Home-based balance training for dynamic balance in independent-living individuals with Parkinson's disease.

by

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Abstract

Background: Individuals with Parkinson's disease (PD), are presented with a variety of motor and non-motor symptoms which progressively affect their independence. As a result surgical and pharmacological interventions are often ineffective, especially for postural instability. Poor locomotion and balance dysfunction in PD ultimately leads to disability, which includes the loss of their ability to perform automated movements in a controlled manner (Floriano *et al*., 2015, Rinalduzzi *et al*., 2015). Accordingly dynamic balance and gait are considered to be one of the most relevant rehabilitation outcomes, and non-pharmacological interventions like exercise should be explored. Home-based balance exercises might be a viable mode of exercise delivery for PD individuals. However research on PD exercise interventions rarely indicate best practices to deliver exercises (King *et al*., 2015).

Aim: The aim of this study was to compare an eight-week home-based balance programme with an equivalent therapist-supervised programme on dynamic balance, functional gait, and self-perceived measures of fall risk and balance confidence, disease severity, and motivation regarding the exercise interventions in individuals with mild to moderate PD.

Methods: Forty participants with idiopathic PD (Hoehn and Yahr stage I–III; age: 65.0±7.7 years) were divided into a Therapist-supervised group (n=24) and Home-based group (n=16). Groups received eight weeks of balance training that including somatosensory cues, three times a week for an hour, either with an exercise therapist or via a DVD. Outcome measures were dynamic balance (FGA), gait and mobility (ITUG), dual-tasking gait and mobility (CTUG), freezing of gait (FoGQ), self-perceived balance confidence (ABC), self-perceived fall risk (FES-I), disease severity (MDS-UPDRS II & III) and intrinsic motivation (IMI).

Results: Treatment effects were observed for the Home-based group with MDS-UPDRS total, subscore II and III ($p < 0.01$), and for the Therapist-supervised group for cadence ($p = 0.047$). Both groups improved ($p < 0.05$) in FGA (>9%, medium effect sze), stride length (>4%, small to medium effect size) and FoGQ (>16%, small effect size). Over the 8 weeks the Therapist-supervised group furthermore improved cadence and balance confidence ($p < 0.05$) with small effect size, stride and turn velocity ($p < 0.05$) with medium effect size, and turn-to-sit duration ($p < 0.0001$) with a huge effect size. The Home-based group improved by 23% in MDS-UPDRS III ($p < 0.001$), but gait deteriorated with dual-tasking. No significant differences observed for FES-I ($p > 0.05$). The therapist supervised group perceived the intervention to be 17% more enjoyable/interesting than Home-based (IMI; $p = 0.002$).

Conclusion: An eight-week balance training programme with somatosensory cues at home may improve dynamic balance, stride length and freezing of gait. However greater improvements are achieved when exercising under supervision of a trained exercise therapist. Therapist-supervised training showed superior improvement in dynamic balance, gait, dual-tasking, balance confidence and motivation.

Abstrak / Opsomming

Agtergrond: Individue met Parkinson se siekte (PD), presenteer met `n groot verskeidenheid motoriese en nie-motoriese simptome, wat hul onafhanklikheid progressief affekteer. As gevolg daarvan is chirurgiese en farmakologiese intervensies dikwels oneffektief, veral vir postuur-onstabiliteit. Swak loopbeweging en balans disfunksies in PD lei uiteindelik tot gestremdheid, insluitend die verlies van hul vermoë om outomatiese bewegings in `n gekontrolleerde manier uit te voer. (Floriano *et al*., 2015, Rinalduzzi *et al*., 2015). Daarmee saam word dinamiese balans en stapgang as een van die mees toepaslike rehabilitasie uitkomste gereken, en nie-farmakologiese intervensies soos oefening moet verder ondersoek word. Tuis-gebaseerde balans oefeninge kan `n werkbare modum bied om oefeninge aan PD individue voor te skryf. Navorsing op PD oefenings intervensies het egter selde aangedui watter oefeningspraktyke die beste sal wees. (King *et al*., 2015).

Doel: Die doel van hierdie studie was om `n agt-weke tuis-gebaseerde balans program met `n soortgelyke terapeut-toesig program te vergelyk ten opsigte van dinamiese balans, funksionele stapgang, self-persepsie van valrisiko, balans selfvertroue, graad van siekte, en motivering ten opsigte van oefening intervensies in individue met ligte tot matige PD.

Metode: Veertig deelnemers met idiopatiese PD (Hoehn en Yahr vlak I–III; ouderdom: 65.0±7.7jare) is opgedeel in ‘n terapeut-toesig groep (n=24) en ‘n tuisgebaseerde groep (n=16). Die twee groepe het vir 8 weke, 3 maal per week vir een uur, balans oefeninge insluitend somatosensoriese cues (aanwysings) ontvang deur ‘n oefeningsterapeut of via ‘n DVD. Die uitkomsmaatstawwe was dinamiese balans (FGA), stapgang en mobititeit (ITUG), dubbel-taak stapgang en mobiliteit (CTUG), stapgang-verstarring (FoGQ), self-persepsie oor balans-verwante selfvertroue (CTUG), self-persepsie oor valrisiko (FES-I), erns van siekte (MDS-UPDRS II & III) en intrinsieke motivering (IMI).

Resultate: Vir die Tuisgebaseerde groep is behandelingseffekte waargeneem vir MDS-UPDRS total, subskaal II en III ($p < 0.01$); vir die Therapeut-toesig groep is ‘n behandelingseffek vir stapritme waargeneem ($p = 0.047$). Albei groepe het verbeter ($p < 0.05$) tov FGA (> 9%, medium effekgrootte), treëlengte (> 4%, klein tot medium effeksgrootte) en FoGQ (> 16%, klein effekgrootte). Oor die 8

weke het die Terapeut-toesig groep het ook verbeter tov stapritme en balansvertroue ($p < 0.05$) met klein effekgrootte, draai- en treëspoed ($p < 0.05$) met medium effekgroote, en tydsduur van draai-na-sit beweing ($p < 0.0001$) met ‘n massieve effekgrootte. Die tuisgebaseerde groep het met 23% verbeter tov MDS-UPDRS III ($p < 0.001$), maar stapgang het verswak met dubbele taakuitvoering. Geen betekenisvolle verskille is waargeneem nie tov FES-I ($p > 0.05$). Die terapeut-toesig groep het die intervensie 17% meer genotvol en interesant ervaar as die tuisgebaseerde groep (IMI; $p = 0.002$).

Gevolgtrekking\Slotsom: ‘n Agt-weeklange tuisgebaseerde balansprogram met somatosensoriese aanwysings mag lei tot ‘n verbetering in dinamiese balans, treelengte, en stapgang-verstarring. Groter verbetering word egter ervaar wanneer die oefeninge onder toesig van ‘n opgeleide oefeningsterapeut geskied. Terapeut-toesig oefeninge het meer merkwaardige verbetering in dinamiese balans, stapgang, dubbele taakuitvoering en motivering tot gevolg gehad.

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Table of Contents

List of Figures

List of Tables

Abbreviations

ABC	Activity-specific Balance Confidence
ADL	Activities of Daily Living
BoS	Base of support
CNS	Central Nervous System
CoM	Centre of Mass
DS	Double Support
ES	Effect size
FES	Fall-Efficacy Scale
FGA	Functional Gait Analysis
FoF	Fear of Falling
FoG	Freezing of Gait
FoGQ	Freezing of Gait Questionnaire
H&Y	Hoehn & Yahr stages
HB	Home-Based
L-dopa	Levodopa
PD	Parkinson Disease
QoL	Quality of life
RoM	Range of Motion
SD	Standard Deviation
SL	Stride Length

SV	Stride Velocity
TD	Turn Duration
TS	Therapist-Supervised
TTS	Turn-to-sit
TUG	Timed-Up-&-Go test
TV	Turn Velocity
UPDRS	Unified Parkinson's Disease Rating Scale
WHO	World Health Organization

Definitions of key terminology

Activities of Daily Living: Routine activities that people tend do every day without needing assistance

Cadence: number of steps per minute (Williams *et al*., 2013; Salarian *et al*., 2010).

Carer / care-giver: a person who gives help and protection to someone (such as a child, an old person, or someone who is sick). Care-givers for elderly can include spouse, child, friend, family member, and neighbour or care-giver nurse (Alliance, 2011)

Double Support: Percentage of the gait cycle time when both feet are in contact with the ground (Salarian *et al*., 2010).

Dual-tasking: Dual-tasking refers to performing two tasks (motor or cognitive) simultaneously whilst dividing attention between the outcome objectives of each task (Conradsson *et al*., 2012 & Floriano *et al*., 2015), for example walking and talking.

Freezing of Gait: a transient halt in walking ability described as the sensation of your feet being 'glued to the floor' resulting in the inability to complete effective stepping (Allen *et al*., 2013; Giladi *et al*., 2008; Rahman *et al*., 2008).

Home-Based: Intervention programme followed at home.

Independent-living: The participant able to lead an independent life without the need for help with most activities of daily living. Categorized typically Hoehn & Yahr stages III and lower, excluding stages IV & V. (Sabari *et al*., 2014).)

Mild to Moderate Parkinson's: Mild to moderate PD between 2 and 3 on the Hoehn and Yahr rating scale (Salgado *et al*., 2013; Holroyd *et al*., 2002)

OFF phase: Refers to period when medication is wearing off and motor fluctuations become more apparent.

ON phase: Refers to period when medication is controlling motor symptoms, or when their symptoms are most under control, in individuals with Parkinson's disease.

Quality of life: the standard of health, comfort, and happiness experienced by an individual or group (Sabari *et al*., 2014).

Somatosensory cues: Somatosensory cues are can be an external or internal generated cue that combines vestibular, proprioceptive, and visual cues to enhance the control of motor responses (Baldan, *et al*., 2013)

Stride Length: Distance between two consecutive strikes of the same foot, presented as a percentage of the subject's height (%height) (Dewey *et al*., 2014; Salarian *et al*., 2010).

Stride Velocity: Walking speed calculated as stride length (in centimetres) divided by stride time in seconds, presented as a percentage of the subjects' height (%height/sec) (Dewey *et al*., 2014; Salarian *et al*., 2010).

Therapist-Supervised: Intervention programme lead by an exercise therapist in a small group setting.

Turn Duration: Duration, in seconds, to make a 180º turn (Dewey *et al*., 2014).

Turn Velocity: Peak angular velocity when performing a 180º turn (Dewey *et al*., 2014).

Turn-to-sit duration: Duration in seconds to perform the transition from a 180º turn to a sitting position (Dewey *et al*., 2014)

Preface

This MSc thesis follows an article-format. The first chapter is a general introduction to the research topic, followed by an overview of the literature review (Chapter 2) on the key concepts of the research, followed by the problem statement as well as the main research aim with objectives. This is to ensure the reader firstly understands the special population and their symptoms, and understands the current research on exercise intervention, especially balance training, before the motivation and rationale for the study. Hereafter research article one (Chapter 3) will address part of the first and fourth objectives and the fifth objectives of the study, and article two (Chapter 4) addresses the second and part of the fourth objectives of the study. While the third research article (Chapter 5) addresses the third and part of the first objective of this study. As this is an article-format thesis, there is no methodology chapter. Methodology is explained in the three articles, and is condensed to accommodate word limitations in the selected journals. Chapter 3 was submitted for review to the journal *Posture and Gait* and follows numerical / Vancouver referencing format in accordance to the journal guidelines (See letter of submission in Addendum B). Chapter 4 and 5 were submitted for review to the journal *Archives of Physical Medicine and Rehabilitation*, and also follows numerical referencing format in accordance to the journal guidelines. Finally the thesis is concluded with an overall discussion and conclusion, as well as study limitations and recommendations for future studies in Chapter 6. The general thesis follows Harvard referencing format.

Chapter 1

Introduction

Background

According to the World Health Organization (WHO) neurological disorders, in particular Parkinson's disease (PD), have become a growing concern worldwide (Campenhausen *et al*., 2005). Furthermore both Bloem *et al*. (2001) and Conradsson *et al*. (2012) reported that individuals with PD have a nine times higher risk of falling compared to their peers. Poor balance, freezing of gait and reduced leg strength in PD are some of the major causes of falling; especially during ambulation and multi-tasking, with falls also being the largest contributor to health care costs (Canning *et al*., 2015; Bloem *et al*., 2001).

Depending on the individual's PD severity, Parkinsonism is typically symptomatically managed throughout the individual's life with pharmacologic and non-pharmacologic treatment such as surgical, physical and psychosocial interventions (Cutson *et al*., 1995). Recently exercise has also become a viable treatment option especially for gait, balance and posture impairments (Abbruzzese *et al*., 2015; Bloem *et al*., 2015; Šumec *et al*., 2015; van der Kolk & King, 2013). In addition, Bloem *et al*. (2015) points out that medication and surgical treatments are inadequate in treating motor impairments i.e. speech, postural stability, and freezing of gait in individuals with PD. A strong association has also been reported between postural instability or balance dysfunction on the one hand, and anxiety, depression, and apathy on the other hand, which again relates to quality of life (Šumec *et al*., 2015). As a result balance, and in particular gait, is considered to be one of the most relevant outcomes in rehabilitation treatments (Nisenzon *et al*., 2011).

Recent findings recommend that intensive and challenging exercises induces neuroplasticity, suggesting that exercise should be essential in PD treatment (Petzinger *et al*.,

2010; Ahlskog, 2011). Training programmes, that focus on balance exercises specifically, have shown to be effective in improving balance (Penzer, Duchateau & Baudry, 2015), and reducing fall risk (Canning *et al*., 2015). Although exercise interventions have been shown to be beneficial in improving most motor aspects and functional ability and thus decrease risk of falling (Lun *et al*., 2005), inactivity still remains one of the greatest problems, especially with PD individuals who are at greater risk of falling (van Nimwegen *et al*., 2011).

However PD research seldom indicates what the best practices are to deliver exercise interventions (King *et al*., 2015). Consequently an important question is whether exercise is also effective when delivered at home, without any special equipment or a qualified exercise therapist. Home-based exercises may be more practical and accessible for individuals with PD as previously been found (Nocera *et al*., 2009). On the other hand King and colleagues (2015) recently found that compared to therapist-supervised training programmes for individuals and groups, an unsupervised home-based agility exercise programme (with a sensory-motor emphasis) was the least effective in improving balance, gait, mobility, balance confidence, quality of life, depression, apathy, self-efficacy, activities of daily living, motor subscale of MDS-UPDRS (part III) and physical performance in individuals with PD. The researchers also suggested that, due to other comorbidities often found in individuals with PD, a therapist supervised programme is best, and that group or individual sessions have different benefits. This study however took place in a developed country which has access to medical aid/insurance, effective public transport and social support systems. Whereas in developing countries such as South Africa, it may not be possible for all PD individuals to receive therapist-supervised balance training programmes due to accessibility i.e. travel or transport, time constraints and costs involved. Thus finding alternative methods to help PD individuals improve balance is needed. Also considering that some researchers have found that the intention to exercise and the adherence to exercise is influenced by a participant's attitude and beliefs, together with the beliefs of others they interact with (Martin *et al*., 2005; Bollen *et al*., 2014).It will therefore be beneficial to see how a balance training programme in a DVD-guided home-based setting will compare to a therapist-supervised intervention with the same programme.

Chapter 2

Literature review

Overview on Parkinson Disease (PD)

Parkinson's disease is defined as a chronic, progressive neurologic disorder involving the nervous system which regulates muscle reflexes (Jankovic, 2008). After Alzheimer's disease, PD is the most common neurodegenerative disorder (Kalia & Lang, 2015). Parkinson's disease affects motor, sensory, as well as cognitive systems, which leads to balance impairment and frequent falling (Kim *et al*., 2013). The disease is prevalent in approximately 1% of individuals aged >65 years, increasing to 4% in individuals aged >80 years (Van der Merwe *et al*., 2012). The amount of PD patients in the most populous countries in Western Europe and the world (including Germany, France, Nigeria and Japan) was estimated to be 4.1 - 4.6 million in 2005; this number is expected to be doubled by 2030 (Van der Merwe *et al*., 2012). The crude prevalence for PD in Africa is 10 – 43 per 100 000 (Kalia & Lang, 2015) and in Sub-Sahara Africa varies from 7 to 20 per 100,000 (Blanckenberg *et al*., 2013). This is considerably less than in the developed world, including Europe and North and South America, where crude prevalence is estimated to range from 66 to 1500 per 100,000 (Kalia & Lang, 2015; Von Campenhausen *et al*. 2005). It is difficult to compare crude prevalence rates between developing and developed countries due to differences in population structures, however according to an overview by Kalia and Lang (2015) PD prevalence does seem to be higher in European, North and South American countries compared to African, Asian and Arabic countries. Unfortunately there are no accurate epidemiological data available for South Africa to date. Nevertheless, considering that Africa is experiencing a demographic transition, the population over the age of 65, it is thought, will increase (Okubadejo *et al*., 2006). Also considering that age is the greatest risk factor for the development of PD (Kalia & Lang, 2015;

Dorsey *et al*., 2007). As a result diseases predominantly affecting older persons, such as PD are expected to become more common (Dorsey *et al*., 2007; Okubadejo *et al*., 2006).

It is well known that the symptoms and characteristics of PD are thought to be caused by dopamine reduction, due to the cells that produce this neurotransmitter deteriorating and eventually dying off (Durstine *et al*., 2009), but the cause of this remains unknown. Possible factors involved in PD pathogenesis include aging, environmental factors, oxidative stress, mitochondrial dysfunction, inflammation, genetic factors and other pathological mechanisms (Kalia & Lang, 2015; Haylett *et al*., 2011; Jankovic, 2008 & Wakabayashi *et al*. 2007).

Parkinson's disease is thought to involve the degeneration of dopaminergic neurons in the Substantia Nigra Pars Compacta coupled within the basal ganglia intracytoplasmic inclusions known as Lewy bodies (Kalia & Lang, 2015; Durstine *et al*., 2009; Wakabayashi *et al*. 2007). Lewy bodies become widely distributed throughout the whole body (Wakabayashi *et al*. 2007), including in the brain, spinal cord and visceral autonomic nervous system, and this widespread distribution can offer some explanation for the variety of motor and non-motor symptoms of PD. The reduction in dopamine and the associated dysfunction of the basal ganglia leads to the four cardinal signs of PD i.e. tremors (resting or active), rigidity, bradykinesia (slowness of movement) and postural and/or gait abnormalities (Durstine *et al*., 2009; Okubadejo *et al*., 2006). This is primarily due to the decreased efficiency with which neural messages are conducted (Durstine *et al*., 2009) and subsequently leads to impairment of muscle tone and loss of voluntary movement (Nocera *et al*., 2009). The impairment of the basal ganglia has a major impact on motor skills (Figure 2.1, p.8) which can clearly be observed with these four cardinal signs, but also furthermore in movement coordination, balance, reaction time, mobility and functionality (Nocera *et al*., 2009; Berardelli *et al*., 2001). This ultimately affects an individual's ability to initiate and perform movements fluently and safely.

Parkinson's disease is typically treated with pharmacological interventions. The main aim for the drug therapies is to minimize symptoms by trying to correct or prevent neurochemical

imbalances. This can be done by supplying levadopa which can be metabolized in the brain to produce and increase the dopamine available to the basal ganglia (Durstine *et al*., 2009). Drug therapies, however, is a double-edged sword as stated and explained in a study by Curtze and colleagues (2015). Most PD medications have side effects, both central and peripheral, such as gastrointestinal distress, confusion and insomnia, to name a few (Durstine *et al*., 2009). Long term use of medication and disease progression can result in reduced responsiveness to medication (Curtze *et al*., 2015), and furthermore, can even cause movements disorders, such as dyskinesia, or dystonia as well as fluctuations of motor disability (Durstine *et al*., 2009). Curtze and colleagues (2015) investigated the effect on gait and balance of PD individuals 'ON' and 'OFF' levadopa and found that during the ON phase participants' walking improved (although not close to the level of healthy controls) but their static and dynamic balance worsened. They also found that levadopa-induced dyskinesia affected gait and balance more than disease severity. Schoneburg *et al*. (2013) however did find that levodopa increases the perceived limits of stability and the speed with which it is reached in individuals with PD. Thus some gait parameters are levodopa-sensitive, whereas others are resistant (Curtze *et al*, 2015; Albani *et al*., 2014). Kalia and Lang (2015) also point out that PD involves other neurotransmitters besides dopamine as well as areas of the nervous system other than the basal ganglia. Therefore dopamine medication does not always result in an improvement in motor and non-motor dysfunction. This indicates that there must be more neurological dysfunctions that contribute to PD symptoms. Keeping this in mind, it is essential to find alternative ways to treat PD and the related symptoms.

2.1 Motor Dysfunction in Parkinson Disease

Motor dysfunction, as well as certain non-motor dysfunctions, results from a variety of cortical and sub-cortical miscommunications, as depicted in Figure 2.2 (p. 9). The basal ganglia play a vital role in the brain; it is a connection between the cerebellum and cortex, and is also closely related to the thalamus and the limbic system in the midbrain (Crossman & Neary, 2000). Dysfunction in the basal ganglia will therefore lead to a disruption in automated movements, problems with motor planning a programmeming, less efficient sensory integration and communication, and lastly result in decline regulations in emotions and executive functions (Crossman & Neary, 2000; Panksepp, 1998). Thus it is easy to see why PD has such a wide range of symptoms, the most prominent signs being the four cardinal signs as stated before. In addition, flexed posture and freezing (motor blocks) have been included among classic features of Parkinsonism, with PD as the most common form (Jankovic, 2008). Jankovic (2008) explain that the clinical motor disturbances in PD are characterized by spatiotemporal control deficits i.e. bradykinesia, hypokinesia, increased timing and scaling variability as well as impaired bilateral coordination. These motor disturbances impair the individual's balance and posture, as well as mobility, resulting in falls and related health problems (Curtze *et al*., 2015; Jankovic, 2008). The motor symptoms mostly manifest only mid to later stages of PD, and are commonly the first symptoms used for diagnosis by neurologist (Kalia & Lang, 2015; Figure 2.1).

Central mechanisms responsible for motor dysfunctions have been hypothesized to impair programming, proprioception and biomechanical parameters due to both basal ganglia and cerebellum dysfunction (Dietz *et al*., 2002). These central mechanisms result in problems with coordination and muscle activation with the lower limbs being more affected than the upper limbs (Albani *et al*., 2014).

Balance control is maintained by integrating data coming from proprioceptive, vestibular, and visual channels (Rinalduzzi *et al*., 2015). Proprioception is the body's sense of itself, meaning the body can sense where its parts are in relation to itself as well as to gravity (Woollacott *et al*.,

1986). It can furthermore be described as a three-fold concept including 1) static awareness of joint position, 2) movement or kinesthetic awareness, and 3) closed-loop efferent reflex response that is required to regulate muscle tone and activity (Beard *et al*., 1993). Proprioception, from a physiologic perspective, is the cumulative neural input to the CNS from mechanoreceptors located in various body components, including the joint capsules, ligaments, muscles, tendons, and skin (Beard *et al*., 1993). It is a specialized variant of the sensory modality of touch (Woollacott *et al*., 1986).

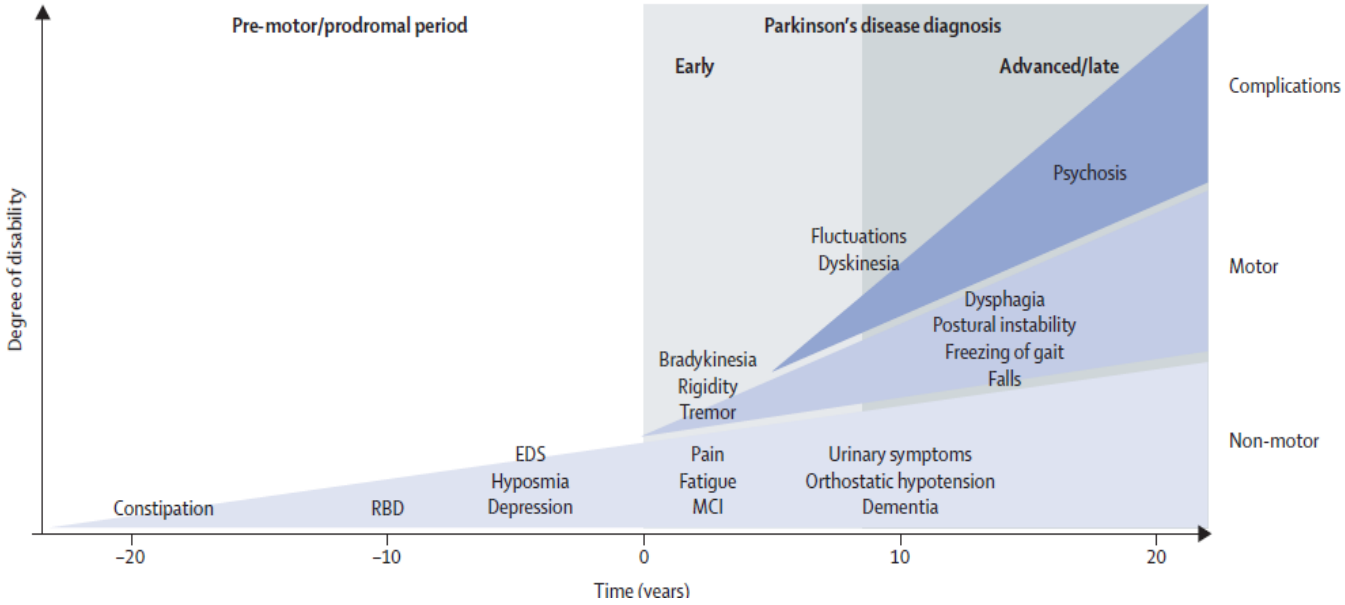

Figure 2.1: Clinical symptoms and progression of PD as illustrated by Kalia & Lang (2015).
"*Diagnosis of Parkinson's disease occurs with the onset of motor symptoms (time 0 years) but can be preceded by a premotor or prodromal phase of 20 years or more. EDS=excessive daytime sleepiness. MCI=mild cognitive impairment. RBD=REM sleep behaviour disorder."*
Lancet 2015; vol. 386; page 898

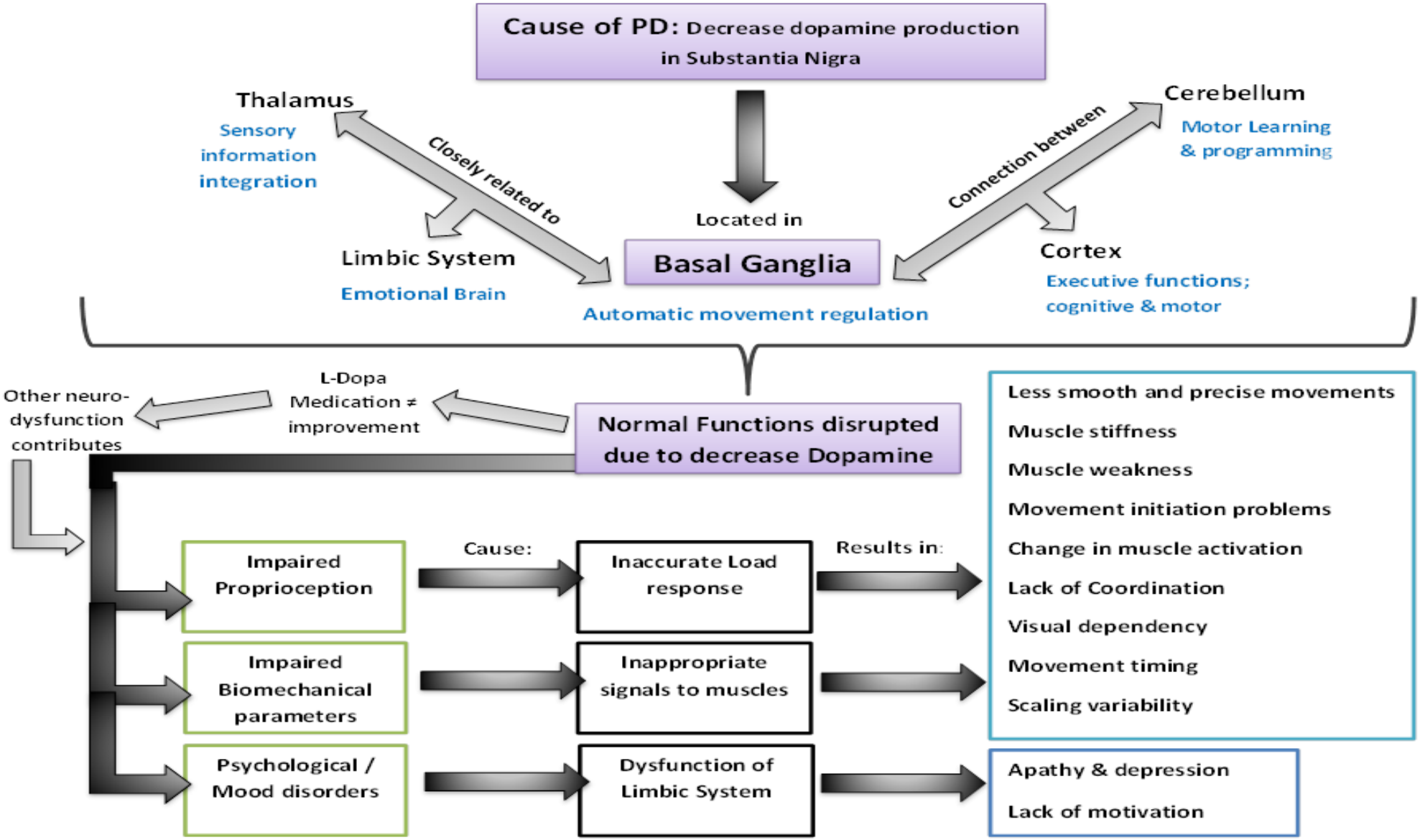

Figure 2.2: Pathophysiology and clinical resultant symptoms of Parkinson's disease

Proprioception has a profound impact on the motor control functioning of clinical populations such as PD and impairment of one sensory system may contribute and compound dysfunction in another, for example, in the visual and vestibular systems. The vestibular system is mainly responsible for the integrating and fine-tuning balance control (Rinalduzzi *et al*., 2015). If it is abnormal, it reduces the quality of feedback provided by the visual and proprioceptive systems, resulting in less efficient balance control (Jankovic, 2008). Impaired proprioception leads to an inaccurate load response in muscle's stretch reflex (Dietz *et al*., 2002), especially in the lower limbs and trunk resulting in flexed posture and difficulty in walking. Through EMG testing Dietz and colleagues (1993), found that PD individuals had lower EMG activation in lower limbs than the healthy aged-matched control group. This implies that the threshold of PD individuals' load receptor reflex loop is maladjusted and biased causing the body to struggle to maintain equilibrium (Dietz *et al*., 1993). This study by Dietz also showed that PD individuals had less activation of the leg extensor muscles during stance which led to greater co-activation of the leg flexor muscles. This incorrect activation pattern can be explained by the impaired proprioception which leads to inaccurate afferent signals being sent to antagonist muscles, and leads to unsynchronized muscle contractions influencing posture and movements (Rinalduzzi *et al*., 2015). In a recent study, proprioception input in PD individuals were manipulated with various somatosensory information (i.e. touch), and resulted in improvements in postural sway (Abbruzzese *et al*., 2015).

In addition to impaired proprioception, impaired biomechanical parameters and programmeming also causes havoc in the body. Basal ganglia and cerebellum dysfunction causes inappropriate excitatory and inhibitory signals to be sent to muscles (Crossman & Neary, 2000). Consequently this ensues difficulties with planning, initiating and executing movement as well as with performing sequential and simultaneous tasks (Berardelli, 2001). The functional implications of this dysfunction will be fully discussed in 2.2 of this thesis when reviewing the effects of balance and gait of PD.

Bradykinesia refers to the slowness of movement and is a hallmark of basal ganglia disorders, which is often used to explain a range of movement-related problems. The initial manifestation is often slowness in performing activities of daily living (ADL); fine and gross motor control movements such as buttoning a shirt, using utensils, or walking (Jankovic, 2008). Very prominent features of bradykinesia are slower reaction times and reduced arm swing while walking, which can be related to inappropriate muscle activation (Dietz *et al*., 2002).

Bradykinesia occurs primarily due to insufficient muscle force production during the initiation of movement (Berardeli *et al*., 2001). Furthermore secondary factors such as muscle weakness, tremor and rigidity may also contribute (Jankovic, 2008). These factors may result in two distinctive features in PD individuals, firstly underestimating targets or underscaling the muscle force needed to perform an action and therefore individuals with PD end up approaching targets in several smaller steps (Jankovic 2008). Secondly, that the slowness of movement can often be amended when external cues or feedback (i.e. vision, sound, proprioceptive) are given to guide the movement (Berardeli *et al*., 2001). The former has led to the suggestion that bradykinesia is a problem of scaling motor output appropriately to the task rather than using intrinsic control during motor execution. The latter is usually interpreted in terms of the preferential access of basal ganglia motor output to medial rather than lateral motor cortical areas. Medial cortical areas are more active in association with internally generated movements, whilst lateral areas are more active during externally cued movement (Berardeli *et al*., 2001).

Consequently, this underscaling of movement commands in internally generated movements, reflect the role of the basal ganglia in selecting and reinforcing appropriate patterns of cortical activity during movement preparation and performance (Berardeli *et al*., 2001). Imaging and EEG studies have shown that other regions of the CNS can adapt to the primary basal ganglia deficit of PD. Thus, the clinical presentation of bradykinesia may be a mixture of the primary deficit and compensatory processes, which may cause long intervals between successive elements of a

sequence, resulting in difficulty in doing more than one thing at the same time and the progressive slowing of long sequences of movement (Rinalduzzi *et al*., 2015; Berardeli *et al*., 2001).

A tremor at rest goes hand-in-hand with PD, or at least that is the general public's impression. People tend to think that tremors, which is indeed a major symptom of PD, occurs in all PD individuals. However, this is a misconception. About 60-80%of diagnosed individuals experience a tremor throughout the course of the disease (Jankovic, 2008). The parkinsonian tremor is thought to result from central oscillators in a wide number of cortical and subcortical areas (Govil *et al*., 2013). Tremors vary among individuals and might occur at time of onset or only develop later (Jankovic, 2008). In addition, it is almost always prominent in the distal part of an extremity (like the hands, fingers or feet) and can be unilateral dominant (Durstine *et al*., 2009). Sometimes a rest tremor can occur in the lips, chin, jaw and legs, and characteristically disappears with action and during sleep (Jankovic, 2008). Interestingly, Govil *et al*. (2013) found that proprioception played a role in tremor onset, and by using force-proprioceptive feedback tremor severity could be reduced.

Rigidity is characterised by increased resistance in the muscles. It is present throughout the range of passive movement of a limb (flexion, extension or rotation about a joint) and is usually accompanied by the ‘‘cogwheel’’ phenomenon (Jankovic 2008, p. 370; Broussolle *et al*., 2007, p. 909), particularly when associated with an underlying tremor. The “cogwheel” phenomenon refers to jerky movements due to abnormal tension in the muscle when the muscle is passively stretched (Broussolle *et al*., 2007). Rigidity usually occurs proximally at neck, shoulder and hips, as well as distally at wrist and ankles (Albani *et al*., 2014; Jankovic 2008). Rigidity in the neck and ankles seem to play an important role in balance control, balance strategies, mobility and coordination (Rinalduzzi *et al*., 2015). Voluntary movements of the contralateral limb of upper and/or lower limbs (known as the Froment's manoeuvre) usually increase rigidity and are particularly useful in detecting mild cases of rigidity (Broussolle *et al*., 2007), but it also demonstrates how rigidity can interfere in daily life where contralateral movements are necessary, like driving a car, or standing

while drinking a cup of tea. Rigidity may be present in the initial manifestation of PD and can exhibit symptoms of musculoskeletal pain and are then often misdiagnosed at arthritis, bursitis or rotator cuff injury (Jankovic, 2008). Rigidity can be explained by the impaired proprioception and biomechanical parameters that lead to incorrect muscle activations which cause muscle and joint stiffness (Albani *et al*., 2014; Winogrodzka *et al*., 2005). Rigidity is further compounded by lack of coordination in the pelvis (due to rigidity) that causes 'out of phase' walking to which the body responds with more rigidity to increase stability (Winogrodzka *et al*., 2005; Dietz *et al*., 2002). To be able to perform functional movements, involving stability and mobility, accurate regulation of phasic and tonic muscular activity is needed, which is normally carried out automatically, without conscious awareness, except in PD this is not the case as rigidity especially interferes with axial automatic activity (Rinalduzzi *et al*., 2015; Wu, Hallett & Chan, 2015).

Individuals with PD may exhibit a number of secondary motor and non-motor symptoms that may impact their daily living. Speech disorders in individuals with PD are characterised by monotonous, soft and breathy speech with variable rate and frequent word finding difficulties, referred to as ''tip-of-the-tongue phenomenon" (Jankovic, 2008). Other manifestations include loss of spontaneous movements and gesturing, drooling because of impaired swallowing, loss of facial expression (hypomimia) and decreased blinking (Berardelli *et al*., 2001). Mood or psychological disorders are also part of PD symptoms with many individuals suffering from apathy and depression, leading to lack of motivation (Kalia & Lang, 2015). Dopamine is closely entangled with the reward centre in the body and thus a decrease in dopamine can lead to disinterest in activities that the individuals use to enjoy or even a decline in willpower (Crossman & Neary, 2000). Panksepp (1998) also stated that dopamine appears to be a major contributor to feelings of engagement and excitement which would explain altered behaviour and mood. Various symptoms of PD are related to, and even exacerbated by emotional state. Individuals have reported freezing of gait (FoG), tremors and speech being affected when in a new or stressful situation (Browner & Giladi, 2010; Šumec *et al*., 2015). Postural instability or balance dysfunction is also strongly associated with anxiety, depression, and apathy (Šumec *et al*., 2015).

Similarly bradykinesia is dependent on the person's emotional state, but actually leads to improvement in the condition. For instance the individual can sometime move quickly when startled or told to do so (Berardelli *et al*., 2001). This phenomenon, called kinesia paradoxical, suggests that individuals with PD have intact motor programmes but have difficulties accessing them without an external cue such as a loud noise, music or visual feedback guiding them (Jankovic, 2008; Nieuwboer *et al*., 2007). External cues might bypass the defective basal ganglia by stimulating the reticular formation in the brainstem of the amygdala in the limbic system, both of which are connected to fear of reaction upon danger (Crossman & Neary, 2000).

2.2 Posture and Balance in Parkinson disease

The ability to maintain standing balance and orientation is crucial to mobility and independence (Jacobs, 2014). Balance is defined as the ability to control your centre of mass (CoM) over your base of support (BoS). Postural control and balance control are often used interchangeably because they are so closely related. Balance control is defined as a multisystem function that strives to keep the body upright while sitting or standing and while changing posture (Rinalduzzi *et al*., 2015). Postural control aligns the body with respects to gravity, the support of the surface, and the visual environment and stabilizes the centre of mass of the body relative to its base of support during daily activities (Schoneburg *et al*., 2013). Balance control is achieved through the dynamic control of the posture in various positions against gravity. Any perturbations to the posture govern the activation of the sensory systems at CNS level and formulate a motor response aimed at maintaining the body's centre of gravity within the base support of the subject (Woollacott *et al*., 1986).

Increased postural instability, associated with poor balance, is considered the most incapacitating as it can directly threaten independent-living as well as quality of life (QoL).In fact stage III on the Hoehn and Yahr (H&Y) severity rating scale, which is delineated by postural

instability, is considered a critical stage for prognostic importance in that it may influence clinician-based interventions (Goetz *et al*., 2004). Furthermore, H&Y stages IV and V is considered as dependent stages; since the individual with PD may not necessarily be able to live independently any more due to severe postural instability and reduced mobility. Postural instability occurs when an individual demonstrates an abnormal dynamic postural control (Rinalduzzi *et al*., 2015). As a multifactor problem, PD postural instability has been partially attributed to dysfunctional visual, vestibular, and proprioceptive systems, incorrect motor scaled neuromuscular response, and increased background muscle tone (Rinalduzzi *et al*., 2015 Toole *et al*., 2005).

Postural instability, and the associated impairment in balance, have been linked to increased risk of falls and identified as one of the most debilitating symptoms of PD (Nocera *et al*., 2009) which gradually increases with PD progression (Conradsson *et al*., 2012). Recurrent falls are common in people with PD (Margaret *et al*., 2009). Bloem *et al*. (2001) as well as Gray and Hildebrand (2000) reported that individuals with PD fell most commonly during walking, turning, and rising from a chair, and a study by Lieberman (2014) demonstrated that falls occur where smaller steps were taken, such as in the above-mentioned situations. Rinalduzzi and colleagues (2015) also suggest that increased falls may be associated with inflexible control of axial postural tone during abrupt alterations in postural orientation, such as a turn. Balance problems are poorly controlled by dopaminergic medications and can be unresponsive or even worsened by certain long term drug therapies. These can result in related movement problems i.e. (dyskinesia), dystonia, and clinical fluctuations of motor disability (Bloem *et al*., 2015; Rinalduzzi *et al*., 2015; Durstine *et al*., 2009).

Instability is further increased by the characteristic “stooped” posture observed, decreased joint range of motion, narrow foot stance and axial rigidity (Conradsson *et al*., 2012). The stooped posture is characterised by the narrow stance with rounding of the shoulders, flexed neck and truck, with increased flexion in the hips, knees and elbows, reflecting an increased flexor tone, and are often associated with rigidity (Schoneburg *et al*., 2013; Jankovic 2008). This recognised type of

static deformity can become evident shortly after the onset of the illness, and worsens as the disease progresses. The stooped posture may even lead to more severe abnormalities of static posture disrupting spinal alignment and leading to significant disability include camptocormia, antecollis, Pisa syndrome, and scoliosis (Rinalduzzi *et al*., 2015). Inappropriate load response due to impaired proprioception can be the cause of this, as leg flexor muscles are more activated and extensor muscles show weakness (Albani *et al*., 2014). Due to impaired proprioception, PD individuals might experience an altered sense of verticality, meaning they have an inaccurate representation of gravitational alignment (Schonebeurg *et al*., 2013). This affects the position of their CoM over their BoS, making them more vulnerable to falls.

Decreased sensory integration leads to impaired proprioception (Konczak *et al*., 2009) and an overreliance on visual feedback for postural control i.e. static and dynamic balance in PD (Rinalduzzi *et al*., 2015; Paquette *et al*., 2011). Hence poor proprioception as a result impacts a PD individual's posture and gait. Static balance, or balance during quiet stance, is defined as the ability to maintain the position of the CoM in unsupported stance when the BoS does not change (Sibley *et al*., 2015); this can include wide stance, narrow, single leg stance, tandem and any standing condition. During quiet stance the CoM is located within the BoS by the feet position, however the body is not entirely still—there is continuous movement of the CoM, termed "postural sway" (Schoneburg *et al*., 2015). Parkinson's disease individuals have significantly more postural sway than aged–matched individuals, especially when standing with their eyes closed (Schoneburg *et al*., 2013). This indicates that PD individuals have a higher dependency on visual inputs to maintain their balance (Rinalduzzi *et al*., 2015). As PD progresses, individuals stand with an increasingly narrow stance and stooped posture (Schoneburg *et al*., 2013), thus increasing their postural sway and decreasing their postural stability. Postural sway is regulated by complex sensory-motor control loops to maintain balance, and can be largely influenced by a person's posture (Schoneburg eta al., 2015), as well as visual, somatosensory and vestibular inputs (Rinalduzzi *et al*., 2015).

Dynamic balance is defined as the ability to exert ongoing control of CoM when the BoS is changing (Sibley *et al*., 2015), for example when walking, turning or performing postural transitions like standing up from a seated position. Dynamic balance is necessary for all functional movements to perform daily activities safely. Furthermore balance control is assured through dynamic control of posture, which in turn is exerted by generating postural responses to planned activities (anticipatory postural control) or external perturbations (reactive postural control) (Rinalduzzi *et al*., 2015). Anticipatory (proactive) postural control is the ability to shift the COM before a distinct voluntary movement, like stepping. Whereas reactive postural control is defined as the ability to recover stability after an external perturbation by bringing the CoM within the BoS, through corrective movement strategy (Sibley *et al*., 2015).

A sudden perturbation to a supporting surface induces loss of stability in standing posture, and in order to regain balance, the muscles of the lower limbs contract automatically (Rinalduzzi *et al*., 2015). The resulting effect is that the person produces an ankle, hip or stepping strategy, depending on the magnitude of the perturbation and the BoS, to prevent falling (Lieberman, 2014). When PD individuals experience external perturbation their dysfunctional proprioceptive mechanisms are apparent. They manifest a type of postural inflexibility by initiating the ankle and hip strategies simultaneously; also increasing postural sway (Rinalduzzi *et al*., 2015). Modifying postural muscle synergies is a crucial part of maintaining balance, a quality lacking in PD individuals. Studies on EMG activity during postural reactions have shown that PD individuals have abnormal generation of motor patterns which results in less effective correction of destabilized posture (Rinalduzzi *et al*., 2015). These abnormal motor patterns include delayed onset of muscle activation, inappropriate amplitude, and reversal of the normal activation sequence (Rinalduzzi *et al*., 2015). This abnormal EMG pattern results in reverse activation of the normal distal to proximal muscle activation sequence, causing contraction of the hip muscles to precede that of ankle muscles. This reverse activation increases the limb stiffness and induces lack of appropriate corrective movements (Schoneburg *et al*., 2013) and inappropriately low scaling of muscle contractions which results in early onset of heel lift or stepping (Rinalduzzi *et al*., 2015).

Reasonably, this is the mechanism explaining why PD actually falls faster than control subjects in response to an external perturbation because their limits of stability are smaller (Schoneburg *et al*., 2013). The biomechanically determined limits of stability during stance are the maximal displacement of the body CoM in various directions without falling or having to take a step. Hence the PD individuals' CoM reaches their limits of stability sooner, before they can reverse CoM displacement with their reactive postural responses (Schoneburg *et al*., 2013) resulting in patients using a premature compensatory stepping response (Rinalduzzi *et al*., 2015).

Several other factors also influence the occurrence of postural instability in individuals with PD. These include other parkinsonian symptoms, orthostatic hypotension, medication state and age-related sensory changes (Jankovic 2008; Rinalduzzi *et al*., 2015). The fear of falling and balance confidence can further impair balance control in patients with PD (Rinalduzzi *et al*., 2015; Jankovic 2008; Franchignoni *et al*., 2005). Balance confidence, of all individuals, are affected by the extent to which individuals can return their CoM over their BoS when leaning toward their limits of stability (Schoneburg *et al*., 2013). With PD individuals these perceived limits of stability decrease, especially in the forward direction, and the speed of movements within these limits are reduced, possibly due to fear of falling (Schoneburg *et al*., 2013; Yang *et al*., 2008). This fear of falling is a natural protective mechanism and increases caution during performance in all other ADL and hazardous activity. However it can be maladaptive and subsequently compels individuals to restrict their mobility, independence and social participation, leading to further deconditioning, functional decline, and poorer quality of life (Franchignoni *et al*., 2005).

Walking would not be possible without dynamic balance. Balance and walking impairments are present even from the early stages of PD, and have been shown to be associated with restrictions in everyday activities and reduced QoL (Conradsson *et al*., 2012). A study by Yang and colleagues (2008) found that a strong correlation exists between increasing balance impairments and decreasing gait ability, unlike healthy age-matched controls.

2.2.1 Gait in Parkinson Disease

Balance and mobility (in particular gait) dysfunction is common in Parkinson disease (Curtze *et al*., 2015). Dynamic limits of stability during walking take into account both the relative position and the velocity of the body's CoM over its BoS (Schoneburg *et al*., 2013). Individuals with PD demonstrate a gait pattern characterized by hesitant, shuffling short and quick steps with increased step time variability, and poor step-to-step coordination (Peterson *et al*., 2014; Plotnik *et al*., 2008). In addition individuals also show difficulties in gait initiation and changes in postural control, mostly resulting from changes in position or direction. As a result a functional task such as turning is difficult as it requires a series of gait initiations. Similar to a person's perceived limits of stability while standing, gait speed may be a self-imposed compensatory measure related to a person's balance confidence when walking (Shoneburg *et al*., 2013). Schoneburg and colleagues (2013) explain that this decrease in gait speed is normal for elderly people and even for young healthy individuals when walking under unfamiliar of hazardous conditions and their balance is threatened. However this slowing, as well as stride-to-stride variability also correlate with falls, especially in PD (Schoneburg *et al*., 2013; Schaafsam *et al*., 2003).

Festinating (galloping forward locomotion) and shuffling gait is very characteristic of PD, and might occur because of biomechanical constraints or due to impaired balance, and thus resulting in every step being caused by the stepping strategy of reactive balance to prevent falls, rather than every step being part of a conscious executive decision (Albani *et al*., 2014). Schoneburg and colleagues (2013) eloquently explain why walking is a challenge to balance, and how this lead to festination in PD. They state that during walking the person's CoM constantly shifts forward outside the anterior limits of stability and from side to side to take the weight of alternating legs. This poses a serious challenge to balance. To counteract these shifts the person needs axial control of their lateral and forward stability as well as appropriate foot placement. In other words, the person places their foot in front of their CoM to prevent themselves from falling forward. However as Schoneburg *et al*. (2013) explain that if this step is too small (to prevent the

forward COM movement) then additional steps are needed. In addition if these following steps, which are meant to regain balance, are too small then festination or propulsion occurs. If this occurs on retreating backwards then it is termed retropulsion. Both propulsion and retropulsion frequently result in falls in advanced PD (Schoneburg *et al*., 2013).

Individuals with Parkinson's disease have been reported to have a slower stride velocity (SV) than healthy elderly individuals, as well as a shorter stride length (SL), and spend longer time in double-support (DS). Cadence however is mostly similar to healthy elderly, but may at times be increased (Schoneburg *et al*., 2013). Impaired gait is often the most limiting factor in independence, and a very pronounced clinical symptom. It is therefore vital to understand why certain symptoms occur and what the biomechanical as well as physiological causes are. Various factors contribute to PD gait throughout the disease; these factors are reported in Figure 2.2 (p.9) and the subsequent clinical manifestations are shown in Figure 2.3 (p.21). Impaired proprioception and biomechanical parameters are at the heart of the neuromuscular dysfunction. Distorted signals and proprioception feedback result in muscles being activated or inhibited (Dietz *et al*., 2002). Several studies have compared normal elderly gait to PD gait, as well as investigated the correlation between gait impairments and disease severity (Albani *et al*., 2014; Roiz *et al*., 2010; Schaafsma *et al*., 2003). These studies found that SL and SV showed the biggest difference between PD and healthy controls (Albani *et al*., 2014; Roiz *et al*., 2010; Yang *et al*., 2008). However in Albani (2014) they found significant differences in cadence as well, but their study took place after a 12 hour medication withdrawal, thus PD individuals were tested in their OFF phase.

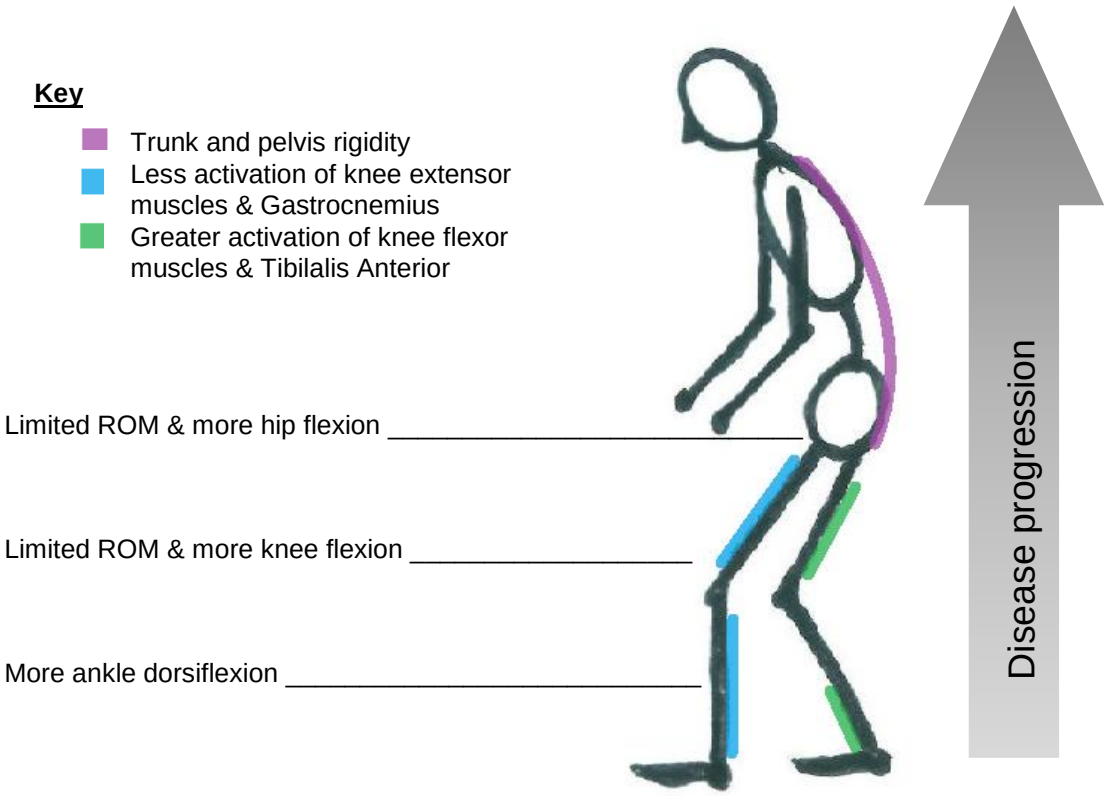

Figure 2.3: Biomechanical & neuromuscular characteristics of PD gait with disease progression (adapted from Albani *et al*., 2014).

Kinematic analysis have shown a decreased range of motion (ROM) in the hip joint – less flexion on swing and greater flexion at initial contact – as well as greater flexion in the trunk (Roiz *et al*., 2010). Studies also found that PD patients had decreased ROM and increased flexion in the knee and ankle joints (Albani *et al*., 2014; Roiz *et al*., 2010). This falls in line with the description of the stooped posture in which a greater amount of flexion is observed in the body. This abnormal posture is the result of increased activation of the flexor muscles of the knee and the tibialis anterior coupled with decreased activation of the extensor knee muscles and gastrocnemius (Figure 2.3) which causes the excessive flexion in the pelvis, trunk and spine (Albani *et al*., 2014; Schoneburg *et al*., 2013). This leads to trunk and pelvis rigidity which causes problems with normal walking coordination, thus resulting in further impaired balance (Abe *et al*., 2003).

Pelvic rotation normally contributes to the appropriate scaling of stride length and stride velocity. However with impaired rotation, along with internal motor planning and initiation problems,

in-phase walking (i.e. normal bipedal walking with contralateral arm and leg moving simultaneously) changes into out-phase walking (Albani *et al*., 2014). This means that the normal coordinated walking diminishes as does the balance aspect associated with bipedal walking (Bruijn *et al*., 2008) and as a result the body tries to ambulate as safely as possible. Arm swing is reduced accordingly since bilateral, or often in the case of PD unilateral, arm swing contributes to the asymmetry experienced in the body, resulting in greater coordination problems (Wu, Hallett & Chan, 2015). Reduced trunk rotation and asymmetrical arm swing are some of the earliest signs of gait dysfunction in untreated PD, and can sometimes be improved with medication (Schoneburg *et al*., 2013). As a result individuals with PD use strategies to maintain balance by adapting the timing of trunk rotations to that of pelvic ones, or refraining from adapting the timing of pelvic rotations to the movements of the leg (Huang *et al*., 2010). This causes abnormal spatiotemporal measurements such as shorter stride length and slower stride velocity, and sometimes even time in DS increases while cadence might increase or decrease depending on the stage of disease.

A study by Braak and Del Tredici (2008) found that the neuropathology of PD changes as the disease progresses. Initially, the disease affects the olfactory structures and other structures located in the peduncle pontine area, then progresses to affect the substantia nigra in the basal ganglia, and in the final stages it affects parts of the cortex (Kalia & Lang, 2015). These results help to explain the neurophysiological differences in disease stages. Albani and colleagues (2014) were able to identify biomechanical parameters that are able to discriminate between PD at different disease stages. Individuals were grouped into an early group (< stage II H&Y), as well as an intermediate stage (≥ stage II H&Y) non-freezers group and freezers group (≥ stage II H&Y and experienced freezing of gait). The researchers observed that the early group experienced more distal biomechanical impairment whereas the freezers group had more proximal impairment. The clinical features translated to the early group showing greater dorsiflexion during stance while the non-freezers group displayed greater knee joint flexion at initial contact and a limited RoM of the knee (Albani *et al*., 2014). The freezers group had reduced RoM in the hip joint and experienced a more flexed position of the hip at initial contact and in the stance phase. The limitation of the hips

later in the disease is a big contributor to increased fall risk because of less coordinated movements of the pelvis (Bruijn *et al*., 2008). Thus as the disease progresses the biomechanical impairments, concerning walking, shifts from the lower extremities (distal) to the trunk (proximal; Figure 2.3).

Spatiotemporal measurements of gait parameters (like stride length, stride velocity, cadence and double support) are an easy and reliable way to assess the gait of PD individuals. However some studies have stated that it is not sensitive enough to distinguish between disease stages (Albani *et al*., 2014 & Roiz *et al*., 2010) although Roiz *et al*. (2010) have also shown that other clinical tests might. However Albani *et al*. (2014) and Schaafsma *et al*. (2003) have shown that gait variability of spatiotemporal parameters are a good predictor of freezing of gait and fall risk. It is speculated that variability in SL and stride time may reflect dysfunction of locomotor pattern generators and that variability in DS time and width of steps reflect neural balance circuits (Schoneburg *et al*., 2013). These parameters are discussed in more details in the articles (Chapter 3, 4 & 5).

2.2.2 Freezing of Gait (FoG)

Typically, FoG is a sudden transient episode, lasting less than 1 minute (usually 10 s), in which movements and gait are haltered and the subject reports the inability to move his or her feet (Browner & Giladi, 2010 & Jankovic, 2008). Freezing most commonly affects the legs during walking, but the arms and eyelids can also be involved (Schoneburg *et al*., 2013). The most common provoking factors for FoG are initiation of gait and turning (Browner & Giladi, 2010). Even in the early stages of PD, individuals have turning deficits i.e. executing turns more slowly and with multiple steps (Jankovic, 2008).

Another gait abnormality observed in some individuals with PD is ‘freezing of gait’ (FoG), which is the inability to complete effective stepping (Giladi *et al*., 2008). In the Unified Parkinson’s

disease Rating Scale (UPDRS) questionnaire FoG is described as the sensation of your feet being glued to the floor during walking in certain environments, when making a turn or when trying to initiate walking. Freezing, also referred to as motor blocks, is a form of akinesia (loss of movement) (Schaafsma *et al*., 2003). Although freezing is a characteristic feature of PD, it does not occur with all individuals, only about 50% of people with advanced PD experience FoG (Jankovic, 2008; Bartels *et al*., 2003). Freezing of gait is a very disabling and distressing symptom that contributes to falls and reduces QoL (Peterson *et al*., 2014; Schaafsma *et al*., 2003). Furthermore, common PD treatments such as anti-Parkinson medication do not consistently provide adequate benefit (Peterson *et al*., 2014).

The FoG or freezing phenomenon has a more complex pathophysiology than that of the classic motor symptoms in PD, and the cause of FoG is still unknown. As a result FoG has been classified separately from the other features of PD as it is not merely just part of the motor symptoms of PD as traditionally thought (Browner & Giladi, 2010). Albani *et al* (2014) suggest that FoG is the clinical expression of a dysfunction of the cortico-subcortical interplay, given its unique response to pharmacologic and surgical interventions, as well as trigger sensitivity to external and internal cues and its correlation with motor planning deficits (Browner & Giladi, 2010). In 2001 Giladi and colleagues found, with a retrospective analysis, that the main risk factor for development of FoG was severe speech impairment, gait difficulties, and balance problems whereas the initial manifestations of tremor was negatively associated with FoG. They also found that cognitive decline and depression, rather than rigidity and bradykinesia, was associated with early occurrence of FoG, which according to Giladi *et al*. (2001) emphasizes the concept that FoG is an independent cardinal sign of Parkinsonism.

There are multiple other factors that have also been shown to affect FoG including walking through narrow passages, approaching a destination, a change in the environment, and walking under time pressure (like crossing busy streets), anxiety, or stress (Browner & Giladi, 2010; Jankovic, 2008). Abe *et al* (2003) suggests that the motor blockage of the freezing is not related to

increased or decreased muscle tone or strength, but rather the result of abnormal retrieval or execution of a motor programme. In a study by Nieuwboer *et al*. (2007) they found that during the phase preceding a FoG episode there was increased hip and knee flexion with a forward sway of the pelvis. This results in greater trunk rigidity and failure of interlimb coordination (Abe *et al*., 2003), thus causing compensatory gait abnormalities, loss of balance and often falls (Albani *et al*., 2014). As explained previously in this chapter Albani and colleagues (2014) also found more proximal biomechanical impairment in freezers compared to non-freezers. The researchers suggested that this distal to proximal progression is indicative of poor rotation of the pelvis and trunk rigidity, which may be due to the degeneration of the locomotor control centres (Figure 2.3). In other words the proximal involvement in freezers reduces the individual's ability to scale SL and consequently reduces SV because the pelvic rotation has failed.

Individuals often utilize certain tricks, like cues, to overcome the freezing, which is associated with substantial social and clinical consequences for them, especially with the greater chance of falls (Schoneburg *et al*., 2013). Once the motor block is overcome the individual can perform walking relatively smoothly by using tricks like sensory and cognitive cues (Browner & Giladi, 2010). Sensory cues can be auditory, visual, haptic or cognitive (Rubenstein, Giladi & Hausdorff, 2002), and involves actions such as marching on the spot or on command, stepping over an obstacle (e.g. a walking stick, cracks in the floor), walking to music or a beat, shifting body weight or visualisation and attentional strategies (Browner & Giladi, 2010; Jankovic, 2008; Rubenstein, Giladi & Hausdorff, 2002). Not all sensory cues work as well for every freezer, and therefore PD individuals have to find the cue that helps them specifically (Rubenstein, Giladi & Hausdorff, 2002).

2.2.3 Dual-Task Interference in Parkinson's disease

Due to automaticity declining as PD progresses (Wu, Hallett & Chan, 2015), gait becomes more reliant on cognitive functioning, as suggested by brain imaging studies that have shown higher activation of part of the cortex involved in conscious processing during automated

movements (Wu *et al*., 2014). When only walking is performed at a time then certain PD gait parameters are already affected compared to healthy age-matched controls as previously discussed. The addition of a secondary task (also known as dual-tasking) exacerbates gait difficulties even more (Kelly *et al*., 2012). This is true even for early stages of the disease (Fuller *et al*., 2013). Dual-tasking (DT), or even multi-tasking, is a critical aspect of balance control and safe ambulation in PD (Conradsson *et al*., 2012). Dual-tasking is defined as the ability to divide attention and simultaneously process multiple tasks (motor or cognitive) and execute them with distinct goals (Strouwen *et al*., 2015). It is often used to test automaticity of elderly individuals (Rochester *et al*., 2011), and individuals with gait difficulties as PD because it is an easy way to assess fall risk (Springer *et al*., 2006).

During DT, attention is shifted away from the balance task when performing secondary tasks, which lead to higher fall incidences (Berardelli *et al*., 2001). This is due to increased gait variability during DT, which has been shown to correlate with increased fall risk in PD (Springer *et al*., 2006; Albani *et al*., 2014). This greater variability has also shown a relationship with impaired executive function (Schoneburg *et al*., 2013). Executive function is used here as an umbrella term to describe the control of goal-directed behaviour through the use of several cognitive abilities (Plotnik *et al*., 2011), which includes switching between tasks, generating or inhibiting responses and updating working memory to manage optimal daily functioning (Yogev-Saligmann *et al*., 2008). This is especially true during non-routine activities that require conscious control, whereas walking becomes automated from the age of about 4 years (Shumway-Cook & Woollacott, 2007) and is regulated by the basal ganglia (Crossman & Neary, 2000). Thus cognitive impairment, which regularly accompanies PD (Yogev-Saligmann *et al*., 2008), results in greater DT interference and can result in more emphasis being placed on the secondary task (Fok *et al*., 2010; Bloem *et al*., 2006), and not on the postural task. This increasing postural instability together with possible freezing (Morris, 2000), increases risk of injuries, and decreases balance confidence (Canning *et al*., 2014).

The cause of DT interference is not yet fully understood. Certain models postulate that it might be due to structural limitations in the brain or it might be that processing is strategically delayed due to ensure that each task is completed successfully, but not simultaneously (Strouwen *et al*., 2015). In a recent review by Strouwen and colleagues (2015) they summarized four theoretical models that sprout from the classic capacity theory of DT interference. The classic capacity theory states that attention, or central information-processing, is a limited resource and performing a task occupies a certain amount of this resource (Neumann, 1996; Siu & Woollacott, 2007). The theoretical models include 1) the bottleneck, 2) capacity-sharing, 3) executive processing with interactive control and 4) multiple resources. The bottleneck theory states that two tasks cannot be performed at the same time because these tasks use the same neural network in the brain and can only be processed one at a time (Strouwen *et al*., 2015). The capacity-sharing theory postulates that two parallel tasks can be performed via the same network, but the amount of capacity is restricted and thus a delay might occur when the network is overloaded. Executive processing and interactive control is the third model in which the assumption is that central and other processing stages are involved when parallel or sequential processing takes place. The fourth model proposes that multiple brain resources are needed to execute various aspects of the tasks, which leads to functional everyday multi-tasking (Strouwen *et al*., 2015). Therefore more interference would be present if there was greater overlapping of resources (Wu *et al*., 2014).

Traditionally individuals with PD and related movement disorders were advised to avoid DT training because it might create a hazardous situation. Recently more studies show that DT training can be beneficial (Strouwen *et al*., 2015). Although research on the effects of DT training is limited, it seems that keeping certain motor learning concepts in mind is vital to make the training effective (Yogev-Seligmann *et al*., 2012), because consolidation and automatization of learned tasks are affected in PD individuals (Abbruzese *et al*., 2015). Motor learning concepts that seem to be of importance include the task-specificity (goal-based), augmented feedback (verbal or proprioceptive), high intensity, practice variability and progressive difficulty (Abbruzese *et al*., 2015; Yogev-Seligmann *et al*., 2012).

One way to practice a task is to break it up into smaller pieces and then combine them to perform the full task, or practice a task as a whole or lastly have a combination of these two methods (Strouwen *et al*., 2015). To improve a task, one must practice the task specifically as successful repetitions enhance the skill (Nieuwboer *et al*., 2009). For DT however alternative methods have also been postulated. For instance, training the walking task and the cognitive task separately was found to be effective for older adults (Springer *et al*., 2006). Conversely this proves more problematic for PD individuals as they have less connectivity between striatum and execution networks especially when asked to perform a learned task (Wu *et al*., 2014). According to various researchers, whole training or combination training seems a better fit for PD participants (Conradsson *et al*., 2015; Yogev-Seligmann *et al*., 2012; Rochester *et al*., 2010; Brauer & Morris, 2010). With the exception for more advanced PD individuals to whom it might be too challenging and fall risk is high.

Feedback during training is an essential part to acquiring and re-acquiring motor skills and for motor performance (Abbruzese *et al*., 2015; Nieuwboer *et al*., 2009). Thus giving feedback on the results of performance (knowledge of results) or of performance during dual-task training (knowledge of performance) can improve motor performance (Yogev-Seligmann *et al*., 2012). There are various types of feedback that humans use every day to influence performance; feedback can be intrinsic (awareness of performance produced within the body) or extrinsic (additional external source of information about performance). It has been hypothesized that different feedback might involve different brain areas; for example internal feedback might be linked to the basal ganglia and supplementary motor area, whereas external feedback might involve sensory and pre-cortex areas (Verschueren *et al*., 1997). Types of feedback include visual, auditory (or verbal), tactile, proprioceptive and vestibular (Greenwald, 1970; Verschueren *et al*., 1997; Nieuwboer *et al*., 2009). Visual feedback can be provided in the form of the individual's own vision of movement or performance outcome, with the help of a mirror or video recording, or therapist demonstration. Auditory feedback can be obtained from sounds of performance outcome or verbal instructions from a therapist or coach; tactile feedback is sensed through receptors in the

skin and can be stimulated by a therapist, or the ground surface or external equipment. Proprioceptive and vestibular feedbacks are both intrinsic feedback mechanisms that relay information about the body's orientation in space and gravity, and with itself, as well as information about speed and rotation.

The exact exercise principles, in terms of intensity, frequency, and duration, at which DT training should be performed has not been established to date, but four weeks of gait training three times a week has showed improvement (Watanabe & Funahashi, 2014). Studies have shown that dual-tasking slows gait velocity and reduces stride length; some studies even found that cadence decreases as well, more so in PD individuals then age-matched healthy controls (Plotnick *et al*., 2010; Fuller *et al*., 2013; Fok *et al*., 2012 & Yogev-soligmann *et al*., 2012). Practicing a task under varying conditions enhances transfer and also makes it more relevant to everyday life, and for PD individuals it is essential to be able to adapt to avoid harmful situations (Springer *et al*., 2006).

Dual-tasking is such a quintessential part of life that an individual only notices the value of it until it deteriorates. Methods and techniques to prevent this is vital to PD individuals who want to remain independent,

2.3 General Overview of Exercise Interventions for Parkinson's disease (PD)

Exercise is a planned, structured physical activity which aims to improve one or more aspects of physical fitness (Morris & Schoo, 2004). The belief that exercise could be considered medicine, or part of medicine, is not new. Exercise has always been seen as a vital part of maintaining good health. This strong emphasis on health, rather than disease, dates back to prominent ancient physicians such as Hippocrates (Berryman, 2010). Exercise have been viewed as medicine for many years, however this concept have been neglected in the past century but is again reaching popularity not only with medical professionals but also in the community as stated by Berryman (2010) in his review article.

Research into exercise from the 1940's and onwards has shown what great correlation there is between inactivity and a variety of chronic diseases (Berryman, Thomas & Cureton, 1996). This has prompted further questions into what else exercise can help with in terms of maintaining health, optimizing functionality and increasing quality of life. Since then exercise has been widely researched as a potential long term, inexpensive way to modify physiological aspects of health to promote longevity. Further investigation also shows the positive effects exercise has on psychology, quality of life, and possible beneficial effect on the brain (Šumec *et al*., 2015; Petzinger *et al*., 2010; Hirsch & Farley, 2009). Current models of rehabilitation often use compensatory strategies as the basis of therapeutic management. However, there is a growing body of evidence regarding the benefits of exercise in terms of neuroplasticity and the ability of the brain to self-repair (Petzinger *et al*., 2010; Smith and Zigmond, 2003). This is a crucial part for the elderly who are at a higher risk of contracting a disease and losing independence (Morris & Schoo, 2004), and even more so for individuals with a neurodegenerative disease such as PD.

For PD, exercise could also have potential neuroprotective mechanisms (Conradsson *et al*., 2012), in that regular exercise could stimulate brain function and extend the period of time before medication starts to have a negative influence on motor tasks (Rubinstein *et al*., 2002). According to Hirsch and Farley (2009), evidence suggests that exercise might promote brain repair and neuroplasticity in people with PD. This reorganization can lead to behavioural recovery, affecting movement as well. In recent years, evidence from animal models suggests that the effects of the exercise are beyond solely improving disease symptoms of PD, and that exercise could also have protective benefits against the onset of symptoms in PD (Smith and Zigmond, 2003; Petzinger *et al*, 2010; Tajiri *et al*., 2010). This appears to be due to the release of neurotrophic factors, and greater cerebral oxygenation, which together promote new cell growth and cell survival (Dishman *et al*., 2006). In PD, it has been found that exercise stimulates dopamine synthesis in remaining dopaminergic cells and thus reducing symptoms by prolonging the progression of the disease (Sutoo *et al*., 2003). Previous research indicates that functional improvements from exercise interventions stem from the activation of the motor cortex that overrides atypical basal ganglia

function demonstrated in PD (Nieuwboer *et al*., 2001). Thus, exercise in general can facilitate neuronal transmission and motor coordination that are essential for improved balance and overall function (Nocera *et al*., 2009).

Physical activity levels decline with advancing age and these reductions contribute to functional decline (Morris, 2000). It has been shown that people with PD are more inactive than their healthy peers (van Nimwegen *et al*., 2011). PD individuals also have lower levels of strength and functional ability (Bridgewater & Sharpe, 1997; Glendinning, 1997) and this observation of muscle weakness is not simply a secondary consequence of ageing and inactivity, but also a primary symptom of PD (Koller & Kase, 1986). Glendinning (1997) claims that this muscle weakness is due to the impaired basal ganglia having an inadequate effect on the cortical motor centres which in turn leads to less activation of motor neurones and therefore muscle weakness (Glendinning, 1994 & 1997). Accompanying muscles weakness are other motor symptoms of PD as discussed earlier such as impaired proprioception, postural instability, rigidity and bradykinesia. These are all possible mechanisms that contribute to impaired balance, falls, and disability (Goodwin, 2011).

PD patients are often referred for physical therapy, primarily exercise, since it has shown to be beneficial for patients as it helps improve their QoL, their self-care independence and cognitive functioning (Lun *et al*., 2005; Hurwitz, 1989; Keus *et al*., 2007; Conradsson *et al*., 2013). Research has demonstrated numerous benefits of exercise for individuals in all stages of PD (Durstine *et al*., 2009). However many of these benefits may be short-lived, especially as the disease progresses (Lun *et al*., 2005).

In a meta-analysis and systematic review by Goodwin and Colleagues (2008) they found that various exercise interventions are effective at improving physical functioning and health-related quality of life, leg strength, balance, and walking (Ashburn *et al*., 2007; Burini *et al*., 2006; Toole *et al*., 2005). The types of interventions include different exercise modes such as treadmill training (Toole *et al*., 2005), aerobic and Qigong (Burini *et al*., 2006), resistance training (Toole *et*

al., 2000), cycling, tango, and boxing (Goodwin *et al*., 2008). Other interventions not fully discussed in their review but which has gained popularity recently include water-based training, yoga (Sharma *et al*., 2015), cognitive movement strategies (Muller *et al*., 1997), Alexander technique (Stallibrass *et al*., 2002), Sensory attention focused exercise (Sage & Almeida, 2009), and balance training (Conadsson *et al*., 2010) to name a few.

Exercise has not been shown to halt or reverse the symptoms but will help most people with PD improve their QoL and ability to perform activities of daily living (Keus *et al*., 2007). In a recent study, Dashtipour and colleagues (2015) discussed the effects that exercise could have on motor and non-motor symptoms of PD. They have found that their invention, Lee Silverman Voice Therapy BIG (LSVT®), and the general exercising control has led to significant improvements in gait speed, speed of upper body movements and depression, anxiety and fatigue ($p = 0.05$). The improvements were noticed at a 4, 12 and 124 week follow-up. In most intervention studies the methodology and intervention differ (Goodwin *et al*, 2008). Future research needs to establish what elements constitute an optimal exercise intervention for people with PD such as the dosage, component parts of intervention, and the targeted stage of the disease. The optimal exercise intervention is of particular importance given the deteriorating nature of PD.

2.3.1 Balance Interventions for Parkinson disease

There is a growing body of research that highlights the role of physical exercise as an essential part of managing PD; and most of the successful studies include balance training in their intervention (Toole *et al*., 2000; Conradsson *et al*., 2012 King *et al*., 2015). Previous studies have found a positive association between balance training and improvement of PD individuals' functional ability (Conradsson *et al*., 2014). Nevertheless questions regarding frequency, intensity and duration still remain (King *et al*., 2015; Kues *et al*., 2007), as well as specific exercises to improve balance control in the different stages of the disease (Conradsson *et al*., 2012).

There have been various studies investigating the effects of balance training on PD (Toole *et al*., 2000; Conradsson *et al*., 2012; Ebersbach *et al*., 2010) and it has been shown to be very beneficial for improving balance, gait speed and mobility. Balance training has even been shown to induce specific patterns of structural brain plasticity (Sehm *et al*., 2014) over six weeks of training, once a week. Conradsson and colleagues (2014) recently showed that highly challenging and progressive balance training with PD individuals is feasible, and four out of their five participants' balance improved. Balance-induced brain plasticity coupled with highly challenging and progressive balance training has brought to light how important balance training might be in the treatment of PD (Conradsson *et al*., 2014). Furthermore best practices to deliver exercise interventions such as home-based unsupervised or therapist-supervised training programmes need to be explored for more effective exercise prescription (King *et al*., 2015).

2.3.2 Home-based vs. Therapist-supervised Interventions

Home-based unsupervised training might be the most cost-effective way to improve functionality of individuals; it is also currently the standard of care for most PD individuals (King *et al*., 2015). Recent reviews by Stolee *et al* (2012) and Novak (2011) found that home-based training for healthy adults and individuals with musculoskeletal disorders can be just as effective as a therapist-supervised training. However King and co-authors (2015) on the other hand found that therapist-supervised training in individual and group sessions are better than unsupervised home-based training. These different findings might be explained by the different methodology, outcome variables, populations and training programmes followed in the various studies. If all PD individuals were able to receive supervised training regular, it might be beneficial for them as well as their caregivers, on whom the progression of the disease becomes a burden (Edwards & Scheetz, 2002). The majority of care of patients with PD is provided by informal caregivers; their caregiving not only offers physical and emotional support for patients but also plays a large economic role and prevents early nursing home placement (Happe & Berger, 2002). In reality it is not possible for all

PD patients to receive therapist-supervised balance training due to financial healthcare costs (Nocera *et al*., 2009), transportation difficulties and shortage of effective medical staff to facilitate such training, especially in developing countries like South Africa (Van der Merwe *et al*., 2012). Therefore it could be of great importance to see how effective a home-based balance programme is on dynamic balance and gait compared to training with an exercise therapist.

To the researcher's knowledge, to date there are about 14 PD studies that discuss and test home-based physical training and its effectiveness. The earliest study was performed by Hurwitz in 1989, where they tested whether individuals, with mild to moderate Parkinson's disease (H&Y stages not reported), who received a weekly home visit with an exercise routine (n=14, aged 57-86 years) performed better than those who only received a home visit (n=15, aged 65-81 years). Exercises, consisting of a 30 minute session of head-to-toe range of motion movements, were supervised by senior nursing students but the whole weekly visit lasted one hour in total. This descriptive study continued for 8 months with testing done at baseline, 4 months and 8 months of exercises. The group who received exercise had a significant improvement in memory and sucking ability, and less nausea, urinary retention and incontinence ($p<0.05$). The results from this study was the first to suggest that regular exercises at home can improve the self-care ability of PD individuals (Hurwitz, 1989), however individuals were still supervised by a nursing student with no background in physical training.

In 2005 two studies were published about the effects of home-based exercises on motor symptoms of PD (Caglar *et al*., 2005; Lun *et al*., 2005). In the prospective blinded study done by Caglar they investigated the effects of home exercises on motor performance over a two-month period on PD individuals (H&Y stages I – III). The home exercise group, consisting of ten men and five women (mean age 67 ± 5 years) were guided through an exercise programme to improve range of motion, functional activity, gait and fine motor dexterity which were to be carried out three times a day, unsupervised. The control group, consisting of eleven women and four men (mean age 64 ± 3 years) did no additional exercise to their normal care. Results showed that the exercise

group significantly improved their walking speed, the length of their first step (which was exclusively measured in this study) and motor performance of both hands ($p<0.001$). Lun and colleagues (2005) compared the effects of a self-supervised home exercise programme and a therapist-supervised exercise programme (with physiotherapist) on motor symptoms in PD patients in a prospective single-blinded clinical trial. Nineteen subjects (six women, 13 men; mean age, 65 ± 8 years) with Hoehn and Yahr Stages II to III were recruited. The intervention, which focused on strength and balance training continued for 8 weeks and participants had to exercise twice a week for approximately 60 minutes. The control group (n=11) exercised with a physiotherapist and the experimental group (n=8) exercised at home after receiving instructions from the same physiotherapist. All outcomes were assessed at baseline and at 8 and 16 weeks. Both programmes were found to result in significant improvements ($p<0.02$) in motor symptoms, as measured by the Unified Parkinson's Disease Rating Scale (UPDRS) Motor subsection III score. However small or no absolute changes were observed in the secondary outcome measurements of balance confidence (measured with the Activity-specific Balance Confidence (ABC) scale), balance (measured with the Berg Balance Scale) and functional mobility (measured with Timed Up and Go tests) for both groups. This result was not unexpected since baseline values were already quite high, and thus little room for improvement was left. This study found that a strength and balance training programme can be just as effective in decreasing motor symptoms when done at home, which is an important finding as this offered a solution to symptomatic treatment of PD.

Several studies followed a similar design to those preceding them but each investigating different aspects of PD with various measurement tools. In addition, successive studies increased the number of participants and the intervention duration, thereby improving the power of the study. In 2006, Ashburn and colleagues evaluated the effectiveness of a personalised home exercise programme and strategies for repeat fallers with PD. Participants with a confirmed diagnosis of idiopathic PD, independently mobile (H&Y II – IV), experiencing more than one fall in the year prior and with no cognitive dysfunction were invited to participate in this randomised controlled trial (Ashburn, 2006). Participants were randomized into a control group that received usual care (n =

72, 48 men, 24 women, mean age 72 ± 9 years) and an exercising group (n = 70, 38 men, 32 women, mean age 73 ± 10 years) following a personalised six-week, home-based exercise programme. The intervention comprised of strength, range of motion, walking and balance training. The primary outcomes were rates of falling, near falls and injuries at eight weeks and six months post-intervention. Secondary outcome variables such as Functional Reach, balance and QoL were rated by a blinded assessor, before and after intervention as well as with the follow-up. The results show that there was a consistent trend towards lower fall rates in the exercise group, although this was not significant. There was a positive effect of exercises at six months on Functional Reach (p = 0.01) and QoL (p = 0.03). No significant differences were found on other secondary outcomes measures like the Berg balance test. This study underscores the value of exercising at home compared to no exercise as it highlights certain physical improvements that leads to a reduction in fall events up to six months after the intervention.

Nieuwboer and colleagues (2007) investigated the effects of a home physiotherapy programme based on rhythmical cueing on gait and gait-related activity. In this single-blind randomised crossover trial-(n = 153, aged 41 - 80 years) individuals with PD classified between II–IV Hoehn and Yahr stage-were included. Participants were allocated to either an early intervention group (n = 76) or late intervention group (n = 77). The early intervention group received a three-week home programme using a prototype cueing device, followed by three weeks without training. Whereas the late intervention group underwent the same intervention and control period in reverse order. Cueing training consisted of nine sessions for 30 minutes of gait-related activities, and was delivered at the participant's home by a therapist. After the initial six weeks, both groups had a six-week follow-up without training. Primary outcome measures included posture and gait scores, while secondary outcomes included specific measures on gait, freezing and balance, functional activities, quality of life and caregiver strain. Participants were assessed at three, six and twelve weeks by blinded testers. Both groups experienced a small but significant ~4% improvement after the cueing intervention in posture and gait scores (p = 0.01) and in severity of freezing, which was reduced by ~6% in freezers only (p = 0.01). In addition specific gait measures such as speed and

step length as well as the timed balance tests improved after the intervention ($p<0.01$). Nieuwboer *et al*. (2007) reported no carry-over effects after the six-week follow-up in functional activities and QoL, with the exception of greater confidence to carry out functional activities, and all further effects of intervention had reduced. This study showed that cueing training may be a useful to the overall management of gait disturbance in PD, but there was no carry-over effect observed a week later once the therapist and the cueing device were absent.

The effects of a home-based exercise programme on postural control and sensory organization in individuals with PD were investigated by Nocera, Horvat and Ray (2009). Ten individuals with PD (H&Y stages II-III, mean age 73.40 ± 8.50) and ten healthy aged-matched controls (mean age 69.79 ± 5.24) were tested with computerized dynamic posturography before and after a ten-week exercise intervention. Participants were instructed on proper technique prior to the intervention, were given an illustrated home programme, and were monitored weekly concerning their progress. The unsupervised intervention included seven strength and muscle endurance exercises set at individualized repetitions in 30 seconds. Baseline assessment demonstrated that individuals with PD had significantly lower scores on a Sensory Organization Test ($p = 0.03$). However following the intervention, results indicated no statistical difference between individuals with PD and aged match controls ($p > 0.05$). This study indicates that a home-based exercise intervention is an effective method of improving postural control in individuals with PD.

In 2010, Ebersbach and colleagues conducted the Berlin LSVT®BIG study comparing exercise interventions in PD. The specific BIG training was derived from the Lee Silverman Voice Treatment (LSVT®) and focused on intensive high-amplitude exercises. The BIG training was compared to Nordic walking and a home-based programme. Fifty-eight patients with mild to moderate PD were randomly assigned to receive one-on-one BIG training, group training of Nordic Walking, or unsupervised home-based exercises. The home-based group (n=19, mean age 69.3 ± 8.4, mean H&Y stage 2.5 ± 0.7) received a training programme consisting of stretching, high

amplitude movements, as well as active workouts for muscular power and posture for four weeks. Sessions lasted one hour and participants were encourage to exercise regularly. The BIG training group (n=20, mean age 67.1 ± 3.6, mean H&Y stage 2.8 0.37) had 16 hours supervised training for four weeks (~4 sessions per week), whereas the walking group (n=19, mean age 65.5 ± 9.0, mean H&Y stage 2.6 ± 0.4) received 16 hours of supervised training for eight weeks (~two sessions per week). The primary outcome was the Unified Parkinson's Disease Rating Scale (UPDRS) subscale III motor score, assessed from baseline and followed-up at 16 weeks between groups. Results showed significant group differences for UPDRS-motor score at the final assessment with the BIG group performing better than the walking group ($p < 0.001$) and the home-based group ($p < 0.001$). The BIG intervention showed improvements in the timed-up-and-go test ($p = 0.04$ vs. walking group; $p = 0.02$ vs home group) and a timed 10m walking ($p = 0.02$ vs. home group), however there were no significant group differences for QoL ($p = 0.26$). These results provide evidence that intensive high-amplitude movements as seen in BIG intervention is an effective technique to improve motor performance in patients with PD, and that unsupervised home-based exercises were not as effective as exercises with a therapist.

Dereli and Yaliman (2010) also found that a home self-supervised programme was not as effective as a therapist-supervised (i.e. physiotherapist) programme on the QoL of PD individuals. Thirty individuals with idiopathic PD were quasi-randomly located to a therapist-supervised (n=15, mean age 66.5 ± 12.9, mean H&Y stage 2.1 ± 0.6) or home-based exercise programme (n=15, mean age 61.3 ± 9.6, mean H&Y stage 2.1 ± 0.7). The exercise programme consisted of stretching, range of motion, mobility, relaxation, balance and coordination exercises as well as gait and breathing exercises; and was performed for 45 minutes, three times per week for ten weeks, either under the supervision of a physiotherapist or at home without supervision. Patients in the therapist-supervised group improved more than the home-based exercise group in QoL, health profile, UPDRS and Depression scores ($p < 0.05$), even though the home-based group had significant improvements ($p < 0.03$) in disease severity, and social function and Parkinson's symptoms, related to QoL. The therapist-supervised compared to home-based exercise

programme was found to be more effective at improving activities of daily living, motor, mental, emotional functions and general health quality in individuals with PD.

In 2012, Schenkman and colleagues investigated three exercise programmes for individuals with early to mid-stage PD (n = 121; H&Y stages I - III) in a 16-month randomized controlled trial. The purpose of the study was to compare the short- and long-term responses specifically of two different therapist-supervised exercise programmes and a home-based exercise programme. The three exercise programmes investigated were i.e. (1) a flexibility-balance-function programme, specifically designed for individuals with PD that consisted out of individualized flexibility exercises followed by group balance/functional training; (2) a standard aerobic endurance programme using a treadmill, bike, or elliptical trainer; and (3) a home-based programme with exercises recommended by the National Parkinson Foundation, as the control group. The flexibility-balance-function group (n = 39, aged 64.5 ± 10.0 years) and aerobic endurance group (n = 41, aged 63.4 ± 11.2 years) were supervised three times a week for 50 minutes over four months, after which supervision was decreased to once monthly for up to 16 months in total. The control home-based group (n = 41, aged 66.3 ± 10.1 years) was supervised once a month for 16 months. The participants were assessed at 4, 10, and 16 months for the primary outcome measures such as overall physical function, balance and walking economy. Secondary outcome measures were UPDRS disease severity and QoL. Immediately following the four month exercise period, the flexibility-balance-function programme was superior to both the aerobic endurance and home-based programmes for improving overall function ($p < 0.05$). However, the aerobic endurance programme was more beneficial for improving economy of walking at 4, 10, and 16 months ($p < 0.002$). Balance was not different among groups at any time point ($p > 0.05$). The only secondary outcome that showed significant differences was ADL subscale scores of UPDRS for disease severity in which the flexibility-balance-function group performed better than the home-based group at four months ($p = 0.03$) and 16 months ($p = 0.04$). Nevertheless based on the absence of a meaningful decline in any measures over the 16-month period, it appears that the

home-based programme also resulted in some benefits, although to a lesser extent than the therapist-supervised programmes.

In recent years, various pilot or preliminary studies have been conducted to experiment with new techniques, equipment and technologies that would not normally be available at home. Canning and colleagues (2012) did a randomized controlled pilot study to investigate the feasibility and effectiveness of six weeks of home-based treadmill training in individuals with mild PD (H&Y stage I – II) with a six-week intervention followed by a further six weeks follow-up. Seventeen participants with gait disturbance took part; eight (four men, four women) participants were randomly allocated to the experimental treadmill training group and the rest (six men, three women) served as the control, receiving their usual care. The treadmill training group followed a semi-supervised home-based programme (a physiotherapist supervised seven sessions) of treadmill walking for 20–40 minutes, four times a week for six weeks. Additional cognitive or manual tasks during walking were introduced systematically from week four of training, with participants aiming to maintain stride length during dual tasking. Exercise adherence and acceptability, exercise intensity, fatigue, muscle soreness and adverse events were recorded to assess feasibility. The primary outcome measure was walking capacity with six-minute walk test. Results from this study show that semi-supervised home-based treadmill training was feasible, acceptable and safe with participants completing 78% of the prescribed training sessions. The treadmill training group did however not improve their walking capacity compared to the control group, but showed a greater improvement than the control group in fatigue at post-test ($p = 0.04$) and in QoL at six weeks follow-up testing ($p = 0.02$). This study shows that home-based treadmill training can lead to improvements above normal care when a therapist is intermittently present.

A pilot study in 2012 by Esculier evaluate the effects of a home-based balance training programme, using the Nintendo Wii Fit game with balance board, on balance and functional abilities in individuals with PD compared to healthy participants. The Wii fit games offer a range of fun balance training games while continuously providing visual feedback. Ten participants with

moderate PD (mean age 61.9 ± 11.0; H&Y stage not reported) and eight healthy aged-matched participants (mean age 63.5 ± 12.0) volunteered for this self-supervised six-week home-based balance training programme which consisted of 40 minute sessions for three days of a week. Measurements taken include Sit-to-Stand test, Timed-Up-and-Go, Tinetti Performance Oriented Mobility Assessment, 10-m walk test, Community Balance and Mobility assessment, Activities-specific Balance Confidence (ABC) scale, single leg stance duration, and a force platform measurement. All measurements were taken at baseline and after three and six weeks of training. The PD group significantly improved their results in all measures ($p < 0.05$) except the ABC scale at the end of the six-week training programme. The healthy subjects group significantly improved in Sit-to-Stand test, Timed-Up-and-Go, single leg stance duration and Community Balance and Mobility assessment ($p < 0.05$). This pilot study suggests that a home-based balance programme using Wii Fit with balance board could improve static and dynamic balance, mobility and functional abilities of people affected by PD.

Masters research by the University of Western Ontario (Canada) in 2012 investigated the effectiveness of a twelve-week home-based unsupervised exercise programme designed around the Wii (Gu *et al*., 2012). The Wii fit intervention consisted of balance training only, in which 15 individuals with PD (aged 58 – 75 years, H&Y stage II – III) had to complete 30 minutes of Wii activities for twelve weeks, three times a week. Static balance was assessed with a force plate in four quiet standing conditions of varying difficulty as well as a balance confidence survey at baseline, six and twelve weeks. Results suggest there might be an improvement in balance and balance confidence, but changes were not significant for either ($p > 0.05$). Good adherence were recorded with participants averaging 23.16 minutes of play per session. Possible reasons for not finding significant changes were attributed to the duration of activity as well as the type of activities permitted, but this study shows that an interactive home-based programme with a Wii is an exercise programme that individuals can adhere to.

In light of these positive findings in the preliminary studies further investigation regarding the effectiveness of home-based training is warranted.

A recent home-based exercise study (2015) by Canning and Colleagues determined the efficacy and cost-effectiveness of a six-month minimally-supervised exercise programme targeting potentially remediable fall risk factors. The study included 231 community dwelling individuals with PD (aged 71 ± 9 years between 41–91 years) were randomised into a home-based exercise or usual care control group for a 6-month intervention period. This programme included 40–60 minutes of progressive balance and lower limb strengthening exercises 3 times per week for 6 months; and cueing strategies to reduce freezing of gait for participants reporting freezing. On average, 13% of the exercise sessions were supervised by a physiotherapist either at home or in an exercise group; the remaining exercise sessions was performed independently at home. Results show that there were no overall significant differences in fall rates ($p = 0.18$) or proportion of fallers ($p = 0.45$) between the exercise and control groups. However they did find that individuals with lower disease severity had significantly fewer falls than those within the control group ($p < 0.01$). Individuals with higher disease severity had a non-significant increase in falls in the exercise group ($p = 0.13$). This study shows that minimally-supervised exercise can prevent falls and is cost-effective in people with mild but not more severe PD.

King and Colleagues (2015) recently did a comparative study of different exercise interventions to see if the method of *how* the exercises are presented makes a different in the outcomes. They compared home-based exercises with individual session with a therapist and group classes with a therapist. Randomization of the 58, predominantly female, PD individuals who volunteered led to 17 individuals being allocated to the home-based intervention (aged 64.6 ± 6.8 years, H&Y stage 2.5 ± 0.5), 21 individuals were allocated to individual sessions (aged 64.2 ± 6.7 years, H&Y stage 2.4 ± 0.5), and 20 individuals were allocated to the group class intervention (63.9 ± 8.5 years, H&Y stage 2.4 ± 0.5). All intervention were standardized and based on the Agility Boot Camp for PD, which consisted of six stations: Tai chi, boxing, lunges, kayaking, Pilates and agility

course. Each station had three different progression levels, such as added or alternating sensory information, restricting external cues, increasing speed or resistance, or adding a secondary task. Each intervention had to follow the 60 minute programme three times a week for four weeks, and only the home-based group did not receive any progressions in exercises. The primary outcome for the study was physical performance, with secondary measures including balance, gait, balance confidence, depression, apathy, and disease severity-linked motor symptoms and activities of daily living. Results showed that only the group doing individual session with a therapist improved their physical performance ($p < 0.01$), as well as apathy, depression and self-efficacy ($p < 0.05$). The home-based group ($p = 0.01$) and the individuals group ($p < 0.01$) both had improvements in balance (Mini-BESTest), and both the home-based group and class group had an improvement in QoL ($p < 0.02$). The individual group and the class group both had significant improvements in UPDRS-ADL, balance confidence, arm swing and trunk velocity. Only the group class had significant improvements in gait including less FoG and stride time variability, and greater stride velocity. This study showed that home-based exercise was the least effective although it still led to improvements in balance and QoL. Therapist-supervised intervention, individual or group, were more effective in improving outcome measures than the same intervention performed at home.

The previously reported research indicate that more comparative investigations are needed to confirm the benefits of home-based compared to therapist-supervised exercise programmes, especially for balance training.

2.4 Problem Statement

The following section summarizes the research problem and identifies the research questions.

2.4.1 The Problem in Context

The global trend in rising life expectancy and the aging population poses a critical public health problem. Age is the greatest risk factor for the development of neurodegenerative disorders such as PD, which is the second most common neurological disorder after Alzheimer's disease (Kalia & Lang, 2015; Okubadejo *et al*., 2006). Dorsey *et al*. (2007) predicted that by 2030 the number of people with PD would increase by more than half.

In PD difficulty with dynamic balance is associated with gait dysfunction including FOG, which relates to poor mobility as well as falls, serious injuries, anxiety, depression, apathy and reduced QoL (Šumec *et al*., 2015). More so reduced dynamic balance and mobility more likely means a loss of independence for individuals with PD. Consequently, poor dynamic balance is considered one the most disabling symptoms of Parkinson's disease and relevant focus areas for rehabilitation treatments (Nisenzon *et al*., 2011).

Unfortunately medication and surgical treatments are insufficient in treating motor impairments such as dynamic balance and mobility problems in individuals with PD (Bloem *et al*., 2015). Exercise on the other hand has been advocated as a possible non-pharmacological intervention for individuals with PD, especially for mobility and balance related problems (Abbruzzese *et al*., 2015; Bloem *et al*., 2015; Šumec *et al*., 2015; van der Kolk & King, 2013). However, another aspect to consider is that not all people or communities in developing countries such as South Africa can afford a qualified exercise specialist.

Accordingly the motivation for this study was to see whether a home-delivered balance training programme is also effective in improving dynamic balance when compared to training with a qualified exercise specialist. Given the high incidence of fall-related injuries within this population,

it is vital to implement on-going assessment of postural stability as well as non-pharmacological interventions for disease management and improved quality of life.

Of the 14 studies that investigated home-based training for PD, only eight studies included balance training in their intervention (Lun *et al*., 2005; Ashburn *et al*., 2006, Dereli & Yaliman, 2010; Esculier *et al*., 2012; Schenkman *et al*., 2012; Gu, 2012; Canning etal., 2015; King *et al*., 2015). Only two of these abovementioned eight studies exclusively focused on balance interventions, although Esculier *et al* (2012) and Gu (2012) trained balance using the Wii fit balance training. Eight of the 14 studies measured dynamic balance gait and mobility as an outcome variable (Caglar *et al*., 2005; Lun *et al*., 2005; Nieuwboer *et al*., 2007; Ebersbach *et al*., 2010; Canning *et al*., 2012; Esculier *et al*., 2012; Schenkman *et al*., 2012; King *et al*., 2015). To date only five of the 14 studies specifically set out to compare home-based with therapist-supervised interventions in PD; Lun and Colleagues (2005) focused on motor functions changes, Dereli and Yaliman (2010) looked at QoL and depression, Ebersbach *et al*. (2010) specifically investigated gait and dynamic balance, Schenkman and colleagues (2012) looked at short- and long-term effects on walking capacity, overall function and balance, and King *et al*. (2015) investigated physical performance, gait and non-motor symptoms.

Only Lun *et al*. (2005), Schenkman *et al*. (2012) and King *et al*. (2015) included some form of balance training as part of their intervention; tested for gait and mobility as an outcome variable and compared home-based training to therapist-supervised training, but Schenkman compared different exercise interventions, not just different exercise delivery methods. These three studies ranged from 19 to 121 participants, between the ages of 40 to 86 years and included individuals with mild to moderate PD (H&Y stage I to III). All of the investigations assessed participants on their regular medication. Interventions took place for 2 - 4 sessions per week over 4 - 16 weeks, with longest follow-up period being 16 months after intervention, and ranged from 40-60 minutes per session. Kin *et al* (2015) was the only study that used sensory cues as part of their intervention; they altered or limited external cues as a progression of exercises. Only one study

(Lun *et al*., 2005) showed that a home-based intervention can be just as effective as a therapist-supervised intervention, whereas the other two showed the therapist-supervised training to be better. This indicates that there is a need to explore alternative exercise interventions such as home-based balance interventions to improve dynamic balance impairments, specifically relating to gait and mobility.

2.4.2 Aims and Objectives

The main aim of this study was to compare an eight-week home-based balance training programme to an equivalent therapist-supervised programme on the dynamic balance of independent-living individuals with Parkinson's disease. A secondary aim was to determine if the eight-week balance training programme improved perceived fall risk and balance confidence

For the purposes of this study independent-living individuals were defined as individuals who are able to lead an independent life without the need for help with most activities of daily living. Categorized typically Hoehn & Yahr stages III and lower, excluding stages IV & V (Sabari *et al*., 2014).

The study objectives were to assess the following changes pre and post-interventions in the two training groups i.e. on:

i. single task dynamic balance and mobility with instrumented Timed-Up-and-Go test, i.e. gait parameters such as stride length, stride velocity, cadence, time in double support, turning duration, turning velocity and turn-to-sit duration (Article 1 & 3)
ii. dual task dynamic balance and mobility with instrumented Timed-Up-and-Go test (Article 2)
iii. freezing of gait with FOG questionnaire (Article 3)
iv. perceived fall risk and balance confidence (Article 1 & 2)
v. participant's perception of exercise programmes (Article 1)

The study set out to compare two different exercise interventions, i.e. TS and HB, for individuals with PD. I hypothesized that the Therapist-supervised group (TS) will be better than Home-based group (HB), in terms of improved gait and mobility variables after the eight week intervention.

2.4.3 Variables

Dependent variable:

- Dynamic balance: sequential gait movements, such as cadence, double support, total time, duration of turn to sit and duration of turn (ITUG & FGA).
- Freezing of gait (Questionnaire)
- Gait during dual-tasking (CTUG)
- Fall risk and balance confidence (Questionnaires)
- Disease severity (MDS-UPDRS)
- Motivation (IMI)

Independent variable:

- 8-week self-supervised balance training programme
- 8-week therapist-supervised balance training programme

Categorical variable: Gender, age, disease stage, most affected side, medication.

Chapter 3

Study/Article 1:

Balance training in individual's with Parkinson's disease: Therapist-supervised vs. Home-based exercise programmes

Abstract

Background: Poor locomotion and balance in Parkinson's disease (PD) often diminishes independence. Accordingly gait is considered to be one of the most relevant rehabilitation outcomes, and home-based balance exercises might be a viable mode of exercise delivery for individuals with PD. However research on PD exercise interventions rarely indicate best practices to deliver exercises. Therefore this study endeavoured to compare the efficacy of a home-based balance programme to therapist-supervised programme on gait parameters, dynamic balance, balance confidence and motivation in individuals diagnosed with PD.

Methods: An experimental study design, including a cluster randomized convenience sample, of 40 participants with idiopathic PD (Hoehn and Yahr stage I–III; age: 65.0±7.7 years). Participants were divided into a Therapist-supervised group (n=24) and Home-based group (n=16). Groups received eight weeks of balance training with either an exercise therapist or via a DVD. Outcome measures include the instrumented Timed-Up-and-Go, Functional Gait Analysis (FGA), Activity-specific Balance confidence (ABC) scale and Intrinsic Motivation Inventory (IMI).

Results: Both groups improved their average stride length ($p<0.05$). Similar FGA improved by 9% and 16% in the Therapist-supervised and Home-based group, respectively ($p<0.01$). Only Therapist-supervised group showed improvements in ABC ($p=0.051$), stride velocity ($p=0.0006$) and cadence ($p=0.046$) over the 8-week study period; the latter two were also better compared to Home-based ($p<0.05$). Post-test revealed that Therapist-supervised group had more motivation ($p=002$).

Conclusion: The Home-based balance programme was effective in improving some aspects of gait, albeit the programme supervised by an exercise therapist included somewhat more benefits after the intervention with stride velocity and cadence in individuals with mild to moderate PD.

Keywords: Dynamic balance; Gait; Parkinson's disease; Balance training; Exercise delivery

3.1 Introduction

Postural control, relating to gait, balance and posture, progressively declines with Parkinson's disease (PD), coupled with an increased fall risk [1-4] which is the largest contributor to health care costs [5]. Abnormal sensory integration within the basal ganglia, poor neuromuscular coordination and muscle tone may in part be the reasons for postural instability and reduced mobility [1]. This increased postural instability is considered one of the most incapacitating symptoms that directly threaten independent living [3] and promotes an inactive lifestyle. Adding to this postural instability is the characteristic "stooped" PD posture together with decreased joint range of motion, narrow foot stance and axial rigidity [6]. Consequently individuals with PD are exposed to a vicious cycle of inactivity that further contributes to the deterioration in balance, locomotion and activities of daily living which reduces quality of life (QoL).

Dopaminergic medication and surgical interventions poorly regulates dynamic postural control; therefore other non-pharmacological interventions need to be explored [1,7]. One such non-pharmacological option especially for gait, balance and posture impairments is exercise and physical therapy [7-10]. Research demonstrate numerous beneficial findings for all stages of PD [11] including improvements in muscle strength and endurance, stability and balance, gait, motor performance axial rigidity and depression [12]. Other benefits associated with exercise include improvement in QoL, independence, cognition and daily functioning [13-15]. Despite these benefits, many of these advantages may be short-lived due to the progressive nature of PD [15-17], as well as the lack of exercise adherence and motivation [18,19].

Balance training, in particular, has received a considerable amount of attention as a successful method to enhance mobility and independence [14]. Comparatively exercise prescription under the supervision of a therapist has shown promising results [20-23]. Nevertheless, it is not always possible for PD individuals to exercise under the supervised care of a qualified exercise therapist mainly due to cost and travel constraints, as well as personal choice. To date, few clinical trials have compared home-based, specifically balance-related exercise

programmes, to therapist-supervised training [15,20,24-29]. To our knowledge, most studies have either compared home-based balance training to a non-exercising control group [26]; or have combined balance with strength training [24,29], but very few studies have compared progressive balance training exclusively.

Consequently, further investigation of alternative methods of exercise delivery, as in the case of enabling individuals with PD to exercise independently at home, is needed. The advantages of home-based balance training would include affordability and convenience. Thus, the main aim of this study was to investigate the efficacy of a home-based balance programme in comparison to a therapist-supervised balance programme on selected gait parameters, dynamic balance and balance confidence in individuals with mild to moderate PD.

3.2 Methods

3.2.1 Study design

This was an experimental study design with a sample of convenience which made use of two experimental comparison groups i.e. one being the Therapist-supervised and the other a Home-based group. Sample size was determined as the number of participants necessary to reach a statistical power of 80% (α = 0.05), with an estimated moderate effect size (d = 0.50). Cluster randomization was used, via the CHIT method, to determine which geographical area would receive the Therapist-supervised and Home-based interventions, with an initial allocation ratio of 30:27 (Therapist-supervised: Home-based).

3.2.2 Participants

Ultimately forty participants with confirmed idiopathic PD participated. Participants were recruited through advertisements at support group meetings, local newspaper articles, as well as

an established database of participants. Volunteers were screened according to the inclusion and exclusion criteria (Table 3.1). Participants provided written informed consent before the start of the study (Addendum A). The study was approved by the Institutional Review Board and Research Ethics Committee (HS1061/2014).

Table 3.1: Inclusion and Exclusion Criteria of Participants

Inclusion Criteria		
General	Ages between 50-80 years Mild to moderate PD (H&Y: I – III), confirmed by neurologist Adequate functional status (perform sit-to-stand and tandem stance) No to mild cognitive impairments (MoCA score > 17 Hoops et al., 2009)	
Group specific	*Therapist-supervised* Transport to and from exercise hall	*Home-based* Access to a DVD player i.e. television or computer Caregiver for assistance with no formal physical or exercise therapy training
Exclusion Criteria		
General	Other neurological conditions other than PD (e.g. Diabetes, stroke) Uncorrectable visual or vestibular problems Any orthopaedic, especially involving lower extremities, or muscular injuries in the previous six months preceding the study Change in medication 4 weeks before the study Adverse side-effects due to medication	
Group specific	*Therapist-supervised* attend at least 70% and participate in two out of the three exercise session per week	*Home-based* had to complete programme in 8 weeks

PD: Parkinson's disease; H&Y: Hoehn and Yahn stage of Parkinson's disease severity; MoCA: Montreal Cognitive Assessment

3.2.3 Procedure

The Therapist-supervised group underwent an 8-week balance training programme and the Home-based group followed the exact same programme with a DVD and their caregiver. Both

groups were assessed before and after their respective 8-week training programmes, by the same assessor. They were assessed during the ON phase, at the same time of day, to ensure they were in the same medicated state for each testing, and at the same place i.e. their homes. Testing venues had to have at least 7m of solid flat surface with good lighting, and Zampieri *et al*. (2010) showed that ITUG testing in a home environment is feasible. This was a single-blinded study, where the asssesors were not blinded but participants. Hence participants were not told the true aim of the study.

3.2.4 Intervention

All participants completed three 40 to 60 minute sessions per week which progressively increased in difficulty (from postural alignment → static → dynamic → functional activities) over the eight weeks. Exercises sessions consisted of 10-minute warm-ups, followed by 15 to 40 minutes of balance training, and finally 10-minute cool-down with relaxation techniques (Addendum C). Simulation, guidance and physical somatosensory (tactile and proprioceptive) feedback were given by the exercise therapist or caregiver i.e. verbal and tactile cues like feeling one's bodyweight shifting from the left to the right side before initiating gait. Research has shown that adding tactile cues in PD improves somatosensory feedback and postural stability even with proprioceptive deficits [31-34].

Participants in the Home-based (with caregiver) group received eight DVD's (See example DVD in Addendum D) with clear instructions, including tactile and verbal cues, and safety guidelines. The Therapist-supervised group attended group sessions with about four to eight other individuals, led by a qualified clinical exercise therapist (registered by the South African Health Professions Council), at either a scout or church hall. The lighting, area and surfaces (solid flat surface, not on carpets) were similar in both venues, and sessions only took place between 09:00 and 11:00 Monday to Fridays.

3.2.5 Evaluations

Primary outcome variables were gait and dynamic balance, which were assessed with the modified instrumented Timed-Up-and-Go (ITUG) and functional gait analysis (FGA). Secondary outcome variables included perceived balance confidence assessed by the Activity-specific Balance Confidence (ABC) scale (Addendum G) and intrinsic motivation with the Intrinsic Motivation Inventory (IMI) questionnaire (Addendum J). Main outcome variables were assessed before and after the interventions.

During the pretesting, participants' anthropometrical data (body mass (kg) and stature (m)), medical as well as personal information were collected prior to assessing balance-related outcomes. For descriptive purposes disease severity was determined with modified Hoehn and Yahr (H&Y) staging and the Movement Disorder Society-Unified Parkinson's Disease Rating Scale (MDS – UPDRS) motor subscale III. In addition cognitive function was assessed with the Montreal Cognitive Assessment.

To assess balance and gait participants completed three ITUG (Mobility Lab^{TM}, APDM®, USA) and a FGA by the same qualified clinical exercise therapist. The Mobility Lab^{TM} consists out of four tri-axial accelerometers with a gyroscope, which automatically processes input signals at (90Hz) and provided objective measures of gait parameters. The ITUG has been established as a sensitive and reliable mobility assessment tool in PD ($p > 0.75$) for most spatial and temporal measures, specifically the subcomponents gait, turning and turn-to-sit [35]. After recording the accelerometer data, it was exported into Excel (Microsoft®, USA). Participants were instructed to stand up from a chair, walk 7m, turn, and walk back and sit down again at their comfortable walking pace [36]. One practice trial and then two assessment trails were recorded and the averages of the two assesments were used for data analysis. During the ITUG duration (total time), double support (DS), stride length (SL), stride velocity (SV) and cadence was assessed. Cadence, SL and SV have been reported as the most sensitive gait parameters in PD individuals [35,37]. Baltadjieva *et al*. (2006) found total time and DS duration to correlate with dynamic balance [38].

Mean SL and SV were normalized as a percentage of the participant's stature. Duration and DS were expressed in seconds, and cadence as steps per minute. Both SL and SV data were recorded for the left and right leg which was then grouped into affected and unaffected sides as reported in questionnaires, and further analysed. If participants did not have a recognized affected side or if both sides were affected their mean score was added to affected side.

Gait variability, as determined by percentage coefficient of variance (CV), of spatiotemporal parameters is a good predictor of freezing of gait and fall risk [39,40]. Gait variability is calculated as: CV = SD / mean x 100 (41).

The 10-item FGA is a walking-based balance test, which has been found to be reliable to assess dynamic balance in PD and elderly individuals (42; 43). In PD specifically Leddy *et al*. (2011) reported test-retest reliability of 0 .91 interrater reliability greater than 0.93 [42]. The test has a maximum score of 30 (with a higher score signifying better balance) and includes walking forward, backward, with eyes closed, stepping over obstacles, changing gait speeds, with different head turns, and with a narrow base of support.

The 16-item self-perceived ABC questionnaire quantifies an individual's perceived ability to maintain balance under different circumstances on a scale of 0 – 100. The highest score indicates full confidence in balance abilities. The ABC scale has been found to have excellent test-retest reliability (ICC = 0.92-0.99) [44]. It has been shown to correlate with postural instability (R^2 = 0.81, $p < 0.01$) [45] and is predictive of falls (Odds ratio = 0.05, $p = 0.013$) [46] in individuals with PD.

The intrinsic motivation inventory (IMI) is a questionnaire used to measure motivation and perceptions following a specific task [47]. The IMI includes five subscales to tests the degree of motivation of a participant; subscales include interest/enjoyment, perceived competence, effort/Importance, pressure/tension and value/usefulness [48,49].

3.2.6 Statistical Analysis

Descriptive statistics are reported as mean ($\bar{x}$), range, 95% confidence intervals (CI) and standard deviation (± SD), unless otherwise specified. Data was assessed for normality with a Shapiro-Wilks test. A Mann-Whitney U test and Kruskal-Wallis were used for non-parametric ordinal data. All outcome variables were tested for differences at pre-tests between the two groups. A repeated measures analysis of variance was used for comparison between the two experimental groups' gait and balance parameters as well as balance confidence with respect to time (from pre- to post-intervention). Further analysis was performed through post-hoc comparisons in accordance with Fisher Exact LSD procedure, as well as Cohen's effect sizes for practical significance, with 0.2 equals small, 0.5 indicates medium and 0.8 equals large effect [50]. All statistical analyses were performed using Excel® (Microsoft Office, USA) and Statistica® software (version 12, StatSoft, Inc., Tulsa, OK, USA) for Windows, with an alpha level set greater than 0.05.

3.3 Results

Eighty PD individuals volunteered to participate in this study of which only 57 met the inclusion and exclusion criteria. Of the 30 participants assigned to the Therapist-supervised group, four did not complete the 8-week intervention with sufficient attendance (< 70%), one sustained an injury at home and another changed medications and suffered subsequent falls at home. Of the 27 participants assigned to the Home-based group, five participants attended less than 70% of the sessions due to time constraints, a family crisis, or unavailability of their caregiver, four participants suffered injuries unrelated to the intervention and two withdrew due to work-related time constraints. Of the 40 participants included for statistical analysis, 17 (70.8%) in the Therapist-supervised group and 15 (93.8%) in the Home-based group used Cabilev during the course of the study. The demographic and anthropometric characteristics of the two groups are summarized in Table 3.2.

Table 3.2 Descriptive characteristics of participants (n = 40; $\bar{x}$ ± SD).

	TS (n= 24)		**HB** (n = 16)		
Variables	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**p-Values**
Gender M (%)	15 (62.5%)		14 (87.5%)		
Age (yrs)	65.0 ± 8.2	50 - 79	65.0 ± 7.1	55 - 78	0.97
Body mass (kg)	80.0 ± 17.1	52.0 - 126.7	78.7 ± 12.7	48.7 - 97.1	0.79
Stature (m)	1.7 ± 0.1	1.5 - 1.9	1.7 ± 0.1	1.5 - 1.9	0.03
BMI (kg.m-2)	28.6 ± 6.0	21.1 - 43.6	25.8 ± 3.0	18.1 - 32.4	0.07
MoCA	25.8 ± 2.5	20 - 30	25.8 ± 2.3	21 - 30	0.95
Years diagnosed	3.5 ± 3.7	0 - 14	7.3 ± 10.5	0 - 44	0.19
MDS-UPDRS III	31.1 ± 12.8	10 - 56	35.9 ± 12.8	17 - 63	0.25
H&Y stage	2.4 ± 0.4	1.5 - 3	2.5 ± 0.5	1.5 - 3	0.53

$p \leq 0.05$ → significant difference; MDS-UPDRS: Unified Parkinson's Disease Rating Scale; H&Y: Hoehn & Yahr; M: Men; BMI: Body Mass Index; Yrs: years, MoCA: Montreal Cognitive Assessment; TS: Therapist-supervised; HB: Home-based

3.3.1 Gait parameters

For the ITUG, there was a significant treatment (TIME x GROUP) effect found for cadence (p = 0.047) with the Therapist-supervised group differing significantly. In addition no treatment effect was observed for duration, SL, and DS (p > 0.05). Groups did not differ at pre-tests (p > 0.05) in any of the gait variables. However for duration there was 18% difference ($d = 0.57^{M}$) but it was not statistically significant (p = 0.10).

Both groups had a significant improvement in mean SL, with Therapist-supervised improving with 5.9% ($d = 0.52^{M}$, p = 0.001) and Home-based improving with 4.29% (p = 0.041). As seen in Table 3.3 the Therapist-supervised group had significant improvements in SV and cadence, which lead to 7.6% difference between groups at post-test for stride velocity ($d = 0.48^{M}$, p = 0.0006) and a 5.6% difference in cadence ($d = 0.68^{M}$, p = 0.046). Neither groups improved significantly in time in double support (p > 0.05). Therapist-supervised group decreased DS time by

6.4% (d = 0.27^{S}, p = 0.095) while Home-based only decreased by a negligible 2.6%, causing a non-significant difference in the groups at post-test of 6.7% (d = 0.30^{S}, p = 0.46).

Significant treatment effects were observed in gait variability for SL, SV, cadence and time in DS (p < 0.007). Only the Therapist-supervised group showed significant improvements over time with a reduction in gait variability for SL and SV, the latter causing a difference between post-tests of Therapist-supervised and Home-based (p = 0.017).

Additional analysis, in which unilateral impairment data was split into affected (Therapist-supervised: n = 24; Home-based: n = 16) and unaffected (Therapist-supervised: n = 23; Home-based: n = 11) revealed that there was no significant treatment effect for SL or SV for affected and unaffected sides over the intervention, and also no treatment effect for the differences between affected and unaffected sides (p > 0.05). Participants' SL and SV on both sides followed the same pattern of change over time (Table 3.3). The Therapist-supervised group improved significantly in SL of affected side (d = 0.52M) and unaffected side (d = 0.46M), as well as SV on the affected side (d = 0.48M) and unaffected side (d = 0.44M) (p < 0.01). The Home-based group only had an improvement in the affected side's SL (d = 0.44M, p = 0.048).

Table 3.3 Gait parameters from pre and post ITUG, (n = 40; $\bar{x}$ ± SD).

Variables	Within groups		Between groups			
	TS	HB	ES		*p* -	Treatment
	Δ over time	Δ over time	(% difference)		Values	effect
ITUG Duration (seconds)						
Mean ± SD	0.14 ± 0.91	-0.07 ± 3.65	Pre-test:	0.57^{M} (17.74)	0.10§	
95% CI	-0.70 - 0.86	-0.88 - 1.03				0.99
CV (%)	1.56	2.50	Post-test:	0.54^{M} (17.84)	0.11§	
ES (% difference)	0.03^{N} (0.4)	0.01^{N} (0.3)				
p-value	0.83	0.87				
SL (% of stature)						
Mean ± SD	4.19 ± 2.44	3.00 ± 4.26	Pre-test:	0.07^{N} (0.93)	0.83	
95% CI	-.6.47 - -1.91	-5.79 - -0.21				0.52§
CV (%)	-4.5	-0.38	Post-test:	0.21^{S} (2.56)	0.56	
ES (% difference)	0.51^{M} (5.9)	0.26^{S} (4.3)				
p-value	0.001§	0.04				
SV (% of stature/s)						
Mean ± SD	4.69 ± 3.21	1.24 ± 5.32	Pre-test:	0.11^{N} (1.99)	0.74	
95% CI	-7.80 - -2.42	-4.53 - 2.05				0.08§
CV (%)	-3.88	-1.94	Post-test:	0.45^{M} (7.62)	0.21§	
ES (% difference)	0.47^{M} (7.7)	0.09^{N} (1.9)				
p-value	0.001§	0.46				
Cadence (steps/minute)						
Mean ± SD	2.82 ± 2.88	-1.66 ± 4.13	Pre-test:	0.14^{N} (1.46)	0.64	
95% CI	-5.77 - -0.09	-1.82 - 5.15				0.05§
CV (%)	0.11	-5.41	Post-test:	0.68^{M} (5.56)	0.08§	
ES (% difference)	0.30^{S} (2.6)	0.15^{S} (1.5)				
p-value	0.05	0.34				
Time in double support (s)						
Mean ± SD	-1.53 ± 1.62	-0.60 ± 2.49	Pre-test:	0.09^{N} (2.74)	0.75	
95% CI	-0.28 - 3.21	-1.53 - 2.74				0.53§
CV (%)	-4.22	-11.78	Post-test:	0.30^{S} (6.72)	0.46	
ES (% difference)	0.27^{S} (6.4)	0.09^{N} (2.6)				
p-value	0.10	0.57				

ES: Cohen's d effect sizes (N = negligible, S = small, M = medium); CI: Confidence intervals; SL: Stride length; SV: Stride velocity; s: seconds; SD: Standard deviation; CV: Coefficient of Variance; $p < 0.05$ → statistically significant difference TS: Therapist-supervised; HB: Home-based.

§ indicates significant diffrences in gait variability, measured by CV.

3.2.2 Dynamic balance

In Figure 3.1 the FGA presented no treatment effect (p = 0.14). Groups did not differ from each other (p = 0.51) at pre- or post-intervention, however both groups improved significantly over time, with Therapist-supervised improving by 9.2% (p = 0.0001; *d* = 0.40[M]) and Home-based group by 19.1% (p = 0.00001; *d* = 0.60[M]).

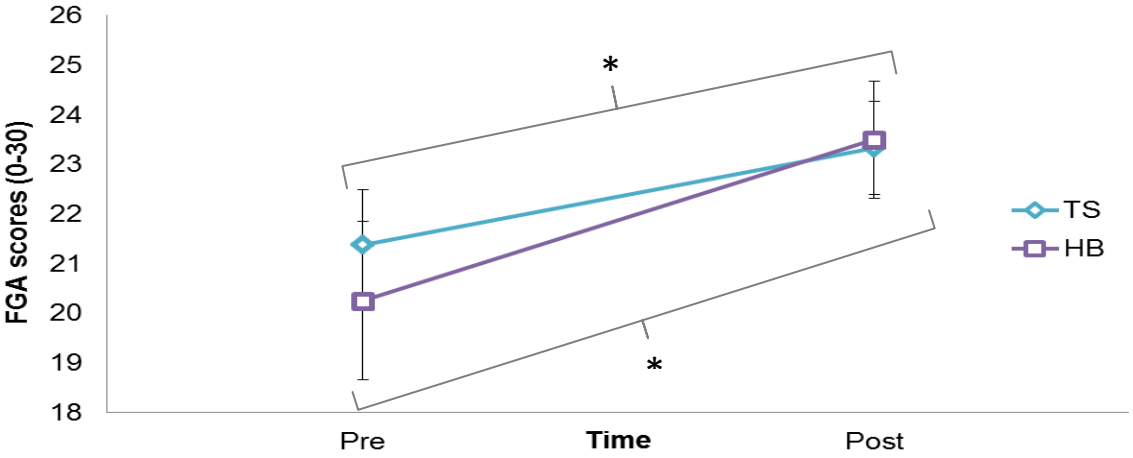

Figure 3.1 The change in dynamic balance and gait over the 8 -week intervention for both home-based (HB) and therapist-supervised (TS) groups ($\bar{x}$ ± SEM). ICC = 0.99; *p = 0.05

3.3.3 Balance Confidence

There was no significant treatment effect (p = 0.73; Figure 3.2). Groups differed by 10% (*d* = 0.41[M], p = 0.13) at pre-test and with 12% (*d* = 0.53[M], p = 0.20) at post-intervention, albeit this was not significant. While the Home-based group did not change over time (p = 0.20; *d* = 0.17[S]), the Therapist-supervised group did improve by 7% (p = 0.051; *d* = 0.34[S]).

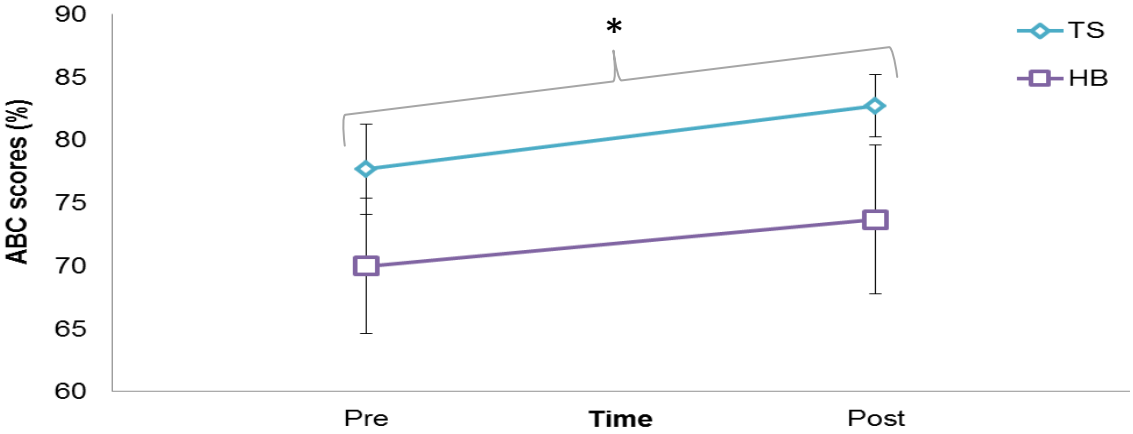

Figure 3.2 The change in balance confidence over the 8-week interventions for both home based (HB) and Therapist-supervised (TS) groups ($\bar{x}$ ± SEM). *p = 0.05

3.2.4 Intrinsic Motivation

Data revealed that both groups had no difference in intrinsic motivation (Table 3.4), except for the Therapist-supervised score who scored significantly higher in Interest/Enjoyment subscale than the Home-based group (17%, p = 0.002).

Table 3.4 Intrinsic Motivation recorded after intervention for Therapist-supervised and Home-based groups

IMI Subscale	**TS**	**HB**	***p - Value (% difference)***
Interest/Enjoyment			
Mean ± SD	6.5 ± 0.6	5.3 ± 1.2	p = 0.002 (17%)
Percentage of Mean	92%	75%	
Perceived Competence			
Mean ± SD	4.9 ± 0.8	4 ± 1.5	p = 0.38 (1%)
Percentage of Mean	70%	71%	
Effort/Importance			
Mean ± SD	5 ± 0.7	5.8 ± 1.1	p = 0.73 (4%)
Percentage of Mean	86%	82%	
Pressure/Tension			
Mean ± SD	2.6 ± 1.2	2.3 ± 1.4	p = 0.31 (6%)
Range	1 - 5.3	0.5 - 5.3	
Value/Usefulness			
Mean ± SD	6.5 ± 0.8	6.2 ± 1.1	p = 0.19 (6%)
Range	3 -7	3 - 7	

TS: Therapist-supervised; HB: Home-based, SD: Standard deviation; CV: Coefficient of Variance;

p < 0.05 statistically significant difference.

3.4 Discussion

The main findings from this study suggest that both modes of balance training may lead to improvements in mobility and dynamic balance, possibly more so for the Therapist-supervised group.

The Home-based group had significant improvements in FGA and SL. However the Therapist-supervised group had significant improvements in all outcome measures except time in

DS. The Therapist-supervised group had a decrease in variability of SL and SV. Groups differed significantly in cadence variability at post-tests. Only the Therapist-supervised group had a significant improvement in balance confidence. Both groups showed good motivation, but Therapist-supervised group enjoyed the intervention significantly more than the Home-based group.

Groups did not differ at pre-test except for stature. On closer inspection of the data it shows the Home-based group have an average height of 1.74m ± 0.08m compared to the 1.68m ± 0.11m for the Therapist-supervised group. This height discrepancy may have resulted in the Home-based group's BMI showing a tendency to differ. Fjeldstad *et al*. (2007) showed that obesity in middle-ages and older adults correlates with postural instability, and might increase fall risk [51;52]. Fjeldstad *et al*. (2007) only tested healthy elderly people and perhaps this relationship between BMI and instability is even more sensitive or exaggerated in PD individuals, who already have impaired balance. Hue *et al*., (2007) suggest that the sensitivity of mechanoreceptors might be reduced in overweight healthy people, which might additionally contribute to impaired load response and proprioception of PD individual's musculature [51].

Mobility and SL improved in both groups over the eight weeks, indicating that the balance training programme presented by either a therapist or on a DVD was successful. The somatosensory cues utilized with the balance training may explain these improvements. These cues helped to simulate the somatosensory cortex and to bypass the defective basal ganglia, and, it is postulated, instead activate the pre-motor cortex which is still intact [33]. Furthermore, the use of systematic visual deprivation and intermittent tactile feedback might have forced PD individuals to be less visually dependant and increase their somatosensory integration; especially for the more modereately affected individuals as suggested by Vitorio and colleagues in 2012 [53].

Dewey *et al*. (2014) found that as PD progresses gait is most influenced by SL giving rise to the typical PD shuffling [36]. In the current study this was the one gait parameter which improved in

both groups, which is an important finding. Shuffling results in greater fall risk, more so than the decrease in SV or the change in cadence [36]. The shorter SL in individuals with moderate PD might be influenced by generalized bradykinesia [30], incorrect muscle activation and weakness [1], impaired proprioception and balance [54]. Resultant trunk rigidity, along with basal ganglia dysfunction, leads to problems with normal automatic bipedal coordination when walking [1,30], including a short SL. Yang and colleagues (2008) showed a correlation between SL and balance as well as coordination [54]. Comparable Yang *et al*. (2008) found reduction in SL correlates with PD disease severity motor symptoms, mobility and balance [54], and is also related to decrease functional range of motion in the ankle and hip [55]. Thus the improved SL found in both groups may have been the contributing factor to improved dynamic balance.

Roiz *et al*. (2010) also found that SV correlates with mobility [55]. Only the Therapist-supervised group improved in SV and cadence over the intervention. Several recent studies has showed that cadence control in PD individuals remain intact [55-57], and that fluctuation in cadence usually occur with individuals who experience freezing of gait, or perhaps in the very early stages of the disease when SL is not affected yet but SV is.

The results from the gait parameters in this study suggest that both groups where able to walk with bigger and faster steps (although Home-based was not significant). Roiz *et al*. (2010) explained that SL and SV are related to one another therefore improvement in one can explain improvement in the other. For instance a longer stride length may also arguably improve control of centre of gravity displacement, which has a strong to moderate correlation between walking speed and aspects of balance, such as the speed, extent and quality of centre of gravity displacement [54]. It may be speculated that the faster PD individuals can move their centre of gravity forward while standing, the greater step length they may achieve while walking, i.e. initiating movement. Vitorio *et al*. (2012) found that individuals with PD have smaller braking and propulsive impulses than healthy controls [57]. This is due to the slower walking and shortend SL. Consequently, an increase in SL will lead to greater braking forces. Perhaps this is why the duration of the ITUG test

did not differ, because individuals exhibited less shuffling gait and walked with more heel strike which increased braking and propulsive impulses. It can possibly also be explained by the decrease in SL, SV and cadence variance which can indicate a more uniform gait pattern [38,39,56,58]. The intervention did not focus on gait specifically although gait exercises formed part of the dynamic and functional phases of the balance training (Addendum C). The Therapist-supervised group might have shown greater improvements because greater perceived balance could have led to less rigidity or co-contractions of muscles responsible for ambulation, allowing for bigger faster steps [46].

Various researchers have examined the clinical importance of gait variability [39,40,58]. Increased coefficient of variance (CV) in cadence and stride length have been related to freezing of gait and increase fall risk, which might reflect dysfunction of locomotor pattern generators [39; 58]. It is speculated that variability in DS time might indicate impaired neural balance circuits [58]. In the current study, the Therapist-supervised group decreased their SL and SV variability significantly after the intervention, whereas the Home-based decrease the cadence variability, albeit not statistically significant but might be clinically significant. Thus both groups could possibly have lowered their fall risk after the intervention, but without following up on the participants' fall history after the study this cannot be confirmed. Both groups had a non-significant decline in time in DS variability, which might indicate an improvement in neural balance circuits, which probably also contributes to decrease fall risk, and may possibly be attributed to improved somatosensory integration.

Poor balance confidence can predict fear of falling in individuals with PD and a score less than 69% has been associated with increases risk for recurrent falls over a 12-month period [46] and a normative score for PD individuals are 73.6% ± 19.3%. The study's ABC scores showed that the Therapist-supervised group score above the norm (77.7%) and was able to significantly increase it, whereas the Home-based group only had an average score of 70.0% and improved it to above the norm, albeit non-significant. The improvement of participants' perceived confidence in

their balance ability in the Therapist-supervised group possibly suggests that the presence of a qualified exercise therapist and/or a social group context may have had an influence on participants' behaviour and perceptions (King *et al.*, 2015). This may be possible, even though there was no group difference at post-test. Considering that both groups did not differ at pre-test however both groups demonstrated improvements in physical performance variables i.e. FGA and SL. In other words physical changes took place in both groups but only the Therapist-supervised group show a perceived improvement in balance confidence. Leddy, Crowner and Earhart (2011) showed that balance performance and self-perceived balance confidence has a high correlation ($r = 0.707$, $p < 0.001$) [42]. This may explain why there was no significant difference at post-testing between the groups. The improved FGA and gait could have resulted in both groups experiencing improved balance confidence, albeit not significant in Home-based, but the added benefit of having a therapist supervise the exercises together with the social interaction of other participants may well have amplified this perception. This might explain the significant difference of 17% in the enjoyment/interest subscale of the IMI for the Therapist-supervised group. King *et al*. (2015) also found that therapist-supervised training improves positive perceptions [59]. This is supported by a review of Dishman *et al*. (1985) who identified factors which influence exercise adherence and behaviour [60]. The researchers reported that the social environment (spouse support, therapist and exercise partner(s)) influences exercise patterns, and reinforces adherence to clinical programmes in several studies. However others have not found the same results [61]. Nevertheless the IMI data also supports this, in that the Therapist-supervised group perceived significantly more enjoyment from their sessions. Intrinsic motivation is the result of internal factors, which drives individuals to participate in activities for the enjoyment, interest or satisfaction derived from of it, rather than due to external awards [47]. Although the positive effect of the group environment, is a particular important benefit in PD populations who experience apathy, but it might also be viewed as a limitation of the study.

This connects to other factors that could have influenced balance confidence such as depression, apathy and lack of motivation. Dopamine plays a critical role in motivation, behaviours and bonding since it is connected to the reward centre in the brain [62]. Yamaguchi, Maki and Yamagami (2010) investigated efficient ways to interact with dementia clients to increase adherence, and found that a positive enjoyable environment and positive feedback increase dopamine secretion which triggered the reward centre [63]. This could hold true for PD participants in this study as well, since the Therapist-supervised sessions were done in small groups, where there could have been a more positive social interaction. A small group can function as a vehicle to enhance motivation and foster member enjoyment in social environment; which can lead to a positive influence on individual behaviour [49]. It could be that the smiles of the fellow participants and especially the therapist could have activated the mirror-neuron system, which leads to the participant experiencing positive feelings [64], which could increase motivation, or possibly even increase dopamine secretion as suggested by Yamaguchi, Maki and Yamagami (2010) [63]. The Home-based group did not have this strong social environment and thus had less motivation. However a study by Khalil *et al* (2011) showed that a DVD programme did improve the motivation and adherence in individuals with Huntington's disease, but also found that commitment from the caregiver played a vital role [49]. Perhaps DVD is a more effective method of Home-based exercises other than just a paper-based Home programme; and thus Home-based group had a slight improvement in balance confidence, motivation and adherence, but not as much as the Therapist-supervised group.

In addition the presence of a therapist may have theoretically added to the quality of the exercise sessions. A qualified therapist might be able to give more accurate feedback to promote a better understanding and improve performance. This feedback included verbal and tactile cues to stimulate somatosensation during the exercise programme; and although the caregivers of the Home-based group were told to also give somatosensory feedback when instructed to do so, there is no way to corroborate if they did follow the instructions correctly. Whereas the therapist, with the

exercise therapy knowledge, made sure to include the somatosensory feedback cues in every session. Interestingly Loken and Olausson (2010) discussed skin as a social organ and states that simple light touch (as was used during sessions) can increase trust and compliance to sessions with a therapist [64]. Perhaps because caregivers and participants are more used to one another's touch, the simple touch in the haptic feedback helped with proprioception but did not have any effect on balance confidence of the Home-based group.

One of the study limitations are that only spatiotemporal parameters were tested, which Albani and colleagues (2014) found not be very sensitive to disease severity, except when investigating the coefficient of variance [39]. Also other measures such as kinematics and muscle activation tests as well as measuring arm swing during the ITUG would have contributed greatly to the understanding of the results. This would have given more supportive biomechanical information. Unfortunately no retention tests were done, due to time constraints, to observe how long beneficial changes to mobility and balance confidence last after the intervention. Participants could also have performed better in the post-test due to the learning effect, but all measurement tools used have great test-retest reliability.

In conclusion, the findings of this study suggest that both home-based and therapist-supervised balance training with somatosensory cues improve dynamic balance and mobility after eight weeks. However the presence of a qualified exercise therapist will likely lead to greater improvements in SV and cadence, as well as improve balance confidence. Future studies can benefit by investigating the long term effects of balance training; and quantifying the psychological and physical benefits of group training for PD individuals.

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Chapter 4

Study/Article 2:

Eight weeks of Home-based balance training not as effective as Therapist-supervised training during dual tasks

Abstract

Objectives: To assess the effect of balance training on dual-tasking gait, and to investigate if a home-based programme is comparable to a therapist-supervised programme.

Design: Experimental pre-post study design.

Setting: Exercise hall and participants' homes.

Participants*:* Participants (n=39) with mild to moderate Parkinson's disease (H&Y I – III) were divided into a Therapist-supervised group (n = 23, age 65.4 ± 8.3yrs) or a Home-based group (n=16, age 64.9 ± 7.1yrs), based on a sample of convenience.

Interventions: Both groups followed eight weeks of balance training, with the Therapist-supervised group attending classes with an exercise therapist, whereas the Home-based group followed the programme with a series of guided DVDs at home with their caregiver.

Main Outcome Measures: Primary outcome variables were measured pre and post the intervention. Outcomes included mobility and gait parameters, assessed with the modified instrumented Timed-up-and-Go (ITUG), and dual-tasking ability, assessed with the instrumented cognitive Timed-up-and-Go (CTUG), from which dual-task interference was calculated. Secondary outcome measures included perceived fear of falling, assessed with the International Fall Efficacy Scale (FES-I), and disease severity, assessed with Unified Parkinson's Disease Rating Scale (UPDRS).

Results: The Home-based group showed a significant decrease in UPDRS III scores($p < 0.001$) after the intervention, and also showed significantly increased dual-task interference for duration, stride velocity, cadence and time in double support ($p < 0.005$). The Therapist-supervised group maintained their disease severity and dual-task interference after the intervention ($p > 0.05$).

Conclusions: The dual-task interference showed that, unlike the Therapist-supervised group, the Home-based group was unable to maintain their gait performance when a secondary task was applied. This study has revealed that eight weeks of balance training with a therapist is more likely to maintain and improve gait during dual-tasking than without the presence of a therapist performed at home.

Keywords: Dynamic balance; Gait; Parkinson's disease; Balance training; Rehabilitation

4.1 Introduction

Independent living of individuals with Parkinson's disease (PD) becomes more difficult as the disease progresses. The loss of independence ultimately leads to disability, which includes the loss of their ability to perform automated movements in a controlled manner.[1] However, the disability state is preceded by a preclinical disability period which has been described as a period during which individuals experience fewer notable difficulties due to successful compensation or coping mechanisms.[2] Preclinical disability could predict future disability by noting small changes in task execution.[3] Consequently, early identification of preclinical disability factors such as balance impairment reduced postural responses and variations in gait due to decline in automaticity may allow for improved care and earlier intervention to delay disability.[4,5] An effective way to test automaticity is through dual-tasking, as decrements in dual-tasking performance may highlight impairments during the preclinical stage.[6]

Dual-tasking (DT) refers to the performance of two tasks (motor or cognitive) simultaneously whilst dividing attention between the outcome objectives of each task[4,1], for example walking and talking. An individual may be able to complete two separate tasks successfully, i.e. single-tasking (ST) such as walking and a cognitive task, such as counting in 3's. However, a decline in the performance of either or both of these tasks during DT may provide evidence for earlier identification of preclinical disability. With PD, studies have found that gait performance deteriorates with dual-tasking.[6]

Gait is a complex activity since bipedal gait is inherently unstable, and thus balance and postural control contributes greatly to produce a complex and nonetheless automated movement of functional gait.[7,8] Postural control relies on the interaction of several physiological systems (the musculoskeletal, neuromuscular, cognitive and sensory systems) with environmental factors and the performed task.[4] A critical aspect of balance control in PD is dual- or multi-tasking[4] because attention is shifted away from the balance task when performing multiple tasks, which leads to higher fall incidences.[9]

Some, but not all, cognitive tasks interfere with postural control and walking in PD.[10] More complex cognitive tasks have a more pronounced influence on postural sway[11], cadence and gait variability.[12,13] This could be due to limited residual neural capacity available to perform simultaneous tasks[14], resulting in poor attentional capacity. These attention deficits appear to be associated with impaired gait and balance. According to Ashburn[15] mental distraction leads to increased postural sway in fallers with PD compared to non-fallers; and dual-tasking leads to freezing of gait or loss of balance in PD individuals whilst walking.[16,10]

Previous research among healthy age-related individuals highlights their adaptability to master DT better than PD individuals[1,13], but not as well as younger adults.[17,18] A study by Bloem and Colleagues[17] found that elderly participants exhibited compensatory mechanisms such as slower cognitive response as well as slower gait speed when completing a DT, where younger adults maintained gait speed, but also had slower cognitive responses. The PD individuals however showed a radically reduced cognitive response and gait speed, sometimes even stopping completely with both tasks.[17] This shows that PD individuals do not prioritize their posture and balance during dual-tasking[19], unlike healthy adults who place safe ambulation and balance as top priority.[1,17] Due to this incorrect prioritizing and executive function competition[1,18], PD individuals have slower gait speeds accompanied by a reduction in cadence and length. They also spend more time in double support, and have more variability of these parameters compared to the elderly participants.[6,19,20]

Contrary to what was originally believed, more recent studies (although few in number) show that dual-tasking can be improved through specific training.[20-23] However, the training benefits are short-lived and have subsequently not been tested over a long period (≥2-month). To the researcher's knowledge, very few studies to date have investigated the effect of balance training on dual-tasking gait ability, and no study has tested the effectiveness of Home-based versus Therapist-supervised training on dual-tasking gait. In this study we aim to assess 1) the effect of balance training on dual-tasking gait and 2) whether a Home-based programme is comparable to a

Therapist-supervised programme. The researchers hypothesise that eight-weeks of balance training will lead to significant improvements in dual-tasking gait, and that a Home-based (HB) programme will be as effective in improving dual-tasking gait as a Therapist-supervised (TS) programme.

4.2 Methods

4.2.1 Participants

Thirty-nine participants with confirmed idiopathic PD (by a neurologist) volunteered in this study. Participants were recruited from support groups and using advertisements in local newspapers. This experimental study design, with a sample of convenience and cluster randomization, made use of two experimental groups, i.e. Therapist-supervised group (n=23) and Home-based group (n=16) (Figure 4.1). This was a single-blinded study, where the participants were blinded by not being fully informed of the true aim of the study. Both groups were assessed before and after their respective eight-week training programmes and at the same time of day to ensure that they were in the same medicated state for each testing. Participants were tested in the ON phase. Individuals between the ages of 50-80 years with mild to moderate PD (Stage I-III on Hoehn and Yahr Scale), adequate functional status and no cognitive impairments (Montreal Cognitive Assessment score >17) were included. Neurological conditions (e.g. Diabetes and/or stroke) other than PD, uncorrected visual or vestibular problems, any orthopaedic or muscular injuries in the six months preceding the study excluded volunteers from the study. Furthermore, participants were excluded if they changed medication four weeks before or during the study, and also if they showed any adverse side-effects due to medication. Participants were also required to attend a total of at least 70% of the sessions and also had to participate in two of the three exercise sessions per week. Participants in the Home-based group had to be assisted, for safety purposes, by a caregiver (i.e. spouse, family member or close friend), however the caregiver was not allowed to have any formal physical or exercise therapy training. Participants provided verbal

and written informed consent before the start of the study. The study was approved by the Institutional Review Board and Research Ethics Committee (HS1061/2014) (Addendum A).

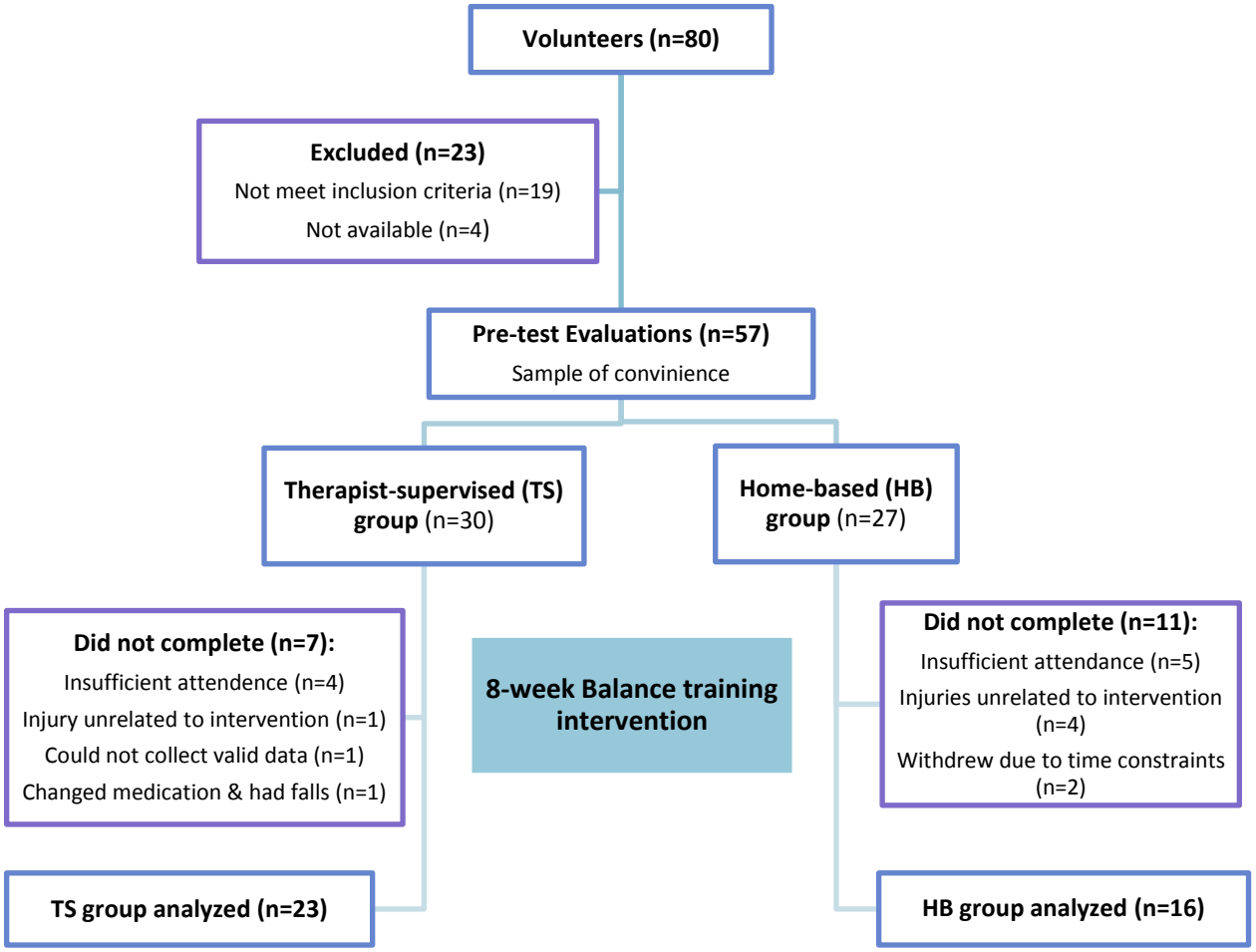

Figure 4.1: Flow chart of number and allocation of participants

4.2.2 Intervention

Participants completed eight weeks of balance training with three 40 to 60 minute sessions per week which progressively increased in difficulty i.e. from postural alignment to static, dynamic and functional balance activities, respectively. Exercise sessions consisted of a 10 minute warm-up, followed by 15-40 minutes of balance training, and ended with 10 minutes of cool-down and relaxing technique activities. Both groups followed the same balance programmes; Individuals in

the Home-based training group, together with their caregivers, received instructions by means of a DVD and the Therapist-supervised group attended sessions, led by a clinical exercise therapist. A new DVD was sent to the participants every week, adding to a total of eight DVD volumes (see example in Addendum F). Specific somatosensory cues were added to each session, and initiated by participant or therapist/caregiver. Somatosensory cues are effective for improving the gait parameters and psychomotor performance of PD patients, by increasing somatosensory (tactile and proprioceptive) feedback to the impaired proprioception.[24-26] The intervention exercises included static, dynamic and functional balance activities with various progressions to challenge sensory information input. The last three weeks of the intervention focused on functional balance; thus consisting of various gait exercises and everyday activities, such as dual-tasking. However, cognitive tasks during exercise sessions only consisted of numerical challenges (randomly counting in 3's, 7's or backwards), and did not include any verbal or word related tasks.

4.2.3 Mobility and gait evaluations

Primary outcome variables were mobility and gait parameters which were assessed with the modified instrumented Timed-up-and-Go (ITUG). The same outcome measures were also assessed with a dual-tasking task, using the instrumented cognitive Timed-up-and-Go (CTUG). Secondary outcome measures included perceived fear of falling (FOF), assessed with the International Fall Efficacy Scale (FES-I) (Addendum H), and lastly UPDRS and H&Y was used to assess disease severity.

During pre-tests, the body mass and height of each participant were assessed. Medical and personal information, such as years diagnosed and medications used, was also collected (see Addendum G). Participants completed a Montreal Cognitive Assessment (MoCA) to assess their cognitive impairment (Addendum K), since cognitive dysfunction previously has been shown to affect balance.[27] Participants were classified into the modified Hoehn and Yahr (H&Y) disease

stages with help from the MDS-UPRDS scores. Participants' mobility and gait were assessed pre- and post- the eight-week interventions.

Participants completed three ITUG (Mobility Lab^{TM}, APDM®, USA) and three CTUG tests by the same qualified clinical exercise therapist to assess single-task and dual-task mobility and gait. The Mobility Lab^{TM} comprises of four tri-axial accelerometers plus a gyroscope, all of which automatically process input signals and provide objective measures related to gait during an ITUG protocol.[28] Participants were instructed to stand up from a chair, walk seven metres in a straight line at a self-selected (comfortable) walking pace, turn 180 degrees, and walk back followed by sitting down again to complete the test. Each participant had one practice trial followed by a further two trials which were recorded. The averages of the two trials were used for data analysis purposes. The tests were conducted at the homes of the participants where there had to be at least a seven meter flat walking space with sufficient lighting. Tests were performed on solid flat surfaces, and not on carpets, and all tests were repeated in the same environment and on the same surface. Salarian and colleagues[31] showed the ITUG to be a sensitive and reliable measure of mobility for PD ($p > 0.75$) for most spatial and temporal measures, and Zampieri[45] showed that testing in a home environment is feasible.

The CTUG followed exactly the same protocol as the ITUG with the additions of participants being asked to recite every second letter of the alphabet whilst walking. Previous studies used other cognitive tasks such as subtracting 3's or 7's, or verbal fluency tasks[11,22] but Fok[29] suggested an alternative cognitive task during testing to create more interference. Muhaidat and colleagues[30] used a similar alternating-alphabet protocol on an elderly population with strong reliability (ICC = 0.78; $p < 0.001$) and in a recent study Conradsson[21] used this cognitive task to successfully test dual-tasking.

The following gait parameters were recorded during the ITUG: total time, double support (DS), stride length (SL), stride velocity (SV) and cadence. The mean SL and SV were recorded and

expressed as a percentage of the participant's stature to normalise the data. Duration and time in DS were expressed in seconds, and cadence as steps per minute. Stride length, SV and cadence have been reported as the most sensitive gait parameters in PD individuals.[31,32] Other variables that have been found to correlate well with dynamic balance include total time and duration of DS.[33,34]

4.2.4 Statistical Analysis

Descriptive statistics are reported as mean ($\bar{x}$), range, 95% confidence intervals (CI) and standard deviation (± SD), unless otherwise specified. Data was assessed for normality with a Shapiro-Wilks test. All outcome variables were tested for differences at pre-intervention between the two groups. A repeated measures analysis of variance was used for comparison between the two experimental groups' gait and mobility parameters as well as fear of falling from pre- to post-intervention. Further analysis was performed through post-hoc comparisons in accordance with Fisher Exact LSD, as well as Cohen's effect sizes for practical significance, with 0.2 = small^S, 0.5 = medium^M and 0.8 = large^L effect. All statistical analyses were performed using Excel® (Microsoft Office, USA) and and Statistica® software (version 12, StatSoft, Inc., Tulsa, OK, USA) for Windows, with $\alpha > 0.05$ and tendencies < 0.10. Decrements in gait under dual-tasking conditions are often expressed as a percentage of single-task performance. Thus the difference between single and dual-task parameters is referred to as dual-task cost or interference. The formula for interference is (ST – DT)/ST x 100.

4.3 Results

Eighty individuals with PD volunteered to participate in this study of which only 57 met the inclusion and exclusion criteria (Figure 4.1). The demographic and anthropometric characteristics of the two groups are summarized in Table 4.1.

There were no significant differences between the ages, body mass, onset of disease, all UPDRS scores and MoCA scores prior to commencement of the interventions (p>0.05). There was however a significant difference in height (p=0.02) among the groups (Table 4.1).

Table 4.1 Descriptive characteristics of participants (mean ± SD)

Variables	**TS** *(n= 23)*		**HB** *(n = 16)*		**p-Values**
Gender M (%)	14 (60.9%)		14 (87.5%)		
Age (years)	65.39 ± 8.30	(50 – 79)	64.94 ± 7.12	(55 – 78)	0.85
Body mass (kg)	77.97 ± 14.32	(52.0 - 108.9)	78.74 ± 12.72	(48.7 - 97.1)	0.86
Stature (m)	1.67 ± 0.11	(1.50 - 1.89)	1.74 ± 0.08	(1.53 - 1.86)	**0.02**
BMI (kg.m^{-2})	28.14 ± 5.73	(21.1 - 43.6)	25.84 ± 3.03	(18.1 - 32.4)	0.11
MoCa	26.00 ± 2.20	(21 – 30)	25.75 ± 2.32	(21 – 30)	0.74
Disease onset (yrs)	3.39 ± 3.73	(0 – 14)	7.25 ± 10.46	(0 – 44)	0.17
UPDRS I	3.50 ± 2.50	(0 – 9)	3.9 ± 2.43	(0 – 7)	0.57
UPDRS II	12.10 ± 5.34	(3 – 22)	15.31 ± 7.92	(3 – 32)	0.17
UPDRS III	30.00 ± 13.00	(10 – 56)	35.94 ± 12.78	(17 – 63)	0.19
UPDRS IV	3.39 ± 3.60	(0 – 17)	3.63 ± 2.03	(0 – 8)	0.80
UPDRS Total	59.44 ± 18.20	(19 – 80)	58.81 ± 21.64	(12 – 103)	0.17
H & Y Stage	2.39 ± 0.41	(1.5 – 3)	2.50 ± 0.52	(1.5 – 3)	0.51

NOTE. Values shown as mean ± SD (minimum – maximum), or a (%). SD: Standard deviation, BMI: Body Mass Index, MoCA: Montreal Cognitive Assessment, MDS-UPDRS: Unified Parkinson's Disease Rating Scale, H&Y: Hoehn and Yahr disease stage

4.3.1 Disease Severity

There was a statistically significant treatment (TIME x GROUP) effect for the UPDRS total score (p = 0.01), but of greater importance was a treatment effect for UPDRS Motor (III) subscores (p = 0.00071), which is a better representation of influences of interventions on motor symptoms. Groups differed at pre-test with 16.6% (d = 0.49^{M}), however this was not significant (p = 0.18). Only the Home-based group had a significant (p < 0.001) decrease in UPRDS III scores of 23.5% (d = 0.74^{M}) (Figure 4.2).

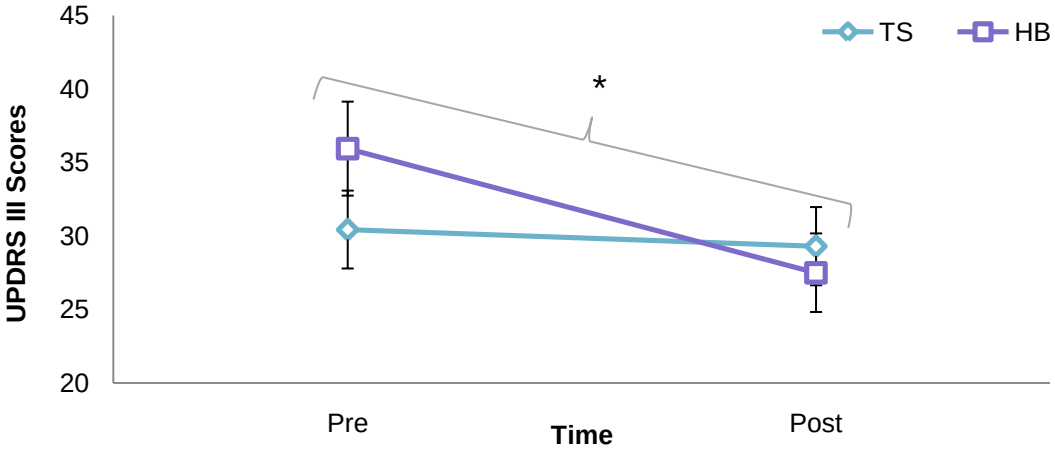

Figure 4.2 The change in disease severity over the 8 week interventions for both HB and TS groups ($\bar{x}$ ± SEM). *p = 0.001

4.3.2 Fear of falling

In Figure 4.3 no significant treatment effect (p = 0.60) was found. Post-hoc analysis showed a significant difference of 27.1% (d = 0.80^{L}) in fear of falling before the intervention (p = 0.025) between groups, and a strong tendency (p = 0.051) to differ after the intervention by 25.8% (d = 0.64^{M}) at post-tests. The Home-based group showed a strong tendency to differ (p = 0. 055), with a reduction of 8.5% (d = 0.20^{S}) from pre- to post-test, whereas Therapist-supervised group only had a 7.2% (d = 0.26^{S}) reduction, respectively.

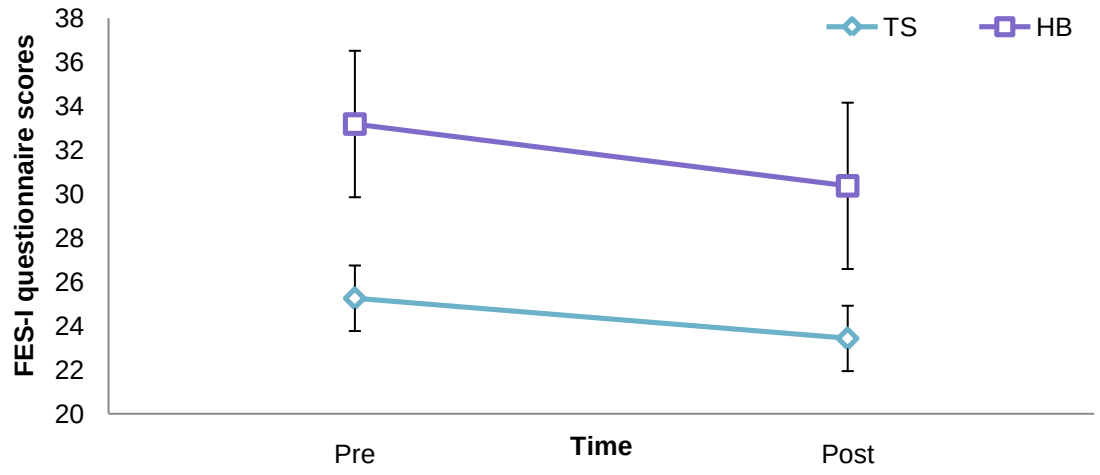

Figure 4.3: Change in Fear of falling over an 8 week balance intervention for both HB and TS groups ($\bar{x}$ ± SEM)

4.3.3 Single vs. Dual-tasking gait parameters

There was a statistically significant treatment effect for duration, SV, cadence and DS of the dual-task ($p \leq 0.01$). Figure 4.4 compares the normalized raw data scores of single-task and dual-task gait parameters. Looking at the dual-task, groups did not differ significantly at pre-tests ($p > 0.05$), but they did have a significant difference at post-tests ($p < 0.05$). The percentage difference between groups for duration changed from 29.0% ($d = 0.69^{M}$) at pre-test to 41.5% ($d = 0.87^{L}$) at post-test; SL changed from 1.7% ($d = 0.49^{M}$) to 7.7% ($d = 0.53^{M}$); and SV changed from 12.2% ($d = 0.49^{M}$) to 26.0% ($d = 0.53^{M}$). Cadence of the two groups differed at pre-test with 6.7% ($d = 0.41^{M}$) and changed to a 21.0% ($d = 1.24^{L}$) difference at post tests, and DS changed from 8.7% ($d = 0.3^{S}$) to 20.8% ($d = 0.84^{L}$).

Dual-task interference was calculated by using single-task and dual-task raw data. Treatment effects were found for duration, stride velocity, cadence and double support ($p < 0.05$). There were no differences at pre-tests ($p > 0.05$), however stride length task difference showed a tendency to differ ($p = 0.06$) at pre-tests and did differ significantly at post-tests ($p = 0.04$). Statistically significant differences were seen at post-tests for duration, stride velocity, cadence and double support ($p < 0.01$). LSD post-hoc tests revealed that Home-based group had statistically significant differences from pre to post ($p < 0.001$) (Table 4.2).

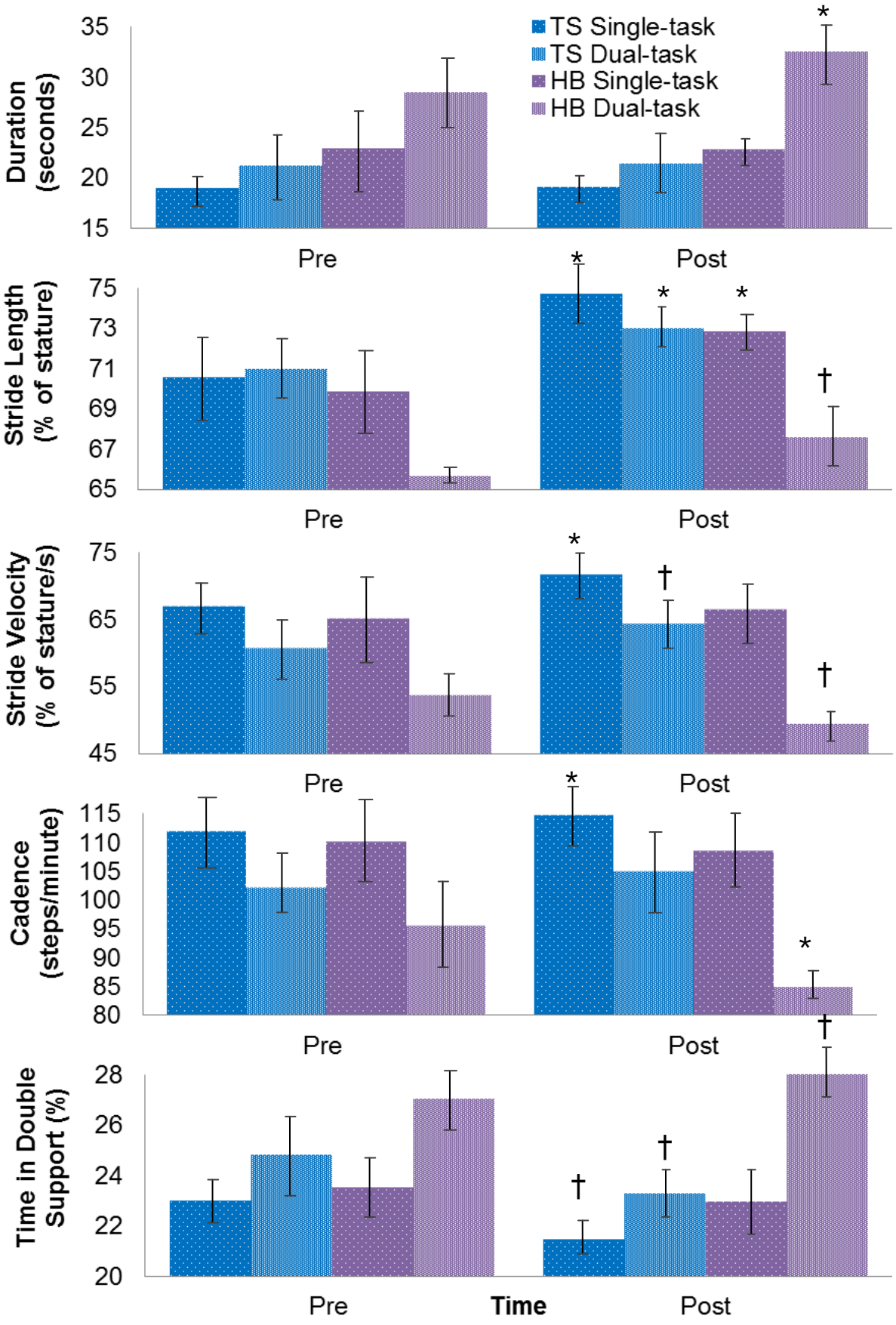

Figure 4.4 Comparing gait parameters of single-task task with dual-task test.

* Significant difference from pre to post, $p < 0.05$; † tendency to differ from pre to post, $p < 0.10$

Table 4.2 Dual-task Interference of pre- and post-intervention gait parameters between TS and HB groups (mean ± SD)

	Between group comparisons				
	% Difference (ES)		p-Value		
	Pre	*Post*	Treatment effect	*Pre*	*Post*
Duration (seconds)	79.3 (0.62^{M})	116.9 (1.04^{L})	0.00054*	0.097	0.00042*
SL (% of stature)	94.9 (0.57^{M})	80.7 (0.70^{M})	0.78	0.062	0.037*
SV (% of stature / s)	42.8 (0.48^{M})	73.4 (0.96^{L})	0.031*	0.17	0.004*
Cadence (steps / minute)	37.1 (0.40^{M})	82.4 (1.08^{L})	0.01*	0.26	0.0016*
Double Support (%)	22.6 (0.15^{S})	83.4 (0.75^{L})	0.0091*	0.62	0.022*

	Within group comparisons							
	Therapist-supervised Group *(n = 23)*				**Home-based Group *(n = 16)***			
	Mean ± SD (Range)		% Difference	p	Mean ± SD (Range)		% Difference	p
	Pre	*Post*	(ES)	Value	*Pre*	*Post*	(ES)	Value
Duration (seconds)								
	-2.39 ± 3.57 (-15.81 to 0.98)	-2.55 ± 3.56 (-15.43 to 0.91)	6.7 (0.05^{N})	0.79	-5.54 ± 6.99 (-22.18 to 1.71)	-9.73 ± 10.26 (-38.13 to -0.58)	75.8 (0.49^{M})	0.000013*
SL (% of stature)								
	1.49 ± 3.58 (-8.06 to 8.34)	2.23 ± 2.91 (-1.87 to 10.37)	50 (0.23^{S})	0.33	4.17 ± 6.26 (-5.32 to 16.34)	5.25 ± 6.03 (-2.4 to 16.33)	25.9 (0.18^{S})	0.24
SV (% of stature / s)								
	7.42 ± 7.49 (-1.56 to 27.63)	7.82 ± 7.25 (-0.9 to 30.32)	5.4 (0.06^{N})	0.76	11.45 ± 9.95 (0.53 to 36.85)	16.88 ± 12.43 (2.15 to 43.65)	47.4 (0.50^{M})	0.003*
Cadence (steps / minute)								
	10.06 ± 10.66 (-1.65 to 39.7)	9.8 ± 9.97 (-1.25 to 41.13)	2.5 (0.03^{N})	0.92	14.63 ± 12.99 (-1.67 to 53.11)	23.53 ± 16.49 (2.11 to 49.87)	60.8 (0.62^{M})	0.002*
Double Support (%)								
	-2.79 ± 4.2 (-18.56 to 3.16)	-2.37 ± 3.76 (-14.56 to 2.7)	15.0 (0.11^{N})	0.46	-3.5 ± 5.49 (-19.14 to 2.59)	-5.76 ± 5.74 (-17.37 to 0.25)	64.6 (0.42^{M})	0.005*

NOTE. Interference is calculated as (ST – DT)/ST x 100; higher values = deterioration & lower values = improvement. Effect sizes (ES) are indicated as N = negligible, S = small, M = medium, and L = large. *Statistically significant differences; $p < 0.05$.

4.4 Discussion

The main aim of this study was to investigate the effects of balance training on dual-task interference in a Home-based compared to a Therapist-supervised programme. The Home-based group had a significant decrease in disease severity, whereas the Therapist-supervised group maintained their PD level. The dual-task interference showed that, unlike the Therapist-supervised group, the Home-based group was unable to maintain their gait performance (i.e. duration, SV, cadence and DS) when a secondary task was applied. The results suggest that a Therapist-supervised balance training programme over eight weeks is more beneficial for mobility and gait than a Home-based programme.

The groups did not differ significantly at pre-tests except in stature, however there was no a significant difference in BMI, which could have an effect on postural instability, and might increase fall risk.[35] The Home-based group had a higher score in disease severity at pre-tests (Figure 4.2), albeit not significant. Martinez-Matin[36] re-evaluated the cut-off values for the UPDRS to define disease severity and found that 32/33 is the cut-off point between mild and moderate PD. Thus the Therapist-supervised could be classified as mild PD and the Home-based group as moderate. This could indicate that the Home-based group was already more prone to greater balance impairments and less mobility, although their H&Y stages did not differ despite the large difference in amount of years since diagnosis (Table 4.1).

Impaired mobility, in particular SL, was not observed in the single-task activity, but manifested only during the DT activity. This may be indicative of preclinical disability, when individuals have successful compensation or coping mechanisms.[2] Disease severity, especially individuals who experience motor fluctuations[11], are more affected by dual-task challenges. Even in an optimal state of medication, DT deficits in gait are still apparent.[6] After the eight weeks of balance training the difference in UPDRS total scores between the groups was reduced to only 4%, and the UPDRS motor subscore changed from 16% to 6%. It is well known that as disease

progresses, PD individuals become weaker and more inactive. So perhaps the Home-based group had more motor symptoms to start with and maybe improved their motor abilities faster to the same level as the mild PD individuals of the Therapist-supervised group who are possibly more active.

Participants with the higher disease severity were also more prone to have a higher fear of falling (Figure 4.3). Both groups had a reduction in fear of falling, which is of clinical importance. Decrease in FoF leads to lower fall risk[37,38], which has been shown to have a relationship to postural control, mobility and QoL. According to the cut-off scores postulated by Delbaere and colleagues[39], the therapist-supervised group was only moderately concerned about falling (scores lie between 20 – 27), where the Home-based group was highly concerned about falling (scores lie between 28 – 64), and it remained in the same classification after the intervention. No significant changes occurred over time, despite the intervention showing to be effective in improving aspects of gait. This could possibly be due to participants becoming more aware of situations they find themselves in where they might be concerned about falling. Increased awareness was the number one feedback comment of all participants, stating that after the intervention they are a lot more aware of how and why they feel unsteady and how to correct it, but perhaps this has not yet led to an improvement in fear of falling. It might be useful to research the effect of increased body and spatial awareness due to balance training in a long-term study.

Home-based balance training did not improve dual-tasking gait, whereas Therapist-supervised training maintained and improved their dual-tasking gait. The Home-based group had a significantly longer duration and slower cadence for the dual-task, and had slower stride velocity and spent more time in double support when performing the dual-task after the intervention. Dual-tasking interference is an efficient way to display the impact of dual tasking on a single-task.[16] In this current study dual-task interference (Table 4.2) the therapist supervised group did not have any significant changes in interference, which shows that dual-task gait parameters improved to the same extent as their single-task counterparts. The Home-based group however had significant

higher dual-task interference after the intervention, indicating deterioration in duration, stride velocity, cadence and double support. These significant changes in interference can be due to single-task gait improving slightly over the intervention coupled with dual-task gait declining in performance. A recent study shows that 10 weeks of highly challenging balance training (in which 7 of the weeks implemented dual-tasking) showed to improve stride length, stride velocity and cadence[21], which supports our findings in the Therapist-supervised group, but not in the Home-based group.

Possible explanations for the Therapist-supervised group maintaining and improving to a greater extent than the Home-based group, who followed the same intervention, are that the Therapist-supervised group received certain benefits above and beyond the balance training. These possible benefits include feedback from the therapist that can enhance the motor learning capacities of the participants and the influence of the social dynamics of a group. Dual-tasking performance can largely be improved by following specific motor learning concepts, as explain by Yogev-Seligmann.[22] These concepts include task-specific training, increased feedback to promote learning, sufficient intensity, variability of practice and progressing the level of difficulty. The Therapist-supervised group sessions perhaps simulated real-life dual tasking challenges more, thus making sessions more task-specific, along with that the therapist also concentrated on exercises being performed correctly by providing feedback and certain progression when necessary. The progression options were also part of the DVDs, but the implementation of the progression for certain exercises where left to their own discretion. Variability of practice was inherently part of the programme design as it promotes transfers to daily life.[22] Transfer of untrained dual-tasking ability was also assessed to some extend in this study by asking a different cognitive task (alternating alphabet) to the one trained in the session (various numerical challenges). The Therapist-supervised group may have had more progression in level of difficulty imposed by the therapist than the Home-based group regulated by the DVD, and caregivers and participants adherence to it. These concepts might have been more enforced during Therapist-

supervised training than Home-based training. The Therapist-supervised group was thus able to effectively implement certain strategies to improve dual tasking gait, whereas the Home-based group reverted to compensatory mechanisms (mainly slowing down walking speed).

Social dynamics of a group can improve adherence and motivation. A small group can function as a vehicle to enhance motivation and foster member enjoyment in social environment; which can lead to a positive influence on individual behaviour.[40] This can be of great benefit to PD individuals as they already suffer from lack of motivation and even depression due to less dopamine secretion.[41] It can also be that a group environment inherently includes more dual-tasking behaviour from participants, as they interact with one another and with the therapist. Lord and colleagues[42] state that a problem of attentional control in PD is recognized as the inability to switch between tasks which "compromises safe and effective performance of functional tasks such as walking in 'real world' environments which are unpredictable and require coordinated, flexible and immediate cognitive and motor responses". Dopaminergic networks appear to mediate attention shifting deficits which seem to be associated with impaired gait and balance.[42,43] Mental distraction leads to increased postural sway in fallers with PD compared to non-fallers, and multiple tasking leads to freezing of gait or loss of balance in PD subjects when walking.[43] Interestingly, Zivotofsky and Hausdorff[44] investigated the phenomenon of people synchronizing their gait parameters when walking along side one another, and they state that this could be of great importance to help people with disturbed gait rhythm. Keeping this in mind, it can be argued that the therapist-supervised group was more influenced by this phenomenon as they walked with the therapist or fellow participants alongside them, whereas the Home-based group did not have different options besides their caregiver. Nevertheless, the Home-based group was exposed to other aspects that also required dual-tasking, such as looking and listening and reacting to instructions from the DVD and somatosensory feedback and cues for the caregiver. Perhaps the DVD is effective in improving ST gait, but does not provide enough stimuli to improve DT gait.

Limitations of this study include the lack of a non-exercising control group to account for the Hawthorne and learning effect of tests. Future studies should include a retention period to determine if the motor abilities learned were maintained. Although all tests used had good test-retest reliability and validity, the alternating-alphabet cognitive task and ITUG have not been used together before, and it may warrant some further research. Another limitation is that the researchers merely focussed on the walking ability and did not quantify the amount of errors of the secondary task.

In conclusion, a Home-based balance training programme seems to not be effective in improving dual-tasking gait compared to a Therapist-supervised programme. The difference in performance of the two groups may be due to the therapist supervision and/or group setting. This study has revealed that eight weeks of balance training with a therapist compared to no therapist can maintain and improve gait during dual-tasking. Thus participants who struggle with dual-tasking and the effects there of would benefit greatly from following a structured programme with a qualified exercise therapist compared to a Home-based DVD.

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Chapter 5

Study/Article 3

Home-based balance training can reduce freezing of gait, but not improve turning ability

Abstract

Objectives: The aim of this study was to assess the efficacy of a home-based compared to therapist-supervised balance training programme on freezing of gait and turning effectiveness.

Design: Experimental pre-post study design

Setting: Exercise hall and participants' homes

Participants: Based on a sample of convenience 40 participants with mild to moderate Parkinson's disease (Hoehn & Yahr stages I – III) were allocated to a therapist-supervised (n = 24, age 65.4 ± 8.3 years) or home-based group (n=16, age 64.9 ± 7.1 years). Within each group 50% of individuals reported experiencing freezing.

Interventions: Both groups followed eight weeks of balance training with somatosensory cues, where the Therapist-supervised group attended classes with a qualified clinical exercise therapist, whereas the Home-based group followed the programme with a series of guided DVDs at home alongside their caregiver with no prior exercise knowledge.

Main Outcome Measures: Primary outcome variables were measure pre- and post-intervention and included turning ability assessed with the modified instrumented Timed-Up-and-Go (ITUG), mobility and gait parameters assessed with a functional gait analysis, and self-reported freezing of gait assessed by the freezing of gait questionnaire. Secondary outcome measures are disease severity assessed with subscale II and III of the Unified Parkinson's Disease Rating Scale (UPDRS) and global cognition determined with Montreal Cognition Assessment (MoCa).

Results: The main findings for this study are that Freezers in the Therapist-supervised and Home-based groups had greater than 50% higher disease severity than Non-freezers, as measured by UPDRS subscore II ($p < 0.004$). Both groups experienced a decrease in reported freezing of gait after intervention, including duration and frequency. Freezers scored worse in balance and gait measurement at pre-test than Non-freezers ($p < 0.05$), but improved significantly after the intervention. Only the Freezers in the Therapist-supervised group improved their turning duration ($p = 0.04$), and turning velocity ($p = 0.02$, while Freezers and Non-freezers of the Therapist-supervised group improved turn-to-sit duration at post-tests ($p < 0.001$).

Conclusions: This study has verified that individuals who experience freezing are likely to have higher severity of the disease and less functional mobility, including gait and turning actions. An eight-week balance intervention with a therapist can improve the efficacy of a turn when the exercises are presented by an exercise scientist. Home-based training does not seem to be nearly as effective as Therapist-supervised training in improving turning ability, but it is however effective in reducing self-reported freezing of gait severity.

Keywords: Parkinson's disease; Balance training; Freezing of gait; Somatosensory cueing; Turning deficits; Rehabilitation

5.1 Introduction

Neurological disorders, like Parkinson's disease (PD), are difficult to treat because individuals present with a variety of symptoms which progressively affect their ability to live independently. Pharmacological and surgical treatments are primarily aimed at correcting or preventing neurochemical imbalances.[1] However certain motor symptoms of PD respond insufficiently to medication or surgery, or might even be worsened by long-term medication use, for example freezing of gait (FoG) and balance.[2] Consequently, even though the exact mechanisms are unclear, exercise has been suggested as a beneficial non-pharmacological treatment[3] for individuals with Parkinson's disease (PD).

Freezing of gait (a transient halt in walking less than one minute), is a major mobility problem for individuals with PD which reduces independence and quality of life.[4,5] It has been described as the sensation of your feet being 'glued to the floor', and not only does it impact the effectiveness of movement but can also be accompanied by postural instability[6] and subsequent falls.[7] The risk of falling is nine times higher in individuals with PD[8] and they are twice as likely to be recurrent fallers[9] compared to healthy peers. It is believed that the inability to cope with coordination demands[10], problems adopting postural synergies and abnormal retrieval or execution of motor commands when shifting from one task to another[11], contribute to increased instability and freezing of gait during fall-related activities.[12] According to Forsaa and co-authors' (2015)[12] twelve year

longitudinal study, postural instability and gait disturbance severity as well as psychosis are independently associated with developing FoG. These risk factors are each related to non-dopaminergic extrastriatal brain areas[12]. However FoG is believed to involve dopaminergic and non-dopaminergic pathophysiology[12,13], which may explain the different types of FoG[5,14].

The prevalence of FoG is inconsistently reported, with studies indicating between 25% and 87%.[15-21] However as the disease progresses the predictability of FoG episodes decline and the frequency increases, affecting the individuals walking ability and independence.[22]

Previous research has shown that FoG more often occur in situations where the PD individuals encounter an obstacle or when visual or proprioception information[7] is limited or distorted.[5,7,23] Turning deficits in gait are often associated with balance impairment.[24,25] Both turning hesitation and starting hesitation (akinesia) has been reported as the two most common occurring types of FoG; where some researchers state the former to be the most prevalent[26,27] and other stating the later to be.[14,28]

Despite the disabling phenomenon of FoG, there have been numerous reports of PD individuals who are able overcome freezing episodes with external cues, and continues walking fairly smoothly.[5,30] The external cues provide somatosensory, visual, auditory or tactile/haptic feedback,[29] which seems to be a vital tool to overcome FoG. Attention strategies might possibly help since it allows the movement to circumvent the automated movement patterns[31] from the basal ganglia which is dysfunctional in PD.[32] Individuals with PD typically have an overreliance on visual feedback to maintain balance,[33] and therefore it would be best suited to implement other cueing strategies that would benefit them without the use of visual cues, such as somatosensory and cognitive cues.[34,35] Tactile cues have been shown to be excellent at helping people with balance disorders[36] improve balance. According to Baldan and co-workers (2013),[37] tactile cues improve haptic feedback which improves impaired proprioception.

Balance training to improve FoG episodes, coupled with sensory cues, such as visual, auditory and somatosensory (tactile and proprioceptive), has been shown to be very beneficial in overcoming FoG,[38; 39] although some effects are short-lived.[40] Currently there is a growing body of research that highlights the role of exercise as an essential part of managing PD, especially considering that FoG responds poorly to dopaminergic treatment. In spite of this, inactivity still remains one of the greatest problems in PD populations; especially those who are at greater fall risk.[41] Consequently, cost-effective home-based interventions should be investigated as alternative exercise modes. To date only three studies looked at adding cueing strategies to a home-based programme which specifically addressed freezing of gait (FoG).[29,42,43] Of which only one of these studies incorporated somatosensory cues together with visual and auditory cues;[29] however none have compared home-based to a therapist supervised balance exercise programme. In addition Fearon *et al*. (2015) reported that auditory-visual processing is abnormal in PD individuals experiencing FoG.[44] Whereas Rabin *et al*. (2013) found that acute tactile feedback improved postural sway in PD[35], which may suggest that investigation should look at somatosensory cueing with exercises in isolation. Therefore this study endeavoured to investigate the efficacy of balance training, with somatosensory cues, on turning ability and FoG in a home-based compared to a therapist-supervised programme in individuals with mild to moderate PD.

5.2 Methods

5.2.1 Participants

For this single-blinded experimental study with a sample of convenience and cluster randomization, forty participants with confirmed idiopathic PD (by a neurologist) participated in this study. Twenty-four participants underwent eight-week Therapist-supervised (TS) balance training with somatosensory cues and sixteen participants followed the exact same balance training programme with a Home-based (HB) DVD and their caregiver. Both groups were assessed before and after their respective training programmes and at the same time of day to ensure they were in

the same medicated state for each testing. Participants were tested in the ON phase. Individuals between the age of 50-80 with mild to moderate PD (H&Y Stages I-III), with adequate functional status and no major cognitive impairments (Montreal Cognitive Assessment [MoCA] score >17)[45;46] were included. Individuals with other neurological conditions or mental health problems other than PD (e.g. Diabetes, stroke) as well as any visual or vestibular problems or inadequate functional status (could not perform a sit to stand or stand in tandem) were excluded. Participants were also excluded from the study if they had any orthopaedic or muscular injuries in the previous six months preceding the study, changed their medication four weeks before the study, and experienced adverse side-effects of medication. Furthermore, individuals in both groups were not allowed to miss more than two consecutive training sessions per week and they had to have at least 70% adherence. Participants in the Home-based group had to be assisted, for safety purposes, by a caregiver. A caregiver signifies someone who assists the person with PD who is, to some degree, incapacitated and needs help i.e. spouse, family of close friend.[47] However the caregiver was not allowed to have any formal physical or exercise therapy training. This information was collected with a general information form. Participants provided verbal and written informed consent before the start of the study, which was approved by the Institutional Review Board and Research Ethics Committee (HS1061/2014; See Addendum L).

5.2.2 Intervention

Participants completed eight weeks of balance training that progressively increased in difficulty and time (Figure 5.1). The intervention exercises were taught in a trial-and-error method as to enhance somatosensory feedback during static, dynamic and functional balance activities.

Individuals in the Home-based training group, together with their caregivers, received instructions via DVDs. The DVD's tallied to one per week, adding up to eight DVD volumes in total (see addendum F for example DVD). Each volume contained clear instructions which both the participant and their caregiver were required to follow closely. Instructions included the aims and objectives, safety guidelines and equipment requirements as well as somatosensory cues relating to certain exercises. Both participants and caregivers were responsible for using them while carrying out the exercises prescribed. Participants were telephonically contacted each week to record adherence and to establish if any problems occurred. The Therapist-supervised group attended group sessions led by a clinical exercise therapist (registered Biokineticist at the South African health profession's council).

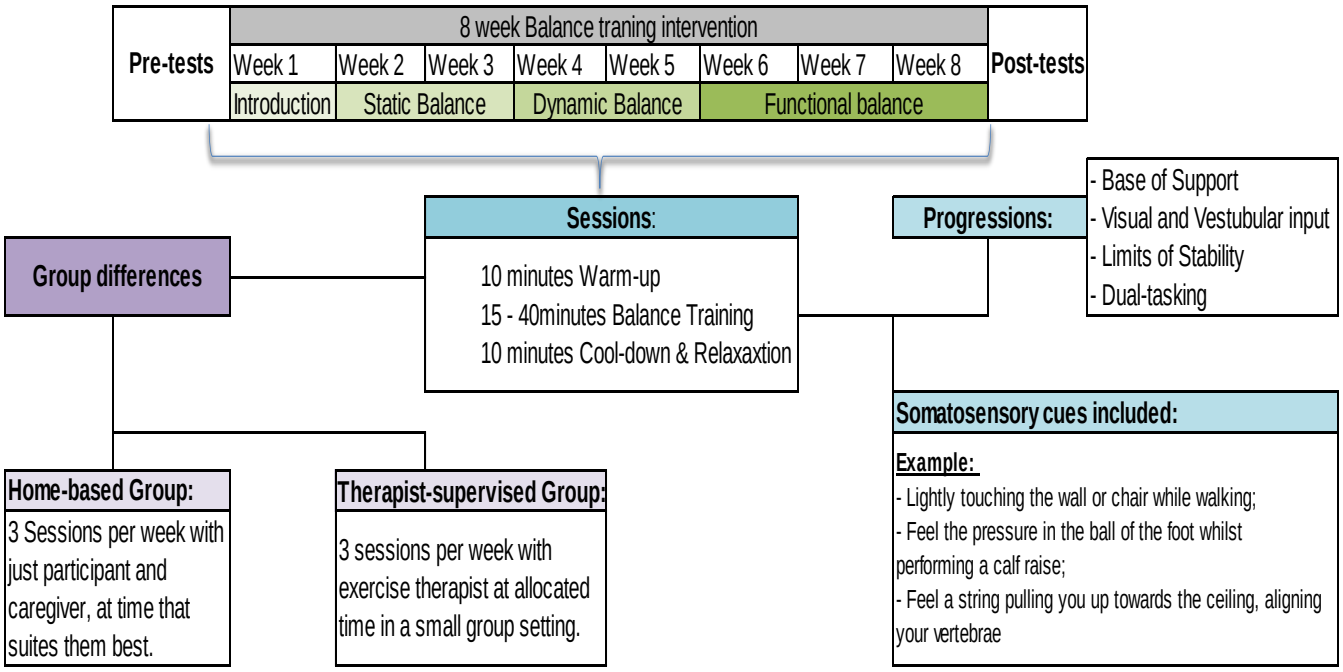

Figure 5.1 Intervention layout for both groups

5.2.3 Evaluations

Primary outcome variables were turning spatiotemporal variables, functional gait analysis (FGA) and the frequency and duration of FoG episodes. Secondary outcome variables were disease severity (UPDRS) and global cognition (MoCA).

At pre-tests participants' body mass and height were assessed. Medical and personal information, such as years diagnosed and medications used (Addendum E and F), were also collected. All participants were evaluated according to Hoehn and Yahr (H&Y) and part II of the Movement Disorder Society-Unified Parkinson's Disease Rating Scale (MDS–UPDRS) to assess disease severity, and Montreal Cognitive (MoCA) to assess global cognition, as Virmani *et al*. (2015)[48] have suggested that impaired cognition may affect postural instability. Participants' dynamic balance and gait were assessed pre- and post- the eight-week interventions.

Participants completed three instrumented Timed-Up-and-Go (ITUG; Mobility Lab^{TM}, APDM®, USA) and a FGA by the same qualified clinical exercise therapist to assess balance and turning spatiotemporal variables. The Mobility Lab^{TM} consists out of four tri-axial accelerometers with a gyroscope, that automatically processes input signals and provide objective measures related to four major components i.e. turning, gait, sit-to-stand and turn-to-sit during a ITUG protocol.[49] Participants were instructed to stand up from a chair, walking seven meters (instead of the traditional three meters of original Timed-Up-and-Go), turn, and walk back and sitting down again at their comfortable walking pace. Each participant had one practice trial and then two trails were recorded. The averages of the trails were used for data analysis. Testing was conducted at the participants home were there had to be at least a 7m flat walking space with good lighting. Tests were performed on solid flat surfaces, and not on carpets, and all tests were repeated in the same environment and surface for each test. The ITUG have shown to be a sensitive and reliable measure of mobility for PD ($p > 0.75$) for most spatiotemporal measures,[50] and showed that testing in a home environment is feasible.[51] The following gait parameters were recorded during the ITUG: Turn duration (seconds), turn velocity (degrees/second), and duration of Turn-to-sit (seconds).[50,52]

For the FGA participants completed a 10-item walking-based balance test, which includes walking forward, backward, with eyes closed, stepping over obstacles, changing gait speeds, with different head turns, and with a narrow base of support.[53] A higher total score signifies better balance with a maximum score of 30 (See Addendum I).

The Freezing of Gait Questionnaire (FoGQ) was developed in response to the difficulties of observing and quantifying freezing of gait (FoG) clinically as well as in laboratory settings.[54] The questionnaire is used to assess FoG severity unrelated to falls in individuals with PD, and furthermore to assess FoG frequency, disturbances in gait and relationship to clinical features conceptually associated with gait and motor aspects (e.g. turning). Currently, the full FoGQ was the only validated tool available to subjectively assess FoG. The questionnaire consists of six items[54]; four items assess FoG severity and two items assess gait. Responses to each item use a 5-point scale that ranges from 0 = absence of symptoms to 4 = most severe stage. Total score ranges from 0 to 24; higher scores correspond to more severe FoG. The reliability and validity of the FoGQ has been tested by numerous studies. According to Giladi *et al.* (2009)[55] the questionnaire has excellent test-retest reliability (r = 0.84; p = 0.56). The questionnaire also has excellent correlation (r = 0.66, p = 0.001) with UPDRS subscore II, and adequate correlation (r = 0.46, p = 0.004) with the Hoehn and Yahr disease stages during the ON phase.[56]

5.2.4 Statistical Analysis

Descriptive statistics are reported as percentages, number of observations (frequencies; *f*), mean ($\bar{x}$) and standard deviation (± SD), unless otherwise specified. Graphs show mean at pre and post with standard measure of error (SEM) bars. Data was assessed for normality and log transformed if not normally distributed. A Mann-Whitney U test was used for non-parametric ordinal data. A Multi-factorial ANOVA with a Fisher Exact Least LSD post-hoc test. When comparing the mean differences overtime between the four independent groups i.e. HB + F, HB + N, TS + F and TS + N, a one-way ANOVA was performed since parametric assumptions were satisfied. Level of significance were set at α = 0.05. Cohen's effect sizes (*d*) were used to determine differences between the groups in each condition and over time. Cohen (1988)[57] defined effect sizes as negligible^{N} ($d < 0.02$), small^{S} ($d = 0.2$), medium^{M} ($d = 0.5$) and large^{L} ($d = 0.8$).

5.3 Results

5.3.1 Participants

Eighty individuals with PD volunteered to participate in this study. After applying the inclusion and exclusion criteria, 57 participants were included in the study. Of the 30 participants assigned to the Therapist-supervised group, 24 participants completed the intervention; meeting all the requirements. Four of them did not complete the eight-week intervention with sufficient attendance, one sustained an injury at home and another changed medications and suffered subsequent falls at home. Of the 27 participants assigned to the Home-based group, 16 participants complied with all the requirements. Five participants did not complete the eight-week intervention due to insufficient adherence, a family crisis, or unavailability of their caregiver. Four participants suffered injuries unrelated to the intervention or had other pressing health concerns and two withdrew due to self-reported time constraints. Thus only the 24 Therapist-supervised participants and the 16 Home-based participants' data were used for analysis. No significant differences were found between the two groups at pre-testing ($p > 0.05$), except for height ($p = 0.03$). Participants were identified as Freezers if they scored one or more on Item 14 of the Unified Parkinson's Disease Rating Scale,[48] and based on this half (50%) of the Therapist-supervised and Home-based groups experienced freezing of gait, and are thus split into Freezers and Non-freezers (Table 5.1).

Table 5.1 Descriptive statistics between Non-freezer (N) and Freezers (F) in each group (mean ± SD)

	Non - Freezing		Freezing		p - Values	
	TS	**HB**	**TS**	**HB**	Between N & F	Between groups
Gender (n)	5 M 41.67%	7 M 87.50%	10 M 83.30%	7 M 87.50%		
Age	65.92 ± 6.88 (58 - 79)	63.63 ± 6.12 (55 - 74)	64.17 ± 9.49 (50 - 76)	66.25 ± 8.21 (55 - 78)	TS: p = 0.610 HB: p = 0.480	N: p = 0.447 F: p = 0.609
H&Y [M (IQR)]	2.5 (2 - 2.5)	2 (2 - 2.625)	2.5 (2.375 - 3)	3 (2.5 - 3)	TS: p = **0.0004** HB: p = 0.09	N: p = 0.983 F: p = **0.020**
Disease onset	2.33 ± 3.00 (0 - 8)	9.63 ± 14.16 (2 - 44)	4.75 ± 4.09 (0 - 14)	4.88 ± 4.58 (0 - 14)	TS: p = 0.113 HB: p = 0.382	N: p = 0.194 F: p = 0.951
Weight	74.36 ± 15.61 (52 - 97.5)	74.01 ± 11.53 (48.7 - 86)	85.63 ± 17.32 (69.8 - 126.7)	83.46 ± 12.75 (57.6 - 97.1)	TS: p = 0.110 HB: p = 0.142	N: p = 0.955 F: p = 0.751
Height	1.61 ± 0.08 (1.5 - 1.76)	1.74 ± 0.06 (1.64 - 1.8)	1.74 ± 0.1 (1.57 - 1.89)	1.75 ± 0.1 (1.53 - 1.86)	TS: p = **0.004** HB: p = 0.809	N: p = **0.001** F: p = 0.821
BMI	28.59 ± 6.12 (21.1 - 40.07)	24.43 ± 2.85 (18.11 - 27.45)	28.54 ± 6.09 (23.48 - 43.62)	27.24 ± 2.65 (24.61 - 32.44)	TS: p = 0.985 HB: p = 0.061	N: p = 0.057 F: p = 0.523
UPDRS II	9.25 ± 4.92 (3 - 19)	10.13 ± 5.69 (3 - 18)	15.83 ± 4.2 (10 - 22)	20.5 ± 6.37 (14 - 32)	TS: p = **0.002** HB: p = **0.004**	N: p = 0.601 F: p = **0.007**
UPDRS III	25.92 ± 14.16 (10 - 56)	32 ± 9.74 (17 - 47)	36.25 ± 9.21 (21 - 50)	39.88 ± 14.83 (18 - 63)	TS: p = **0.046** HB: p = 0.230	N: p = 0.267 F: p = 0.504
MoCA	26.17 ± 2.48 (21 - 29)	26.25 ± 2.66 (22 - 30)	25.33 ± 2.5 (20 - 30)	25.25 ± 1.98 (21 - 28)	TS: p = 0.421 HB: p = 0.408	N: p = 0.945 F: p = 0.935

NOTE. Values indicated as mean ± SD (range), unless otherwise specified. Bold values are significant; $p < 0.05$. BMI: Body mass index, UPDRS: Unified Parkinson's Disease Rating Scale, H&Y: Hoehn & Yahr, TS: Therapist-Supervised, HB: Home-based, M = Median; IQR = Interquartile range

Freezers and Non-freezers across both groups did not differ in age, disease onset, weight, and MoCA ($p > 0.05$). There were significant differences in the Therapist-supervised group between Freezers and Non-freezers for Hoehn and Yahr disease stages, height and UPDRS II and III. The Home-based group's Freezers and Non-freezers only differed significantly for UPDRS II, and furthermore had a strong tendency for BMI to differ and a weak tendency for Hoehn and Yahr stages to differ. The Freezers of both groups had a significant difference in Hoehn and Yahr disease stages and UPDRS II, whereas Non-freezers only differed significantly in height.

5.3.2 Turning Variables of Gait

No significant treatment effect (TIME x GROUP x FREEZING) was found for turn duration, turn velocity or turn to sit duration ($p > 0.05$). There was however a TIME x GROUP effect observed in turn to sit duration ($p < 0.0001$). At pre-tests the Therapist-supervised and Home-based groups did not differ significantly except for turn velocity ($p = 0.047$). Statistically significant differences between the pre-tests of the Freezers and the Non-freezers of the Home-based group was observed for all turning variables ($p < 0.006$), as well as significant differences between Non-freezers of the Therapist-supervised and Home-based groups ($p < 0.02$) (Table 5.2). The difference in change over time for each group and subgroup was not significant for turn duration ($p = 0.35$) and turn velocity ($p = 0.52$), but was significant for turn-to-sit duration ($p < 0.0001$). Both Freezers and Non-freezers from the Therapist-supervised group changed to the same degree ($p = 0.45$) over time, and changed significantly more than both subgroups of the Home-based group.

Table 5.2 Turning variables of Non-Freezers and Freezers of TS and HB group (mean ± SD)

	Non-freezing		Freezing		
	TS	HB	TS	HB	p-value
Turn Duration					
Pre	2.34 ± 0.44	2.48 ± 0.54	2.98 ± 1.1	4.53 ± 2.8	Within N TS: p = 0.93
Post	2.32 ± 0.42	2.44 ± 0.63	2.49 ± 0.58	4.09 ± 2.21	Within N HB: p = 0.91
% diff	-0.86	-1.3	-16.53	-9.7	Within F TS: p = 0.04
ES	0.05^{N}	0.06^{N}	0.59^{M}	0.19^{S}	Within F HB: p = 0.13
Turn Velocity					
Pre	155.98 ± 20.09	149.62 ± 27.39	137.39 ± 23.47	103.34 ± 29.35	Within N TS: p = 0.66
Post	159.1 ± 28.94	159.77 ± 28.46	154.62 ± 27.12	108.7 ± 28.63	Within N HB: p = 0.25
% diff	2.00	6.78	12.54	5.19	Within F TS: p = 0.02
ES	0.13^{N}	0.39^{S}	0.71^{M}	0.20^{S}	Within F HB: p = 0.53
Turn-to-sit Duration					
Pre	4.15 ± 0.66	3.97 ± 0.46	4.77 ± 1.18	6.92 ± 3.02	Within N TS: p < 0.001
Post	2.55 ± 0.57	4.1 ± 0.76	2.43 ± 0.62	7.1 ± 4.62	Within N HB: p = 0.77
% diff	-38.51	3.25	-49.02	2.56	Within F TS: p < 0.001
ES	2.70^{L}	0.22^{S}	2.59^{L}	0.05^{N}	Within F HB: p = 0.69

Note. Values shown are pre- and post-intervention means ± standard deviation (SD) and effect size (ES). Percentage differences (% diff) between pre and post tests are shown. HB = Home-based, TS = Therapist-supervised, N = negligible effect size, S = Small effect size, M=medium effect size, L = Large effect size.

5.3.3 Functional Gait and Balance

There was no statistically significant treatment effect (GROUP X TIME X FREEZING) (p = 0.542). Freezers differed significantly to Non-freezers in both groups at pre and post (p < 0.05) (Figure 5.2). Non-freezers in the Therapist-supervised group improved by 5.6% (p = 0.09; *d* = 0.34^{S}) while freezers improved with 14.4% (p =0.003; d = 0.54^{M}). In the Home-based group, Non-freezers improved by 8.8% (p = 0.03; *d* = 0.20^{S}) while Freezers improved by 28.7% (p < 0.001; *d* = 0.86^{L}). However the difference between the changes over time for all groups was not significant, but showed atendency to differ (p = 0.058).

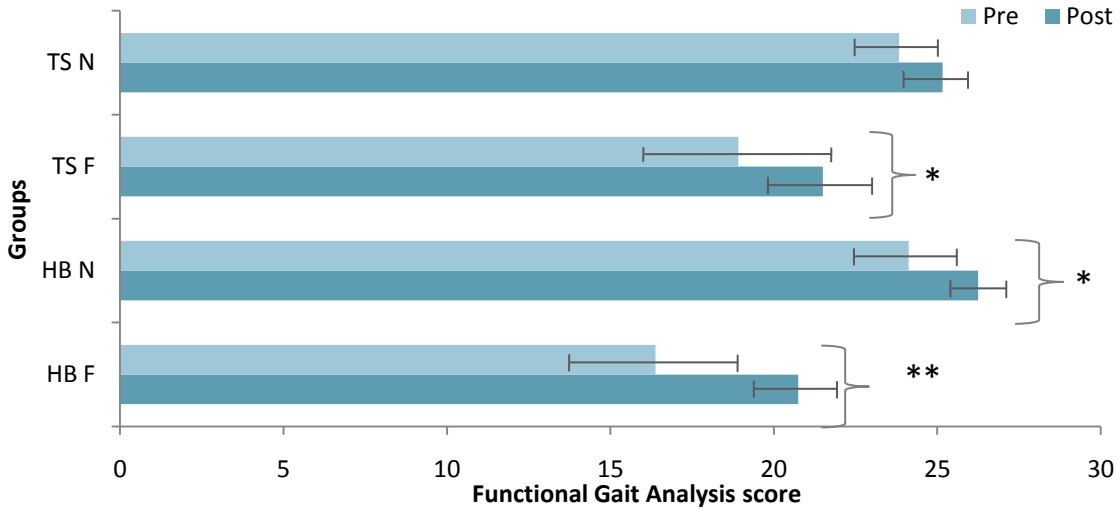

Figure 5.2 The change in functional gait and balance scores of Freezer (F) and Non-freezers (N) of both Home-based (HB) and Therapist-supervised (TS) groups over eight-week intervention. *p < 0.05; **p < 0.001

5.3.4 Self-reported Freezing of Gait

There was no statistically significant treatment (GROUP x TIME) effect for self-reported FoG. However both groups experienced a statistically significant difference form pre to post with a decrease of 17.8% (p = 0.042; $d = 0.22^{S}$) for the Therapist-supervised group and a 16.9% (p = 0.045; $d = 0.24^{S}$) decrease for the Home-based group (Figure 5.3).

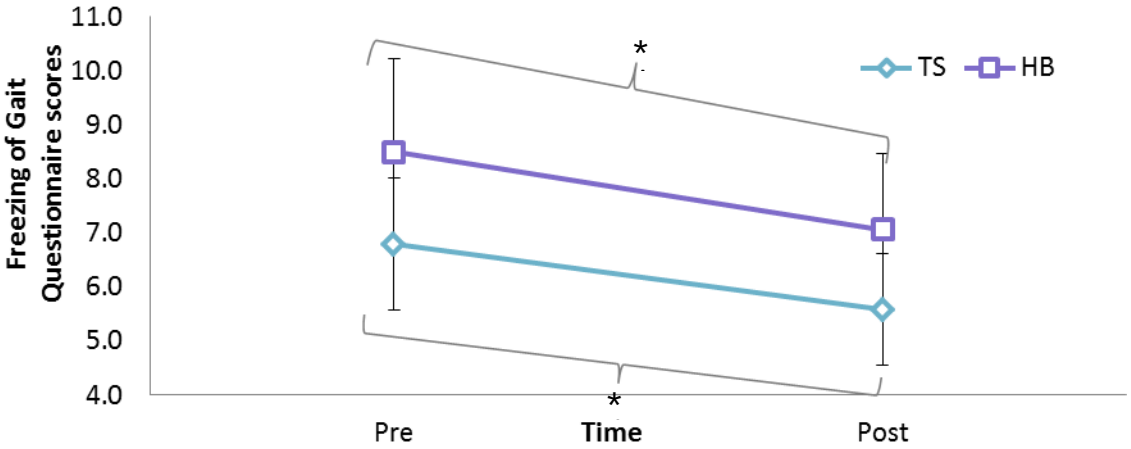

Figure 5.3 The change in self-reported freezing of gait over the 8 week interventions for both HB and TS groups ($\bar{x}$ ± SEM). *p = 0.05

5.3.5 Disease Severity

For disease severity rated by the UPDRS subscale II there was a treatment effect (GROUP X TIME X FREEZING) ($p < 0.0001$). Freezers differed significantly from Non-freezers in the Therapist-supervised group by 52.5% ($p < 0.001$; $d = 1.50^{L}$) and Home-based group by 67.8% ($p < 0.001$; $d = 1.84^{L}$). The Non-freezers in each group did not differ ($p = 0.60$; $d = 0.18^{S}$), but Freezers differed from one another by 25.7% ($p = 0.01$; $d = 0.95^{L}$). None of the groups improved significantly over time ($p > 0.05$) (Figure 5.4)

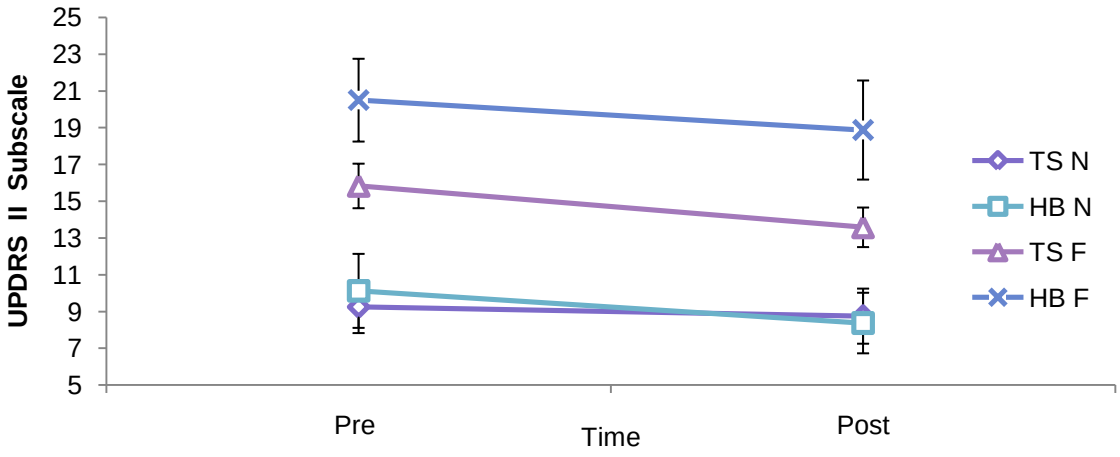

Figure 5.4 Disease severity measure with UPDRS II from pre- to post-test, for Freezers (F) and Non-freezers (N) in Therapist-supervised (TS) and Home-based (HB) group ($\bar{x} \pm$ SEM).

5.4 Discussion

The main findings for this study are that both groups' Freezers experienced a decrease in reported duration and frequency of FoG after the intervention. Freezers also performed significantly worse in dynamic balance measurements and turning variables at pre-test. However Freezers in both groups improved their functional gait more than Non-freezers after the intervention. Only the Freezers in the Therapist-supervised group improved their turning duration, turning velocity and turn-to-sit duration at post-tests. It was found that Freezers have significantly higher disease severity, affecting and interfering in their daily activities of living.

Freezers differed from Non-freezers within each group. For instance, in the Therapist-supervised group there was a significant difference in height between Freezers and Non-freezers, which can be explained by the gender difference. The Non-freezers only consisted of 5 (42%) men whereas the Freezers group had a total of 10 (83%) men. In the Home-based group there was a tendency for BMI to differ between Freezers and Non-freezers ($p = 0.061$), as well as Non-freezers to differ from each other ($p = 0.057$). An elevated BMI have been associated with a decrease in balance[58], but that is mostly for BMI measures above 30 $kg.m^{-2}$. However none of the group means exceeded that measurement point, although all groups would be classified as overweight. Significant differences in disease severity was also observed. Harrison and colleagues (2011) showed that the UPDRS II score have a greater relationship to disease severity and progression than any of the other sub-scores of the UPDRS when ON medication.[59] This is possibly because it quantifies the impact of the disease on activities of daily living during the normal course of an individual day[59], instead of clinical observations as in UPDRS III. The Freezers in both groups had significantly higher scores, where the Freezers of the Therapist-supervised group had 52.5% and the Home-based group 67.8% higher score, respectively, than their non-freezing counterparts. Only the Therapist-supervised Freezers had a significantly higher Hoehn and Yahr rating ($p < 0.001$), whereas the Home-based Freezers did not ($p = 0.09$). Interestingly the Freezers from the two groups differed significantly (Table 5.1).

Both intervention groups reported significantly less freezing after the intervention with the FoG questionnaire. In a previous study[29] a 5.5% reduction in questionnaire score has been stated to be clinically significant. In the current study the Therapist-supervised group had a 17.8% reduction and the Home-based group had a 16.9% reduction. This reduction follows the same pattern as the slight non-significant improvements in UPDRS II scores. This is consistent with the findings of Nilsson and Hagell (2009) who also reported an excellent positive relationship ($r = 0.66$) between the UPDRS subscore II.[56] Giladi and colleagues (2009) also found that the FoGQ is more sensitive to changes in FoG episodes than item 14 of the UPDRS, because it quantifies frequency

and duration of various types of FoG[55] and not just the presence of it. Considering that FoG is difficult to test clinically, the benefit of the questionnaire is that it provides insights into FoG throughout the whole day.[60] The significant reduction in freezing shows that balance training can improve the frequency and duration of freezing. Previous studies showed similar results, but found that effects were short-lived.[29,40] One limitation to the current study is that no follow up data was collected. Hence future longitudinal studies are needed.

It is difficult to determine whether the intervention resulted in improved dynamic balance which led to less FoG or whether it caused freezing to occur less which resulted in improved dynamic balance and gait. However since all the Freezers and the Therapist-based Non-freezers improved significantly in the dynamic balance, concluded from the FGA results, it more supports the argument that improved dynamic balance led to less FoG. Freezers from both groups significantly improved their FGA scores between 3 – 5 points; the minimal detectable change is 4.2 points, as established by Lin *et al*. (2010) with stroke patients.[61] Freezers and Non-freezers in both groups differed significantly from one another at pre-test which may indicate the effect freezing has on functional gait. The Home-based group's Freezers scored 15/30 at pre-test, which has been shown to be the cut-off score[53] for identifying individuals at higher fall risk. This group was able to improve by 5 points, not only reducing their fall risk but also achieving a clinical significance and large effect size. None of the groups improved to a greater extent than the other, which again attested to the effectiveness of the balance programme to improve dynamic balance and thus functional gait. Studies have revealed that PD individuals who experience FoG have greater asymmetry in their gait and turning[62] and less coordination.[63] This results in them having worse balance than non-freezing PD individuals, especially concerning gait stability and reactive balance.[24]

Turning is widely known to possibly increase FoG, and is also best related to disease progression compared to other gait parameters.[64] This could be due to various factors such as the asymmetry of turning, combined with the asymmetry of the disease, the timing and coordination

involved during turning, as well as weight shifting[62] and postural instability that are aspects of turning.[24;25] According to Duncan and colleagues (2015) these are the reasons for PD individuals turning slower plus using compensatory mechanism to achieve a safe turn. The current study show definite differences between duration and velocity of Freezers and Non-freezers, especially in the Home-based group which had a significantly higher disease severity according to the UPDRS subscore II, which have been linked to disease progression.[59] The Home-based group had significant differences between Freezers and Non-freezer at pre-test, indicating Freezers took longer to turn 180° and also had significantly less velocity in agreement with the study by Bhatt and colleagues (2013). Interestingly the Therapist-supervised Freezers group was the only to improve significantly after the intervention. Thus the balance training helped them to improve their turn duration by 16.5%, whereas the Home-based group only improved by 9.7%, and increased their turn velocity by 12.5%, compared to 5.2% for the Home-based group's Freezers. The Non-freezers did not improve their efficacy of turning to such an extent as the Freezers. The reason for the increase efficacy of turning can possibly be attributed to improved balance and gait due to external cues from the therapist. External cues[29,39,40,65] have been shown to reduce the incidence of freezing. Cueing can decrease cadence which results in less FoG but it can lead to an increase in turn duration,[62] although it is a more stable turn. Thus it is difficult to conclude whether the cues helped turning efficacy or not. Although the DVD that the Home-based group followed had the exact same cues and demonstrations as used in the Therapist-supervised group, the small amount of feedback, personal attention and social group dynamics could have led to greater increase in performance. In previous studies[66,67] this phenomenon has also been noticed, concluding that exercises done at home can lead to some improvements but exercise with a therapist lead to greater improvement in performance and perception of improvement.

In this study the duration of the turn-to-sit was also recorded, as this is a functional every day movement that might provide insight into the efficacy of the intervention. Interestingly only the Therapist-supervised group, Freezers and Non-freezers, experienced improvement in that and

both subgroups almost halved their time. The argument for this improvement is the setup of the group classes that perhaps contained more commands to sit down than the Home-based group, who could have just not done the movements.

In conclusion, this study has verified that individuals who experience freezing are likely to have higher severity of the disease and less functional mobility, including gait and turning ability. An eight-week balance intervention with a therapist can improve the efficacy of a turn when the exercises are presented by a qualified exercise therapist. Home-based training does not seem to be nearly as effective as Therapist-supervised training in improving turning ability, but it is however effective in reducing self-reported FoG severity. Future studies might benefit from investigating the effect of balance training of FoG and turning ability ON and OFF medication, as it might be a more accurate representation of real life scenarios.

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Chapter 6

General Discussion and Conclusion

6.1 Introduction

The main aim of this study was to compare an eight-week home-based balance training programme with a therapist-supervised programme on the dynamic balance of independent-living individuals with Parkinson's disease (PD). The secondary aims were to determine if the eight-week balance training programme would improve perceived fall risk and balance confidence in individuals with mild to moderate PD. To answer these research questions, the study assessed dynamic balance and mobility, specifically stability in gait, the influence of dual tasking on gait and mobility, freezing of gait, perceived fall risk as well as balance confidence, and the participants' perception of the two modes of exercise programme delivery.

The main findings from this study were that both groups improved their functional gait and stride length after the intervention, as well as their self-reported freezing of gait scores. The therapist-supervised group improved other parameters of gait, including stride velocity and cadence, dual-tasking gait as well as all aspects of turning ability. In addition, the therapist-supervised group was the only group to improve their gait variability of stride length and velocity, and balance confidence significantly. Whereas the home-based group on the other hand had a reduction in motor symptom-related disease severity, as measured by the MDS-UPDRS III, but had no improvements in dual-tasking gait and turning unlike the therapist-supervised group.

The possible primary reason for similarities found in some of the results between the groups, might be due to 1) the PD individuals' impaired balance (Jankovic, 2008) which allows for greater room for improvement, and 2) the effectiveness of the balance programme to cause such significant improvements. While the main reasons for the differences in the results between the two groups could likely be attributed to the effects a therapist has on a group, the nature of group

exercises and the accompanying motivation, which is usually problematic in PD individuals (King *et al*., 2015; Kalia & Lang, 2015; Martin *et al*., 2005). Additionally the possible difference in disease severity between the groups, albeit not significant, and the heterogeneity in PD could have caused the participants to react differently, which may have affected results. Martinez-Matin *et al*. (2015) re-evaluated the cut-off values for the UPDRS to define disease severity and found that 32/33 is the cut-off point between mild and moderate PD. Using this scale the therapist-supervised could be classified as mild PD and the HB group as moderate. Both Canning *et al*. (2015) and Albani *et al*. (2014) found that individuals with a higher disease severity reacted differently to interventions and tests, highlighting the physical, motor and non-motor differences in different stages of the disease, which is also associated with different disease progression rates (van Rooden *et al*., 2011). It is these differences which contribute to the heterogeneity in PD (Jankovic *et al*., 1990). Other researchers have reported on different types of phenotypes found in PD populations i.e. tremor-dominant (TD) and postural instability/gait disturbance-dominant (PIGD) types (Herman *et al*., 2014; Stebbins *et al*., 2013; van Rooden *et al*., 2011). Clinically the TD subtype has less balance and gait deficits compared to PIGD. This suggest that different types of PD may have different neural pathways involved, which may also contribute to individuals responding differently to activities depending on their PD phenotype. However others have found no significant difference between TD and PIGD types for gait variability, speed and stride length (Herman *et al*., 2014). In the current study, no statistical significant differences were found between the groups for the H&Y and MDS-UPDRS II and III at pre-testing, except between Freezers and Non-freezers within each group. Nevertheless, when considering that the minimal detectible change (or difference) for MDS-UPDRS II and III has been reported as a difference of more than 2 and 3.5 points, respectively (King *et al*., 2015; Horváth *et al*., 2015), then the two groups which differed by 3 and 6 points between UPDRS II and III, respectively may have been considered as having clinically different disease severity status.

Independence and functionality for activities of daily living, are largely dependent on dynamic balance and mobility of individuals with PD (Jacobs, 2014). The study revealed that dynamic balance and functional gait can improve with a home-based balance training programme to the same significant extend as a therapist-supervised group. The functional gait analysis assessed the individual's ability to manipulate and control their speed of walking, direction changes, base of support and obstacle clearance (Leddy *et al*., 2010). This offers good evidence which supports the success of the programme as a method to facilitate dynamic balance and gait improvements.

Significant improvements in stride length were also found in both groups, but the therapist-supervised group improved even more with their stride velocity, cadence and turning ability. These improvements are of great importance and clinical significance because numerous studies have reported that SL and SV are the two gait parameters that differ the most between healthy age-matched controls and PD individuals (Albani *et al*., 2014; Roiz *et al*., 2010 & Yang *et al*., 2007). Turning abilities of PD individuals are also severely affected, especially if the individual experiences freezing of gait, which often leads to falls (Lieberman, 2014; Bloem *et al*., 2001). One question which may be asked is why the two groups can result in similar outcomes for the above-mentioned aspects but not for others? The only likely answer seems to be the difference between the therapist and the group en environment. The exercise therapist is able to provide augmented real time feedback and can also enforce certain principles stressed in the programme. These principles are explained in the DVD and booklet accompanying the DVD, but it is difficult to measure to what extend the home-based participants and their caregivers followed the DVD's instructions.

In a recent article by King and colleagues (2015) stated that the "*wha*t" of an exercise programme have been researched multiple times and over many years, but the "*how*" of the programme might be the most important part. They researched individual sessions with a physiotherapist, compared to group classes with a physiotherapist as well as a home-based programme. They found that the individual sessions improved the most in functional and balance

measures, and the group classes resulted in greater improvements in gait, while the home-based group improved the least across all outcome measures (King *et al*., 2015). Their explanation for improvement in gait in the group class links to the relationship between cognition and gait, which has also been supported by other researchers (Kelly *et al*., 2015; Hausdorff *et al*., 2003). Consequently during group classes more interaction is involved between the participants and therapist, which could result in a greater emphasis on cognitive function and divided attention when compared with exercising alone.

This relationship between cognition and gait, and the effect of the group environment, might explain why only the therapist-supervised group improved in dual-tasking gait. The dual-tasking gait performance of the home-based group worsened in duration of CTUG and cadence after the intervention. The home-based group had greater dual-tasking interference for duration, SV, cadence and time in double support. This means that those aspects which improved for single-tasking gait, did not show the same improvements when a secondary cognitive task was added, since their gait performance declined. While in the group environment the participants were using dual-tasking more often and subconsciously than what the actually exercises about dual-tasking entailed (Hausdorff *et al*., 2003). Subconscious dual- or multi-tasking during therapist-supervised sessions could have occurred by having to follow the therapist, by other participants distracting them, or by chatting to one another during some exercises. The home-based group did not experience this to the same extend, although they also had some dual-tasking elements in their program i.e. watching and listening to the DVD as well as their caregiver. However the amount of subconscious dual-tasking that they were exposed to was more in their control, unlike having to adapt to the group setting.

Other aspects that could have influenced dual-tasking are freezing of gait, and possibly clinically significant differences in disease severity. Disease severity did not differ significantly but the home-based group had consistent had higher score on the MDS- UPDRS, for all subscores, which bears clinical significance as previously discussed (Herman *et al*., 2014). This became even

more apparent when the groups were divided into freezers and non-freezers; with the freezers having significant higher scores on the MDS-UPDRS, especially for motor and activities of daily living (ADL) subscores. Although 50% of the home-based group reported experiencing FOG (same as in the therapist-supervised group), it could indicate that the freezers in the home-based group experienced freezing more severe than the therapist-supervised group.

Freezing of gait might already occur due to subconscious dual-tasking competition, according to dual-tasking theories stated by Strouwen *et al*. (2015), and thus conscious deliberate dual-tasking may exacerbate gait difficulties associated with FOG and dual-tasking (Strouwen *et al*., 2015; Siu & Woollacott, 2007). This is of interest because both groups reported to have significantly less FOG after the balance training, but this did not seem to affect the degree of the dual-tasking interference experienced by the home-based group. Furthermore it did not affect or improve the turning abilities of the home-based group's single-tasking gait. Only the freezers of the therapist-supervised group significantly improved their turning duration and velocity, and both freezers and non-freezers of the therapist-supervised group improved their duration of the turn-to-sit transition. This again underscores the effect of a therapist, who can provide feedback, as well as the class environment where more turning maneuverers were done when listening to instructions or looking at demonstrations.

The presence of an exercise therapist and the class environment might also be a very important aspect when looking at subjective measurements such as balance confidence and self-perceived fall risk (King *et al*., 2015). Both groups had a reduction in self-perceived fear of falling, as measured with the FES-I, although these reductions were not significant. Morgan and colleagues (2013) found that a change of greater than 8.2 points is the minimal detectable change; both groups only experienced a change of ~3 points from pre to post. However, when separating the questionnaire into freezers and non-freezers, it shows that freezers had more concerns about falling with scores higher than 7 points for both groups. The home-based non-freezers group were the only group who improved their perceived fall risk significantly. Perhaps this could be due to

exercises done in a home-based environment might translate more into real life experiences. This was observed in a study by Clemson *et al*. (2010) who found that home-based balance exercises for at-risk elderly led to decrease in falls, and increase in dynamic balance and self-efficacy beliefs. The home-based freezers did not improve significantly perhaps because of the nature of freezing of gait, making them more cautious and concerned about falling in real life situations (Canning *et al*., 2014). The non-freezers were less concerned about falling than the freezers to start with but then experienced a further reduction in perceived fall risk perhaps because the home-based exercises made them more aware of how to avoid and compensate in situation where their safety is compromised. In contrast the therapist-supervised group, i.e. freezers and non-freezers, did not experience this although they did improve in objective measures of dynamic balance and other fall risk factors. This could be due to their improvements being based, and facilitated by, the presence of a therapist, and therefore become reliant of the therapist. When asked about daily situations that occur outside the exercise location (as is asked in the fall efficacy questionnaire), the therapist-supervised group did not significantly feel less concerned about falling, even though their actual fall risk might have been lower due to improvements in dynamic balance (Clemson *et al*., 2010). Their balance confidence, on the other hand, did improve significantly whereas the home-based group had non-significant increase in balance confidence. This result was also noted in King's study (2015) where only the group class had improvement in balance confidence, although the individual therapy resulted in actually improvement in balance. The overall movement, interaction, and accidental environmental dual-tasking that takes place during class activities may improve participant's perception of balance control (King *et al*., 2015; Zivotofsky and Hausdorff, 2007).

To determine whether a home-based exercise programme is really effective, one has to consider how the participants experienced the programme, and what the obstacles were that may have hindered them. To achieve this one has to look at adherence, motivation, quality of experience as well as perceived quality of the intervention. The exercise therapist recorded/noted adherence during class sessions or via a weekly phone call to the home-based participants. The

minimal adherence rate was preselected at 70%, which Allen and colleagues (2010) established to be a sufficient adherence rate to achieve changes for individuals with PD over the course of a 6 week multimodal intervention. The therapist-supervised group had an average of 89% adherence, ranging from 71 – 100%; there were 4 participants who didn't achieve sufficient adherence and were thus excluded. From the home-based group there were 5 participants who had insufficient adherence and 2 participants who withdrew due to time constraints, and thus the remaining 16 participants had quite a high adherence of 97% (ranging from 89 – 100%). Despite the high adherence of the home-based group, improvement in dynamic balance and mobility did take place but was not as high as the therapist-supervised group.

Other factors affecting adherence could be closely linked to motivation as well, which has been found in previous research as limited in PD individuals (Jankovic, 2008). These factors can include clear and understandable communications with the therapist or researcher about the aims of the exercises as well as proposed values (Martin *et al*., 2005); trust in the therapist plays a vital role (Bollen *et al*., 2014); and furthermore personal connection and support, and an inclusive and empathetic environment for various beliefs, socioeconomically status, and attitudes can enhance adherence (Bollen *et al*., 2015; Martin *et al*., 2005). Allen *et al*. (2015) recently confirmed that social support, emotional health and physical condition, including PD duration and pain, might also play a role in adherence and motivation to do exercises.

Home-based care is the form of care most used and most accessible to PD individuals and perhaps a one-dimensional adherence score of an intervention programme does not give sufficient evidence about how the programme, and its benefits were perceived. Therefore after the intervention programme participants from each group were asked to complete the shortened Intrinsic Motivation Inventory (IMI), which tests the degree of motivation of a participant while performing a certain activity. This is a multidimensional questionnaire with five subscales i.e. interest/enjoyment, perceived competence, effort/Importance, pressure/tension and value/usefulness (Weisera & Garibaldi 2015; Khalil *et al*., 2011). Intrinsic motivation is considered

to be measured with the interest/enjoyment subscale; and positive predictors and behavioural measures of intrinsic motivation are measured with subscales of perceived competence, effort/importance, and value/usefulness; with higher scores indicating better motivation. A negative predictor of intrinsic motivation is the pressure/tension subscale is considered, with better motivation indicated with lower scores (Weisera & Garibaldi 2015). The participants completed the IMI as soon as possible after the cessation of the intervention. Only in the interest/enjoyment subscale was there a significant difference, with the therapist-supervised group scoring 92% and the home-based group scoring 75%. There were no statistically significant differences in any of the other subscales. Perceived competence received a score in the 70% bracket, groups differed with 1%; effort/importance scored in the 80% bracket, therapist-supervised group scoring 4% more than home-based group; pressure/tension scored below 40%, with the home-based group scoring 6% lower than the other group and lastly values/usefulness received a score of 93% in the therapist-supervised group and the home-based group scoring 88%. The main conclusion from this questionnaire is that the therapist-supervised group enjoyed the intervention and exercises significantly more and viewed its value as higher than the home-based group.

To receive a better idea of how the DVD was received by the participants, they were asked to complete an additional survey regarding the DVD (Addendum M). The subscales for the DVD survey included ratings about the DVD (presentation, clear verbal and visual instructions, user-friendly); about the programme (frequency, duration, progression, space and equipment); and lastly about aspects concerning a home-based programme (caregivers, safety, repeatability, recommendations, social component). The latter are the aspect of keen interest to us for this study. Of the 15 participants who completed the survey, 76% felt that the caregivers contributed to the programme, 81% said that they would repeat the programme because they feel that it is useful to them, 88% said they would recommend the programme to friends, family and other PD individuals, 91% stated that they felt safe during the exercises and 66% said that they would have had greater

enjoyment in a more social environment. This supports the finding of the interest/enjoyment subscale of the IMI.

6.2 Study limitations and Future studies

The study is limited by the following factors:

- There was no non-exercising control group part of the study to account for the Hawthorne effect. This would have made the results from the study stronger, and allow the data to be compared to no intervention.
- A bigger sample size would have contributed to the power of the analysis, but due to limited human resources, financial resources, geographical factors, time and inclusion/exclusion criteria this was difficult.
- A retention period would have added a lot of value to the study. Future studies should include retention or follow-up periods to measure the longevity of the exercise programme, as this will provide insight into the retention of the balance improvements.
- The fact that the participants were based on a sample of convenience also limits the study, but it was selected to make the best use of possible resources. Future studies need to ensure that groups are randomized to make the data more applicable to the general population, and not just the northern of southern suburbs of a town.
- Evaluators were not blinded to group selection. This might have made the result biased. Future studies need to aim to use blinded evaluators as this will make results more accurate.
- Kelly *et al*. (2015) reported that PD phenotype differences exist when assessing specific cognitive domains and postural instability. They stated that postural instability and gait dysfunction (PIGD)-dominant phenotypes have greater global cognitive impairments, more MCI prevalence and an increased risk for dementia, compared to tremor-dominant PD. The

current study did not assess groups to determine their phenotype, which suggests that some individuals may have responded to the intervention and testing based on their phenotype more readily.

- Home-based exercises always run the risk of not showing improvement simply because participants might exaggerate their participation. It is also difficult to ensure that home-based intensity were kept consistent with the therapist-supervised intensity, and furthermore the quality of movement cannot be held at the same standard with a home-based group.
- Future studies would benefit from adding arm swing parameters to their measurements, as it will give them full-round analysis of gait. Unfortunately in this study it was not possible, as the equipment was limited.
- Future studies would benefit from using kinematic analysis of gait in conjunction with spatio-temporal measures as it allows the researcher to describe characteristics of gait more accurately. Again, this was not possible in the current study due to equipment limitations.
- A limitation for the study was the confounding factor of the social interaction of the group exercises. Group exercises were chosen for practical reasons, but it has led to a greater influence on outcome measures than anticipated. Future studies could compare one-on-one home-based training to one-on-one therapist training for a more direct comparison.
- In future studies where number of participants might be bigger, researchers should consider using an analyisis of covariance. This will help to exclude the effect of cofounding variables on the results. In the current study, none of the variables differed significantly at pre-tests, except for stature. However stature was normalized for gait variables, and therefore did not impact the data. Disease severity might have shown a clinical difference but not statistical one, and thus in future studies with more power a difference might be evident. Using an analysis of covariance should be considered when that is the case.

6.3 Conclusion

Home-based exercises are currently the standard of care in developed countries, because it is affordable, easily accessible, do not require transportation and also do not challenge PD individuals who sometimes prefer social isolation. There are is unfortunately even greater barriers in a developing country such as South Africa, where home-based exercise information is not easily available. Because of the inconsistent help that PD medication offers, it was important to test the efficacy of a home-based balance training programme on dynamic balance of independent-living PD individuals.

The results from this study show that home-based balance training can improve dynamic balance and mobility by increasing stride length and functional gait, but therapist-supervised training has a greater improvement. To receive optimal improvement from the balance training working with an exercise therapist would be best, but for PD individuals who have mild disease severity and do not experience FoG a home-based programme could also be recommended. For individuals with moderate disease severity, experiencing FoG or having difficulty with dual-tasking, therapist-supervised training would be best suited. These individuals would gain more from specialized directed training, including certain cueing from a therapist.

In conclusion, if therapist-supervised balance training is at all possible it is recommended to start training to improve independent living. Home-based training would be a second option as it will still lead to improvements if you have sufficient adherence and motivation. Further research is needed to examine what intensity of balance training offers the best improvements, and the longevity of these improvements.

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Addendums

Table of Contents

A. Addendum A – Informed consent

UNIVERSITEIT•STELLENBOSCH•UNIVERSITY
jou kennisvennoot • your knowledge partner

STELLENBOSCH UNIVERSITY

CONSENT TO PARTICIPATE IN RESEARCH

The Efficacy of home based balance training on dynamic balance in independent-living individuals with Parkinson's disease.

You volunteered to participate in a research study conducted by Elizma Atterbury (Main researcher, Biokineticist & MSc Student) and Dr Karen Welman (Study Leader & Biokineticist) from the Sport Science Department at Stellenbosch University. The results will contribute to a research paper and MSc Thesis, as well as to the pool of knowledge on Parkinson's disease. You were selected as a possible participant in this study since you meet the inclusion criteria, for this study.

1. PURPOSE OF THE STUDY

Main aim:

To compare a home-based balance training programme with a therapist-supervised programme on the dynamic balance of individuals with mild to moderate Parkinson's disease (PD).

2. PROCEDURES

You will be visited three times; at your place of residence. Each visit will last between 30 and 60 minutes.

The first contact session will be done through a telephonic interview and you will be asked to verbally give consent to participate in the study. Hereafter you will be given enough time to ask questions. Only after you have given consent and if you qualify for the inclusion criteria will you be included in the study. You will be informed about the five questionnaires, as well as this informed consent form, that will be sent to you and which you need to complete before our next session.

During the second visit, we will measure your height and weight. In addition, the Instrumented timed up and go test (ITUG) and functional gait assessment (FGA) will be used to assess your gait and lastly the cognitive timed up and go test (CTUG) will be used to assess your dual-tasking ability. During the third visit, after the eight weeks of balance training, all the tests and questionnaires will be repeated to see if there are any changes. We want to test you in the same medication state, so kindly just note at what time you take your last medication before the testing. We will then replicate this at the post testing by keeping the testing time the same.

3. INTERVENTION

The balance training will take place over an 8-week period. There will be 3 sessions every week, each having different goals and objectives. Specific tactile cues will be added to each session and the therapist as well as caregivers will be obligated to perform certain touch-related cues as part of the balance training intervention.

Therapist-supervised training group (TS)

If you are selected for the therapist-supervised group, you will perform training led by a Biokineticist (an exercise therapist specialising in rehabilitation), starting with a 10 minute warm-up, followed by 15-40 minutes (dependent on week) of challenging balance training, where you will be given short rest periods in between the exercise sessions. Lastly, the sessions will be ended off with 10 minutes cool-down and relaxation technique activities.

Home based training group (HB)

If you are selected for the home-based training group you will receive a DVD with instructions on how to perform the exercises. You will receive a new DVD each week, adding up to 8 volumes in total. Each volume will contain clear instructions that you and your caregiver must follow closely. You will be contacted weekly via telephone to record adherence and to discuss any problems that you might experience.

4. POTENTIAL RISKS AND DISCOMFORTS

The procedures used in this research project involve no serious risks. We will do all within our power to reduce possible risks. There is a possibility that you may experience a loss of balance or near-falls during some of the balance assessments. However, there will be a chair behind you and soft gymnastic mats will be placed

around the testing area to prevent injury. You will be assessed away from obstacles and in a safe environment without distractions. You may also stop at any time if you feel that you cannot continue the activity. There will also be 1 or 2 research assistants, who are qualified biokineticists, to assist the researcher during training. Furthermore, you will be more than welcome to talk to us in case you experience any problems. If you are not able to contact us for some reason, you are advised to contact your family doctor or go to the emergency department of your local hospital.

We are competent and experienced in exercise testing and will not expose you to unnecessary risks or discomfort. Health and safety procedures are in place to deal with emergencies that may arise during the tests, i.e. a first aid kit, as well as Netcare Stellenbosch (082 911) and/or Stellenbosch Medi Clinic (021 861 2000). We want to remind you that your participation is voluntary and that you are free to withdraw from the research at any time, with no prejudice or discrimination by Stellenbosch University or the researchers.

5. POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

You will benefit directly by taking part in this study, as you will participate in a training program for 8 weeks. You will also be learning more about Parkinson's disease and will contribute to the pool of knowledge on ways to improve quality of life and decrease the risk for falls in individuals with PD.

6. PAYMENT FOR PARTICIPATION

There is no cost involved to participate in this study. This is a research study and not part of a treatment plan or diagnosis of Parkinson's disease. Participation is voluntary and therefore you will not receive any payment by taking part in our study.

7. 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 storing personal information and results from testing on a computer with a password. This computer is located inside the Motor Learning Laboratory in the Sport Science Department and access to it is limited to the project supervisor and the researchers.

If the article is published, your name will not be mentioned and all personal information will be kept anonymous. Results will be given as averages, percentages, etc. of the entire group and no exceptions will be made.

8. 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.

If you find out that you have any other neurological conditions (e.g. Diabetes, stroke) or either visual or vestibular problems you will not be allowed to continue testing. If you sustain any muscular injuries you will also be asked to withdraw from testing.

9. IDENTIFICATION OF INVESTIGATORS

If you have any questions or concerns about the research, please feel free to contact Dr Karen Welman [welman@sun.ac.za; 021 808 4733 or 082 098 5387] or Ms Elizma Atterbury [15670953@sun.ac.za; 072 952 2567] at the Sport Science Department of Stellenbosch University.

10. 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.

SIGNATURE OF RESEARCH SUBJECT OR LEGAL REPRESENTATIVE

The information above was described to _____ [*me/the participant]* by _____ [*name of relevant person]* in _____ [*Afrikaans/English/Xhosa/other]* and _____ [*I am/the participant is]* in command of this language or it was satisfactorily translated to _____ [*me/him/her*]. _____ [*I/the participant]* was given the opportunity to ask questions and these questions were answered to _____ *[my/his/her]* satisfaction.

[I hereby consent voluntarily to participate in this study/I hereby consent that the participant may participate in this study.] I have been given a copy of this form.\

_____

Name of Participant

_____ _____

Signature of Subject/Participant or Legal Representative Date

SIGNATURE OF INVESTIGATOR

I declare that I explained the information given in this document to _____ [*name of the participant]* and/or [his/her] representative _____ [*name of the representative]. [H*e/she] was encouraged and given ample time to ask me any questions. This conversation was conducted in [*Afrikaans/*English/*Xhosa/*Other*] and [*no translator was used/this conversation was translated into* _____ by _____].

_____ _____

Signature of Investigator **Date**

B. Addendum B – Letter of Submission

----Original Message-----
From: ees.gaipos.0.33829c.e40d36ba@eesmail.elsevier.com [mailto:ees.gaipos.0.33829c.e40d36ba@eesmail.elsevier.com] On Behalf Of Gait & Posture
Sent: 25 October 2015 09:37 PM
To: Welman, KE, Dr <welman@sun.ac.za> <welman@sun.ac.za>
Subject: Submission Confirmation

Dear E Atterbury,

Your submission entitled "Balance training in individual's with Parkinson's disease: Therapist-supervised vs. home-based exercise programmes ." has been received by Gait and Posture

You may check on the progress of your paper by logging on to the Elsevier Editorial System as an author. The URL ishttp://ees.elsevier.com/gaipos/.

Your username is: welman@sun.ac.za

If you need to retrieve password details, please go to: http://ees.elsevier.com/GAIPOS/automail_query.asp

Your manuscript will be given a reference number once an Editor has been assigned.

Thank you for submitting your work to this journal.

Yours sincerely,

Elsevier Editorial System
Gait and Posture

C. Addendum C – Intervention program

Week 1

Aim: Familiarization and alignment

To increase proprioceptive input to foot, sacro-iliac joint (SIJ) and cervical spine to ensure proper positioning during exercise sessions.

Session 1	**Session 2**	**Session 3**
Objective: Foot proprioception • Short foot	*Objective:* SIJ proprioception • Short foot • Neutral pelvic positions	*Objective:* Cervical spine proprioception • Short foot • Neutral pelvic positions • Neutral neck positions

Week 2

Aim: Static balance

1. To maintain postural control on smaller surfaces and progress to weight shifting, eliminating vision or adding head movements.
2. Focus on using the ankle strategy during exercise sessions.

Session 1	**Session 2**	**Session 3**
Objective: Posture	*Objective:* Base of support	*Objective:* Centre of gravity

Week 3

Aim: Static balance

1. To maintain postural control on smaller surfaces and progress to weight shifting, eliminating vision or adding head movements.
2. Focus on using the ankle strategy during exercise sessions and introduce on hip strategy.

Session 1	**Session 2**	**Session 3**
Objective: Posture	*Objective:* Base of support	*Objective:* Centre of gravity

Week 4

Aim: Dynamic balance

1. To maintain postural control on smaller unstable surfaces while adding upper- and lower extremity movement.
2. Maintain ankle strategy during exercise sessions and focus hip strategy.

Session 1	**Session 2**	**Session 3**
Objective: Posture	*Objective:* Base of support	*Objective:* Centre of gravity

Week 5

Aim: Dynamic balance

1. To maintain postural control on progressively smaller surfaces while adding upper- and lower extremity movement, as well as incline surfaces.
2. Maintain ankle strategy, focus on hip strategy and start introducing stepping strategy in exercise sessions

Session 1	**Session 2**	**Session 3**
Objective: Posture	*Objective:* Base of support	*Objective:* Centre of gravity

Week 6

Aim: Functional balance

1. To perform functional movements of everyday life on progressively smaller surfaces, including dual-tasking activities.
2. Maintain ankle and hip strategy and focus on stepping strategy in exercise sessions

Session 1	**Session 2**	**Session 3**
Objective: Posture	*Objective:* Base of support	*Objective:* Centre of gravity

Week 7

Aim: Functional balance

1. To perform functional movements of everyday life on progressively smaller surfaces, including dual-tasking activities. .
2. Maintain ankle and hip strategy and focus on stepping strategy in exercise sessions

Session 1	**Session 2**	**Session 3**
Objective: Posture	*Objective:* Base of support	*Objective:* Centre of gravity

Week 8

Aim: Functional balance

1. To perform functional movements of everyday life on progressively smaller surfaces, including dual-tasking activities.
2. Maintain ankle and hip strategy and focus on stepping strategy in exercise sessions

Session 1	**Session 2**	**Session 3**
Objective: Posture	*Objective:* Base of support	*Objective:* Centre of gravity

D. Addendum D – Example DVD of Intervention

An example of the FVF programme used in the intervention can be requested from the author. Contact Elizma Atterbury at ematterbury@gmail.com.

E. Addendum E – Personal information form

Personal Information Form:

Name:

Surname:

Age:

Gender:

Contact number (please indicate your preferred contact method):

Physical Address:

Level of Parkinson's (Hoehn &Yahr Scale), if known

When were you diagnosed with PD?

Occupation (if retired, state previous):

Current medication; and duration of use:

Any adverse effects of medication:

Who is your caregiver:

Relationship of caregiver:

Time spent without caregiver:

Would your caregiver like to attend the exercises as well?

Household chores:

Leisure time activities:

Has your doctor given you approval to participate in this study?

Who is your doctor?

Would you mind if we contact him/her?
If not please provide us with his/her contact no.

Are you going away anytime between November 2014 and March 2015? If yes, please state dates.

F. Addendum F – Health form

Health Form

Complete the following questions as accurately as possible. Tick the appropriate block (☐).

1. Has your doctor given you permission to participate in this study? ☐ Yes ☐ No
   Doctor's name and contact details _____

2. Are you on regular medication? ☐ Yes ☐ No
   If yes, please indicate name, dosage and purpose _____
   _____
   Most affect side: ☐ Left ☐ Right ☐ Both

3. Occupation (if you are retired, please indicate this and what you did before you retired:

_____

4. Do you do housework and / or gardening? ☐ Yes ☐ No
   If yes, please indicate what chores you do_____

5. How often do you participate in physical activity or exercise?
   Times per week: _____ Duration: _____ Type: _____

6. Do you have a history of any of the following?

☐ Heart attack	☐ Coronary thrombosis	☐ Narrowing arteries
☐ High cholesterol	☐ High blood pressure	☐ Leaking valve
☐ Stroke	☐ Angina /Chest pains	☐ Other heart condition or disease
☐ Rheumatic fever	☐ Known heart murmur	☐ Palpitations
☐ Recent operation	☐ Edema / swelling of ankles	☐ Breathing problems / difficulties
☐ Low blood pressure	☐ Seizures	☐ Lung disease
☐ Fainting or dizziness	☐ Cancer	☐ Diabetes
☐ Intermittent claudication	☐Unusual fatigue / shortness of breath	☐ Pain/ discomfort in chest, neck, jaw, arms

   ☐ Other (please indicate): Colonoscopy, Gastroscopy, Drop foot

7. Do you have a recent history of, or currently have, any joint / muscle injuries or pain?

☐ Neck	☐ Upper back	☐ Lower back	☐ Hip
☐ Thigh☐ Knee		☐ Lower leg	☐ Ankle
☐ Foot (drop)	☐ Shoulder	☐ Elbow	☐ Wrist or hand

   ☐ Other (please specify: _____

8. Has your doctor previously indicated any other conditions that we should know of?
   _____

G. Addendum G – ABC

Activity-specific Balance Confidence Scale (ABC Scale)

0%	10	20	30	40	50	60	70	80	90	100%

No confidence — **Completely confident**

How confident are you that you will not lose your balance or become unsteady when you…

	0%	10	20	30	40	50	60	70	80	90	100%
1. Walk around the house?											
2. Walk up or down stairs?											
3. Bend over and pick up a slipper from the front of a closet floor											
4. Reach for a small can off a shelf at eye level?											
5. Stand on your tiptoes and reach for something above your head?											
6. Stand on a chair and reach for something?											
7. Sweep the floor?											
8. Walk outside the house to a car parked in the driveway?											
9. Get into or out of a car?											
10. Walk across a parking lot to the mall?											
11. Walk up or down a ramp?											

12. Walk in a crowded mall where people rapidly walk past you?

0%	10	20	30	40	50	60	70	80	90	100%

13. Are bumped into by people as you walk through the mall?

0%	10	20	30	40	50	60	70	80	90	100%

14. Step onto or off an escalator while you are holding onto a railing?

0%	10	20	30	40	50	60	70	80	90	100%

15. Step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing?

0%	10	20	30	40	50	60	70	80	90	100%

16. Walk outside on icy sidewalks?

0%	10	20	30	40	50	60	70	80	90	100%

H. Addendum H - FES-I

Fall Efficacy Scale International (FES-I)

	Not at all concerned 1	Somewhat concerned 2	Fairly concerned 3	Very concerned 4
1. Cleaning the house (e.g. sweep, vacuum, dust)				
2. Getting dressed or undressed				
3. Preparing simple meals				
4. Taking a bath or shower				
5. Going to the shop				
6. Getting in or out of a chair				
7. Going up or down stairs				
8. Walking around in the neighbourhood				
9. Reaching for something above your head or on the ground				
10. Going to answer the telephone before it stops ringing				
11. Walking on a slippery surface (e.g. wet or icy)				
12. Visiting a friend or relative				
13. Walking in a place with crowds				
14. Walking on an uneven surface (e.g. rocky ground, poorly maintained pavement)				
15. Walking up or down a slope				
16. Going out to a social event (e.g. religious service, family gathering, or club meeting)				
Sub Total				
Total: /64				

I. Addendum I – Functional Gait Analysis

Functional Gait Assessment		
Parameters	**Instructions**	**Rating scale:**
1. GAIT LEVEL SURFACE	*Walk at your normal speed from here to the next mark (6 m).*	(3) Normal—Walks 6 m in less than 5.5 seconds, no assistive devices, good speed, no evidence for imbalance, normal gait pattern, deviates no more than 15.24 cm outside of the 30.48-cm walkway width. (2) Mild impairment—Walks 6 m in less than 7 seconds but greater than 5.5 seconds, uses assistive device, slower speed, mild gait deviations, or deviates 15.24–25.4 cm outside of the 30.48-cm walkway width. (1) Moderate impairment—Walks 6 m, slow speed, abnormal gait pattern, evidence for imbalance, or deviates 25.4– 38.1 cm outside of the 30.48-cm walkway width. Requires more than 7 seconds to ambulate 6 m. (0) Severe impairment—Cannot walk 6 m without assistance, severe gait deviations or imbalance, deviates greater than 38.1 cm outside of the 30.48-cm walkway width or reaches and touches the wall.
2. CHANGE IN GAIT SPEED	*Begin walking at your normal pace (for 1.5 m). When I tell you "go," walk as fast as you can (for 1.5 m). When I tell you "slow," walk as slowly as you can (for 1.5 m).*	(3) Normal—Able to smoothly change walking speed without loss of balance or gait deviation. Shows a significant difference in walking speeds between normal, fast, and slow speeds. Deviates no more than 15.24 cm outside of the 30.48-cm walkway width. (2) Mild impairment—Is able to change speed but demonstrates mild gait deviations, deviates 15.24–25.4 cm outside of the 30.48-cm walkway width, or no gait deviations but unable to achieve a significant change in velocity, or uses an assistive device. (1) Moderate impairment—Makes only minor adjustments to walking speed, or accomplishes a change in speed with significant gait deviations, deviates 25.4–38.1 cm outside the 30.48-cm walkway width, or changes speed but loses balance but is able to recover and continue walking.

		(0) Severe impairment—Cannot change speeds, deviates greater than 38.1 cm outside 30.48-cm walkway width, or loses balance and has to reach for wall or be caught.
3. GAIT WITH HORIZONTAL HEAD TURNS	*Walk from here to the next mark 6 m away. Continue alternating looking right and left every 3 steps until you have completed 2 repetitions in each direction.*	(3) Normal—Performs head turns smoothly with no change in gait. Deviates no more than 15.24 cm outside 30.48-cm walkway width. (2) Mild impairment—Performs head turns smoothly with slight change in gait velocity (eg, minor disruption to smooth gait path), deviates 15.24–25.4 cm outside 30.48-cm walkway width, or uses an assistive device. (1) Moderate impairment—Performs head turns with moderate change in gait velocity, slows down, deviates 25.4–38.1 cm outside 30.48-cm walkway width but recovers, can continue to walk. (0) Severe impairment—Performs task with severe disruption of gait (eg, staggers 38.1 cm outside 30.48-cm walkway width, loses balance, stops, or reaches for wall).
4. GAIT WITH VERTICAL HEAD TURNS	*Walk from here to the next mark (6 m). Continue alternating looking up and down every 3 steps until you have completed 2 repetitions in each direction.*	(3) Normal—Performs head turns with no change in gait. Deviates no more than 15.24 cm outside 30.48-cm walkway width. (2) Mild impairment—Performs task with slight change in gait velocity (eg, minor disruption to smooth gait path), deviates 15.24–25.4 cm outside 30.48-cm walkway width or uses assistive device. (1) Moderate impairment—Performs task with moderate change in gait velocity, slows down, deviates 25.4–38.1 cm outside 30.48-cm walkway width but recovers, can continue to walk. (0) Severe impairment—Performs task with severe disruption of gait (eg, staggers 38.1 cm outside 30.48-cm walkway width, loses balance, stops, reaches for wall).
5. GAIT AND PIVOT TURN	*Begin with walking at your normal pace. When I tell you, "turn and stop," turn as quickly as you can to*	(3) Normal—Pivot turns safely within 3 seconds and stops quickly with no loss of balance. (2) Mild impairment—Pivot turns safely in _3 seconds and stops with no loss of balance, or pivot turns safely within 3 seconds and stops with mild imbalance, requires small steps to catch balance.

	face the opposite direction and stop.	(1) Moderate impairment—Turns slowly, requires verbal cueing, or requires several small steps to catch balance following turn and stop. (0) Severe impairment—Cannot turn safely, requires assistance to turn and stop.
6. STEP OVER OBSTACLE	*Begin walking at your normal speed. When you come to the shoe box, step over it, not around it, and keep walking.*	(3) Normal—Is able to step over 2 stacked shoe boxes taped together (22.86 cm total height) without changing gait speed; no evidence of imbalance. (2) Mild impairment—Is able to step over one shoe box (11.43 cm total height) without changing gait speed; no evidence of imbalance. (1) Moderate impairment—Is able to step over one shoe box (11.43 cm total height) but must slow down and adjust steps to clear box safely. May require verbal cueing. (0) Severe impairment—Cannot perform without assistance.
7. GAIT WITH NARROW BASE OF SUPPORT	*Walk on the floor with arms folded across the chest, feet aligned heel to toe in tandem for a distance of 3.6 m.*	*The number of steps taken in a straight line is counted for a maximum of 10 steps.* (3) Normal—Is able to ambulate for 10 steps heel to toe with no staggering. (2) Mild impairment—Ambulates 7–9 steps. (1) Moderate impairment—Ambulates 4–7 steps. (0) Severe impairment—Ambulates less than 4 steps heel to toe or cannot perform without assistance.
8. GAIT WITH EYES CLOSED	*Walk at your normal speed from here to the next mark (6 m) with your eyes closed.*	(3) Normal—Walks 6 m, no assistive devices, good speed, no evidence of imbalance, normal gait pattern, deviates no more than 15.24 cm outside 30.48-cm walkway width. Ambulates 6 m in less than 7 seconds. (2) Mild impairment—Walks 6 m, uses assistive device, slower speed, mild gait deviations, deviates 15.24–25.4cm outside 30.48-cm walkway width. Ambulates 6 m in less than 9 seconds but greater than 7 seconds.

		(1) Moderate impairment—Walks 6 m, slow speed, abnormal gait pattern, evidence for imbalance, deviates 25.4–38.1 cm outside 30.48-cm walkway width. Requires more than 9 seconds to ambulate 6 m. (0) Severe impairment—Cannot walk 6 m without assistance, severe gait deviations or imbalance, deviates greater than 38.1 cm outside 30.48-cm walkway width or will not attempt task.
9. AMBULATING BACKWARDS	*Walk backwards until I tell you to stop.*	(3) Normal—Walks 6 m, no assistive devices, good speed, no evidence for imbalance, normal gait pattern, deviates no more than 15.24 cm outside 30.48-cm walkway width. (2) Mild impairment—Walks 6 m, uses assistive device, slower speed, mild gait deviations, deviates 15.24–25.4 cm outside 30.48-cm walkway width. (1) Moderate impairment—Walks 6 m, slow speed, abnormal gait pattern, evidence for imbalance, deviates 25.4–38.1 cm outside 30.48-cm walkway width. (0) Severe impairment—Cannot walk 6 m without assistance, severe gait deviations or imbalance, deviates greater than 38.1cm outside 30.48-cm walkway width or will not attempt task.
10. STEPS	*Walk up these stairs as you would at home (ie, using the rail if necessary). At the top turn around and walk down.*	(3) Normal—Alternating feet, no rail. (2) Mild impairment—Alternating feet, must use rail. (1) Moderate impairment—Two feet to a stair; must use rail. (0) Severe impairment—Cannot do safely.
		TOTAL SCORE: _____ MAXIMUM SCORE 30

J. Addendum J – IMI

Name: _____ Date: _____

For each of the following statements, please indicate with regard to the exercises you have performed in the programme how true it is for you, using the following scale:

1 2 3 4 5 6 7

not true somewhat true very true

	Statement	**Score**
1	I enjoyed doing this exercise programme very much	
2	I think I am pretty good at the exercises	
3	I put a lot of effort into the exercises	
4	I was very relaxed while doing the exercises	
5	I believe the exercises could be of some value to me	
6	The exercises were fun to do	
7	I am satisfied with my performance of the exercises	
8	I tried very hard while doing the exercises	
9	I was anxious while doing these exercises	
10	I think that doing these exercises is good for my health and fitness	
11	I thought the exercises were boring	
12	I think I was pretty skilled at the exercises	
13	I didn't put much energy into the exercises	
14	I felt pressured while doing the exercises	
15	I believe doing the exercises could be beneficial to me	
16	I thought the exercises were quite enjoyable	
17	These are exercises that I couldn't do very well	
18	It was important to me to do well at the exercise	
19	I did not feel nervous at all while doing the exercises	
20	I would be willing to do the exercises again as they have some value to me	

Thank you for taking part in our research

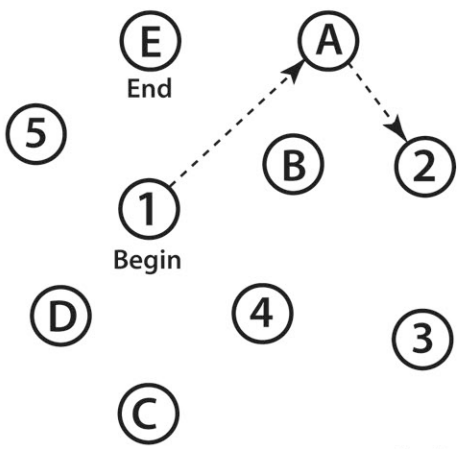
K. Addendum K – MoCA

MONTREAL COGNITIVE ASSESSMENT (MOCA)

Version 7.1 Original Version

NAME :
Education : Date of birth :
Sex : DATE :

VISUOSPATIAL / EXECUTIVE



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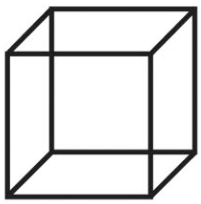


Copy cube

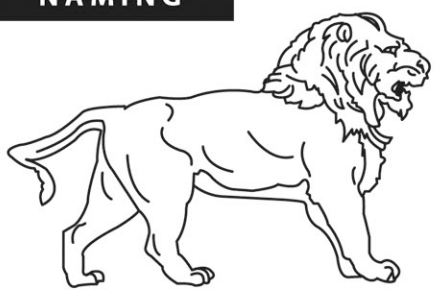
[ ]

Draw CLOCK (Ten past eleven)
(3 points)

[ ] Contour [ ] Numbers [ ] Hands

POINTS ___/5

NAMING



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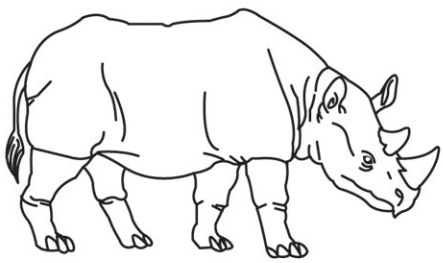

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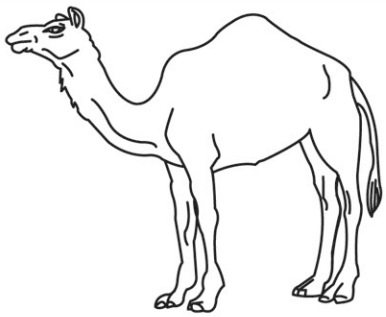


[ ]

___/3

MEMORY

Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.

	FACE	VELVET	CHURCH	DAISY	RED
1st trial					
2nd trial					

No points

ATTENTION

Read list of digits (1 digit/ sec.). Subject has to repeat them in the forward order [ ] 2 1 8 5 4

Subject has to repeat them in the backward order [ ] 7 4 2

___/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors

[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B

___/1

Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65

4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt**

___/3

LANGUAGE

Repeat : I only know that John is the one to help today. [ ]

The cat always hid under the couch when dogs were in the room. [ ]

___/2

Fluency / Name maximum number of words in one minute that begin with the letter F [ ] _____ (N ≥ 11 words)

___/1

ABSTRACTION

Similarity between e.g. banana - orange = fruit [ ] train – bicycle [ ] watch - ruler

___/2

DELAYED RECALL

Optional

	FACE	VELVET	CHURCH	DAISY	RED
Has to recall words **WITH NO CUE**	[ ]	[ ]	[ ]	[ ]	[ ]
Category cue					
Multiple choice cue					

Points for UNCUED recall only

___/5

ORIENTATION

[ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City

___/6

www.mocatest.org

Normal ≥ 26 / 30

TOTAL ___/30

Add 1 point if ≤ 12 yr edu

Administered by: _____

L. Addendum L - Ethics

UNIVERSITEIT·STELLENBOSCH·UNIVERSITY
jou kennisvennoot • your knowledge partner

Approved with Stipulations

Response to Modifications- (New Application)

14-Nov-2014
ATTERBURY, Elizabeth Maria

Proposal #: HS1061/2014

Title: The efficacy of home-based balance training on dynamic balance in independent-living individuals with Parkinson's Disease.

Dear Miss Elizabeth ATTERBURY,

Your **Response to Modifications -** ***(New Application)*** received on **06-Nov-2014**, was reviewed by members of the **Research Ethics Committee: Human Research (Humanities)** via Expedited review procedures on **13-Nov-2014**.

Please note the following information about your approved research proposal:

Proposal Approval Period: **14-Nov-2014 -13-Nov-2015**

The following stipulations are relevant to the approval of your project and must be adhered to:

1. Referral to clinical psychologist

The researcher mentions in her response to the REC's modifications that in a case where she identifies a depressive mood among participants, she will recommend the participant to see a clinical psychologist. However, the link to a UK website is provided. The researcher is requested to clarify why this website is cited, and whether it would not be more practical to select a registered clinical psychologist based in South Africa, offering counselling services at no or low cost.

The researcher is requested to respond to the comment above before data collection commences.

Please provide a letter of response to all the points raised IN ADDITION to HIGHLIGHTING or using the TRACK CHANGES function to indicate ALL the corrections/amendments of ALL DOCUMENTS clearly in order to allow rapid scrutiny and appraisal.

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with these guidelines.

Please remember to use your **proposal number** (**HS1061/2014**) on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 218089183.

Included Documents:

REVISED_Appendices

Informed consent form_AFR

Research proposal

Questionnaires and scales

DESC application

Informed consent_eng

REVISED_DESC application

REVISED_REC application form

REVISED_Research proposal

REVISED_Response to modifications

REC application form

Sincerely,

Clarissa Graham
REC Coordinator
Research Ethics Committee: Human Research (Humanities)

Investigator Responsibilities

Protection of Human Research Participants

Some of the general responsibilities investigators have when conducting research involving human participants are listed below:

1.Conducting the Research. You are responsible for making sure that the research is conducted according to the REC approved research protocol. You are also responsible for the actions of all your co-investigators and research staff involved with this research. You must also ensure that the research is conducted within the standards of your field of research.

2.Participant Enrollment. You may not recruit or enroll participants prior to the REC approval date or after the expiration date of REC approval. All recruitment materials for any form of media must be approved by the REC prior to their use. If you need to recruit more participants than was noted in your REC approval letter, you must submit an amendment requesting an increase in the number of participants.

3.Informed Consent. You are responsible for obtaining and documenting effective informed consent using **only** the REC-approved consent documents, and for ensuring that no human participants are involved in research prior to obtaining their informed consent. Please give all participants copies of the signed informed consent documents. Keep the originals in your secured research files for at least five (5) years.

4.Continuing Review. The REC must review and approve all REC-approved research proposals at intervals appropriate to the degree of risk but not less than once per year. There is **no grace period.** Prior to the date on which the REC approval of the research expires, **it is your responsibility to submit the continuing review report in a timely fashion to ensure a lapse in REC approval does not occur.** If REC approval of your research lapses, you must stop new participant enrollment, and contact the REC office immediately.

5.Amendments and Changes. If you wish to amend or change any aspect of your research (such as research design, interventions or procedures, number of participants, participant population, informed consent document, instruments, surveys or recruiting material), you must submit the amendment to the REC for review using the current Amendment Form. You **may not initiate** any amendments or changes to your research without first obtaining written REC review and approval. The **only exception** is when it is necessary to eliminate apparent immediate hazards to participants and the REC should be immediately informed of this necessity.

6.Adverse or Unanticipated Events. Any serious adverse events, participant complaints, and all unanticipated problems that involve risks to participants or others, as well as any research related injuries, occurring at this institution or at other performance sites must be reported to Malene Fouch within **five (5) days** of discovery of the incident. You must also report any instances of serious or continuing problems, or non-compliance with the RECs requirements for protecting human research participants. The only exception to this policy is that the death of a research participant must be reported in accordance with the Stellenbosch Universtiy Research Ethics Committee Standard Operating Procedures. All reportable events should be submitted to the REC using the Serious Adverse Event Report Form.

7.Research Record Keeping. You must keep the following research related records, at a minimum, in a secure location for a minimum of five years: the REC approved research proposal and all amendments; all informed consent documents; recruiting materials; continuing review reports; adverse or unanticipated events; and all correspondence from the REC

8.Provision of Counselling or emergency support. When a dedicated counsellor or psychologist provides support to a participant without prior REC review and approval, to the extent permitted by law, such activities will not be recognised as research nor the data used in support of research. Such cases should be indicated in the progress report or final report.

9.Final reports. When you have completed (no further participant enrollment, interactions, interventions or data analysis) or stopped work on your research, you must submit a Final Report to the REC.

10.On-Site Evaluations, Inspections, or Audits. If you are notified that your research will be reviewed or audited by the sponsor or any other external agency or any internal group, you must inform the REC immediately of the impending audit/evaluation.

M. Addendum M – DVD Survey

Name of Participant:_____

Name of Caregiver &

Relationship:_____

Please mark the correct one: Survey answered by participant / caregiver**.**

The following items concern your experience with the DVD exercise programme in your home. Please answer all items. For each item, please indicate how true the statement is for you, using the following scale below as a guide. There is a section at the end of survey allocated for comments.

1 2 3 4 5 6 7

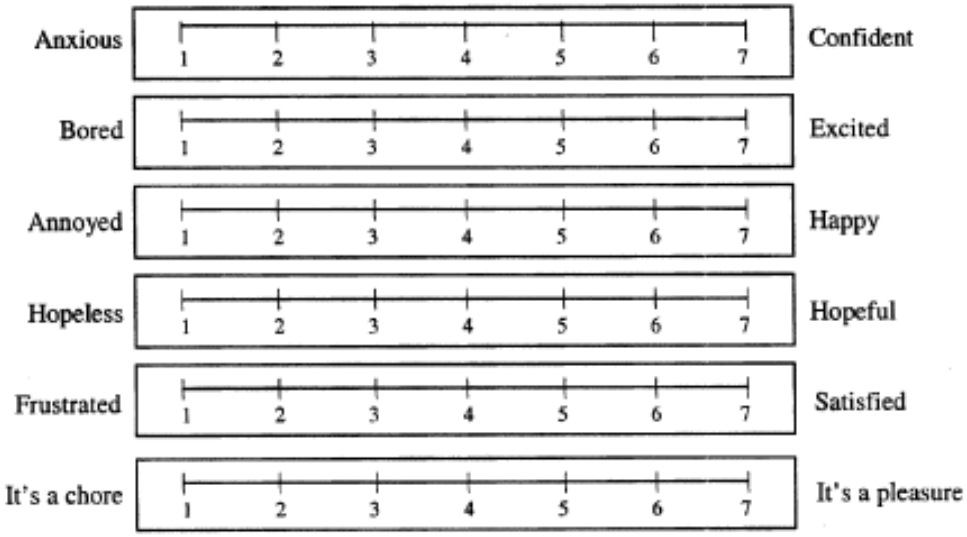
Not at all true Somewhat True Very true

Questions	**Score:**
The DVDs looked professional	
The progression of the exercises were too fast for me	
I would recommend this programme to friends and family	
I think I will be able to incorporate the concepts learned during the exercises in my daily life	
I did not find the booklet informative	
I would not do work through the DVD programme again	
Caregivers were helpful	
The terminology in the DVD confused me	
The DVD demonstrations help me to understand the activities	
The comfortable home environment made it easier for me to exercise	
I would like more exercises in addition to these that I have done already	
I found the instructions in the booklet helpful	
I would do the exercise programme again because I felt it benefitted me	
Having an off day made me delay doing the exercises	
I found it easy to load and use (play) the DVD	
I found time in my daily routine to do the whole duration of the exercise session	
I think the use of caregivers limits the effectiveness of the programme	
I do not think the exercises are suitable for a home environment due to space	
I found the DVD package presentable	
I feel that the equipment did not contribute to the exercise programme	

The demonstrations of the exercises on the DVD was clear	
I didn't know how to start the DVD	
Caregivers contributed to the quality of the exercise programme	
The equipment was too expensive	
My rooms were not large enough for the activities	
The whole DVD package was user-friendly	
I felt unsafe when doing the exercises at home	
I think I would have enjoyed the exercises more in a group setup	
Three sessions per week was too difficult for me to keep up with	
I could easily fine the space to do the exercises in my home environment constraints	
I struggled to follow the demonstrations on the DVD	
The programme asked me to do exercises outside my comfort zone	
The booklet's instructions was confusing	
I could easily follow the DVD instructions	
I sometimes felt physically unable to do the exercises	
I found time in my weekly routine to fit in 3 sessions per week	
The duration of each exercise session was too long for me	
There was too many exercise sessions a week	
I believe it would have been easier to comply with the programme if I were to attend sessions at an location	
Except for the Swiss ball and incline plank, I could easily obtain the other necessary equipment from my immediate environment (I had it at home, or could get it from a friend)	
I found the progression of exercises applicable and easy	
I think I would be able to do the exercises without a caregiver	
I would not advise other individuals with Parkinson's to follow this programme	

How do you feel about each of the following?

"When I think about carrying out my home exercises I feel..."



How long (in minutes) did each session take you on average

_____

Was there any week you didn't do 2 sessions a week? Elaborate please_____

_____

_____

Comments (Specify to which question your comment relates, if applicable):

_____

_____

_____

_____

_____

_____

N. Addendum N – Turnitin Report