, eyes closed, hands above head and counting backwards	1x30 seconds
	Walking and stepping over obstacles	1x30 seconds
	Seated on big ball, feet on Airex mat , lift one foot and throwing ball sideways to partner	1x30 seconds

WEEK 12	EXERCISE	SETS AND REPS
	Seated on big ball, eyes closed, hands above head , lift one foot and counting backwards	1x30 seconds
	Walking with pivot turns	1x30 seconds
	Seated on big ball, feet on Airex mat , lift one foot, lateral rotations with ball out in front	1x30 seconds

POSTURAL STRATEGIES

-ANKLE STRATEGY: *week 1 to 4*

This strategy was practised between two chairs with the upper and lower body moving 'in phase' (in the same direction). A slow pace was used to ensure that the ankle muscles were used to control the amount of sway.

-HIP STRATEGY: *week 5-8*

This strategy was also practiced between two chairs which were placed further apart than when compared to the ankle strategy, and the speed of the sway was increased in order to spontaneously adopt the hip strategy.

-STEP STRATEGY:*week 9-12*

Subjects were instructed to lean forward until they felt they had reached their stability limits and then take a step. They practiced this with both the left and the right leg. This voluntary step activity was also practiced in a backward and lateral (left and right) direction.

GAIT TRAINING

WEEK 1	EXERCISE	SETS AND REPS
	Walking forward on toes	
	Walk ing with feet along straight line, placing one foot in front of other	1x30 seconds
	Walking while stepping over objects	1x30 seconds
	Walking with change in gait speed	1x5

WEEK 2	EXERCISE	SETS AND REPS
	Walking forward on toes	
	Walk ing with feet along straight line, placing one foot in front of other	1x30 seconds
	Walking while stepping over objects	1x30 seconds
	Walking with change in gait speed	1x5

WEEK 3	EXERCISE	SETS AND REPS
	Walking forward on toes	
	Walk ing with feet along straight line, placing one foot in front of other	1x30 seconds
	Walking while stepping over objects	1x30 seconds
	Walking with change in gait speed	1x5

WEEK 4	EXERCISE	SETS AND REPS
	Walking forward on toes	
	Walk ing with feet along straight line, placing one foot in front of other	1x30 seconds
	Walking while stepping over objects	1x30 seconds
	Walking with change in gait speed	1x5

WEEK 5	EXERCISE	SETS AND REPS
	Walking sideways on toes	
	Walking with feet along straight line, placing one foot in front of other	1x30 seconds
	Walking while stepping over objects	1x30 seconds
	Walking with change in gait speed	1x5

WEEK 6	EXERCISE	SETS AND REPS
	Walking sideways on toes	
	Walking with feet along straight line, placing one foot in front of other	1x30 seconds
	Walking while stepping over objects	1x30 seconds
	Walking with change in gait speed	1x5

WEEK 7	EXERCISE	SETS AND REPS
	Walking sideways on toes	
	Walking while performing a dual task	1x30 seconds
	Walking with intermittent pivot turns	1x5
	Walking while weaving in between beacons	1x30 seconds

WEEK 8	EXERCISE	SETS AND REPS
	Walking sideways on toes	
	Walking while performing a dual task	1x30 seconds
	Walking with intermittent pivot turns	1x5
	Walking while weaving in between beacons	1x30 seconds

WEEK 9	EXERCISE	SETS AND REPS
	Walking backward on toes	
	Walking while performing a dual task	1x30 seconds
	Walking with intermittent pivot turns	1x5
	Walking while weaving in between beacons	1x30 seconds

WEEK 10	EXERCISE	SETS AND REPS
	Walking backward on toes	
	Walking while performing a dual task	1x30 seconds
	Walking with intermittent pivot turns	1x5
	Walking while weaving in between beacons	1x30 seconds

WEEK 11	EXERCISE	SETS AND REPS
	Walking backward on toes	
	Walking while performing a dual task	1x30 seconds
	Walking with intermittent pivot turns	1x5
	Walking while weaving in between beacons	1x30 seconds

WEEK 12	EXERCISE	SETS AND REPS
	Walking backward on toes	
	Walking while performing a dual task	1x30 seconds
	Walking with intermittent pivot turns	1x5
	Walking while weaving in between beacons	1x30 seconds

STRENGTH AND ENDURANCE

*AW=Ankle weights
*TB=Theraband
*DB=Dumbells

WEEK 1	EXERCISE	SETS AND REPS
	Seated shoulder shrugs with DB's	1x12
	Wall squats	1x10
	Side bends with DB's	1x10 each side
	Seated ball squeezes	1x12

WEEK 2	EXERCISE	SETS AND REPS
	Standing Chest press with TB	1x12
	Sit to stand squats	2x5
	Horizontal pulls with TB	1x10
	Calf raises	1x10

WEEK 3	EXERCISE	SETS AND REPS
	Seated shoulder shrugs with DB's	1x12
	Wall squats	1x10
	Side bends with DB's	1x10 each side
	Seated ball squeezes	1x12

WEEK 4	EXERCISE	SETS AND REPS
	Standing Chest press with TB	1x12
	Sit to stand squats	2x5
	Horizontal pulls with TB	1x10
	Calf raises	1x10

WEEK 5	EXERCISE	SETS AND REPS
	Rowing with TB with partner	1x12
	Bridging + ball squeeze	2x8
	Alt front and lateral raises	1x10 alternating
	Standing leg curls with AW	1x12

WEEK 6	EXERCISE	SETS AND REPS
	Wall pushups	1x10
	Standing toe rasies	1x10
	Bicep curls	1x10
	Step ups	1x10 each leg

WEEK 7	EXERCISE	SETS AND REPS
	Rowing with TB with partner	1x12
	Bridging + ball squeeze	2x8
	Alt front and lateral raises	1x10 alternating
	Standing leg curls with AW	1x12

WEEK 8	EXERCISE	SETS AND REPS
	Wall pushups	1x10
	Standing toe rasies	1x10
	Bicep curls	1x10
	Step ups	1x10 each leg

WEEK 9	EXERCISE	SETS AND REPS
	Tricep extensions	1x10
	Standing Flexion	1x12
	Alt front and lateral raises with DB	1x10alt
	Standing abduction	1x12

WEEK 10	EXERCISE	SETS AND REPS
	Ball chest squeezes	1x10
	Standing squats	1x10
	Ext rotations with TB	1x10
	Standing hip lifts with AW	1x12

WEEK 11	EXERCISE	SETS AND REPS
	Tricep extensions	1x10
	Standing Flexion	1x12
	Alt front and lateral raises with DB	1x10 alternating
	Standing abduction	1x12

WEEK 12	EXERCISE	SETS AND REPS
	Ball chest squeezes	1x10
	Standing squats	1x10
	Ext rotations with TB	1x10
	Standing hip lifts with AW	1x12

APPENDIX E

HPCSA CERTIFICATE

HPCSA
Health Professions Council of South Africa

CERTIFICATE OF REGISTRATION

THIS IS TO CERTIFY THAT

SURNAME: DEKENAH

FIRST NAMES: GHABRIELLE ANNE

REGISTRATION NUMBER: BK 0011193

QUALIFICATIONS: BA (Human Movement Science) Hons Biokinetics UPE - 2005

REGISTER: BIOKINETICIST

IS REGISTERED AS A

BIOKINETICIST

in the Category

INDEPENDENT PRACTICE

With effect from

05 Dec 2005

REGISTRAR
PRETORIA

HPCSA Building
553 Vermeulen St
Arcadia, Pretoria
0002

02939643 2006/01/17

APPENDIX F

CPR CERTIFICATE

EMT™

EMTSA - Emergency Medical Training South Africa

Certificate

Awarded To

Gabi Dekenah

For Successfully Completing The

Cardio Pulmonary Resuscitation

Course

817123

Certificate Number

13/03/2013

Head of Training **Expiry Date** **Head of Organisation**

Registered with the Department of Labour - Registration. No: CI - 196

Telephone: 021 712 5290 Facsimile: 086 515 6047 e-mail: national@emt.co.za P.O. Box 114, Steenberg, 7947