UNIVERSITY OF SOUTHAMPTON

FACULTY OF HEALTH SCIENCES

Dancing with Parkinson's – An exploration of teaching and the impact on whole body coordination during turning.

by

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Thesis for the degree of Doctor of Philosophy

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ABSTRACT

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Parkinson's is a common, progressive, neurodegenerative movement disorder of the central nervous system, presenting with particular impairment of the motor system. Despite a growing body of literature recommending the use of dance for the treatment and management of Parkinson's, the exact impact and effect on turning ability has not been investigated. In addition, the experience of those teaching dance has also received little attention.

The purpose of this research study was to explore the experience of teaching ballroom and Latin American dance classes for people with Parkinson's (PwP) from a qualitative perspective alongside the main aim of investigating effects on turning in PwP from a quantitative perspective.

Qualitatively, three dance teachers were approached to participate in semi-structured interviews before and after teaching dance classes for PwP over one year. A thematic analysis was undertaken using a framework approach, informed by the principles of Interpretative Phenomenological Analysis. Two dance teachers participated, with analysis generating four themes: 1) the role of adaptation, 2) the context and 3) practical application of the class and 4) how achievement was measured and the impact of the teacher.

Quantitatively, twenty-four PwP were randomly allocated to receive either twenty, one-hour dancing classes over 10-weeks (n=12), or usual care (n=12). Using 3-dimensional movement analysis before and after the intervention period, measures of latency and horizontal movement of the eyes, head, thorax, shoulders, pelvis and feet, centre of mass displacement, and the total time of a 180 degree on-the-spot turn were taken alongside clinical measures.

Statistical analysis (4-way ANOVA) demonstrated a significant four-way interaction for head latency (p=0.008), with mean values showing longer latency in the usual care. Similar trends were also shown in pelvis latency (p=0.077), first (p=0.063) and second (p=0.081) foot latency, with mean values suggesting longer pelvis latency and slower foot movement in the usual care group, although all results were affected by prediction and preference of turn direction. Significant between-group differences were also found for pelvis rotation (p=0.036), with the usual care group showing greater rotation. No differences were found in the centre of mass displacement, turn time or clinical measures. As a result of interpretation the main findings suggest a tighter coupling and greater co-ordination of all segments following dance.

In conclusion, teachers' expectations and experiences suggest a multidimensional impact of dance for PwP with importance of socialisation, increased confidence, level of achievement and participation, knowledge of which will support the development of dance classes for PwP. Specifically, body segments (head, pelvis and feet) appear more coordinated in time and sequence following dance in PwP, suggesting a more 'en bloc' turning pattern with greater inter-segmental coordination. However, this is influenced by direction of turn preference and prediction, with further research required to comment on the clinical implications.

Table of Contents

List of tables

List of figures

DECLARATION OF AUTHORSHIP

I, Sophia Hulbert

declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

Dancing with Parkinson's – An exploration of teaching and the impact on whole body coordination during turning.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. Parts of this work have been published; please refer to 'Dissemination' section of thesis for further details.

Signed:...

Date:...

Dissemination

Summary of awards and dissemination events for this thesis

	Title	Event/location
Awards	Improving balance through dance– Helping people with Parkinson's.	**First Prize** – NIHR New Media Competition 2014.
	Parkinson's dance – The effects on Turning.	**'People's choice Award'** 2014 University of Southampton – Faculty of Health Sciences – 3-Minute Thesis Competition.
	A feasibility study of whole body coordination during turning, in people with Parkinson's disease.	**Runner up** – 2013 University of Southampton – Faculty of Health Science Postgraduate Research Conference.
Publications – Papers	A narrative review of turning difficulties in people with Parkinson's disease.	Published in 'Disability and Rehabilitation' Early Online: 1-8, Sep 25th 2014.
	A design to investigate the feasibility and effects of partnered ballroom dancing on people with Parkinson disease: randomised controlled trial protocol.	Published in JMIR Research protocols 2014, Vol, 3, (3).
Publications – Posters	Dancing with Parkinson's – The effects on whole body coordination during turning.	2015 WCPT conference – Singapore.
	Dancing with Parkinson's: feasibility randomised controlled trial.	2015 WCPT conference – Singapore.
	Towards a better understanding of turning in people with Parkinson's.	2014 ISPGR conference – Vancouver.
	Towards a better understanding of turning in people with Parkinson's.	2014 CSP Physiotherapy UK conference.
	'Fall Back' – Dance for Parkinson's.	2014 University of Southampton – Litmus Project.

	A feasibility study of whole body coordination during turning, in people with Parkinson’s disease.	2013 University of Southampton – Research on Ageing Exhibition.
Publications – Oral	‘Dance for Parkinson’s’ – dissemination and future plans	2015 Pavilion Dance Southwest – World PD day.
	‘Dance for Parkinson’s’ – ‘Everybody can dance’	2014 RfPB study dissemination event.
	The effects of ballroom dancing on turning ability in people with Parkinson’s.	2014 ‘Dance for PD Network UK’ conference.
	‘Dance for Parkinson’s’– Research summary and future plans.	2014 Pavilion Dance Southwest – World PD day.
	Towards a better understanding of turning difficulties in people with Parkinson’s.	2014 University of Southampton – Research and Health Technologies Research group.
Media	‘Dancing with Parkinson’s’.	BBC South today – News report, Nov 2014.
	PD dance class – DM Dance Centre.	BBC Solent Radio – Katie Martin show, March 2014.

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Definitions and Abbreviations

A/P – Anterior/Posterior.

A/P weight transfer – A measure of the movement of weight in the anterior/posterior direction. Defined as the difference in distance between the position of the point of application at the cue and at the point of first foot movement in the anterior/posterior direction. Translated to a percentage of the total depth of stance. Discussed further in Section 5.9.

Axial body segment deficits – 'non-optimal movement' of the axial structures of the body (being the head, shoulders and pelvis in this case). Discussed further in Chapter 4.

Ballet – An artistic dance form performed to music, using precise and highly formalised set steps and gestures.

Ballroom dance – Social dance usually performed by couples. Dances in this study include the waltz, social foxtrot and tango.

BBS – Berg balance scale, a measure used to indicate clinical balance performance (Berg et al. 1992). Discussed further in Section 5.9.

Body segment to body segment relationship – A measure in degrees of the change in angle of each body segment (head, shoulders, thorax and pelvis) from the point of initiation to the point of first foot movement. Discussed further in Section 5.9.

Contact improvisation – The term given to a system of improvised movement which are based on the relationship between two moving bodies and the effect that the laws of gravity, momentum, friction and inertia have on their movement (Mackrell & Craine 2010).

Community dance – Any form of dance where community dance artists work with people from any background, irrelevant of their previous dance experience.

'en bloc' turn – a loss of axial rotation of the spine, with little dissociation between the head, trunk and lower limbs. Discussed further in Chapter 4.

FFM – First foot movement.

Ground reaction forces – A force created as a result of the vertical and horizontal forces applied by the participant to the force plate. Discussed further in Section 5.9.

Latin American dance – Social dance usually performed by couples. Latin American dances included in this study included the rumba, Rock 'n' Roll and cha-cha-cha.

M/L – Medial/Lateral.

M/L weight transfer – A measure of the amount of 'weight shift' between the feet prior to the start of turning. Defined as the greatest distance the point of application reached from right to left and recorded as a percentage of the total width of the base of support (as determined by the toe and heel markers). Discussed further in Section 5.9.

Modern dance – Theatrical dance that is not based on the academic school of classical ballet (Mackrell & Craine 2010).

Perpendicular body segment deficits – 'Non-optimal movement' occurring in any aspect of the perpendicular areas of the body (being the lower limbs in this case). Discussed further in Chapter 4.

Point of application – An intersection of the ground reaction force vector with the force plate. Used as a measure of the position of weight bearing forces. Discussed further in Section 5.9.

PwP – People with Parkinson's.

Segment latency – A measure of the time delay in seconds from the light cue to the initiation of movement in each segment (eyes, head, shoulders, thorax, pelvis, first and second foot). Discussed further in Section 5.9.

SS180 – Standing start 180 degree turn test (Stack et al. 2002b, Stack & Ashburn 2005).

SS180 turn time – A measure in seconds of the total time of a 180 degree turn from the point of movement initiation to the first step out of the turn (measured visually from video footage).

Stance – A measure in millimetres of the length between the mid-point of each foot (as defined by heel and toe markers on the feet). Discussed further in Section 5.9.

Step number – A measure of the number of steps taken to complete a 180 degree turn. Measured by the SS180. Discussed further in Section 5.9.

Turn quality – A measure of the quality of the turn as determined by 5 variables, each scoring one if present – independence, clearance, stability, continuity and posture. Measured by the SS180.

Total Coda turn time – A measure in seconds of the total time taken to complete the turn, from the initiation of movement of the shoulders to the point where no movement in the shoulders is detected by 3-dimensional movement analysis. Discussed further in Section 5.9.

Total weight transfer – A measure of the total distance travelled by the point of application in the M/L direction from the light cue to the FFM. Recorded in millimetres. Discussed further in Section 5.9.

Turn type – A measure of the type of turn completed, selected from pivotal, towards, lateral, incremental or delayed. Measured by the SS180.

Weight bearing position A/P – A measure of the percentage of participants that had either an anterior or posterior weight bearing position. Defined as the position of their point of application at the first foot movement. Discussed further in Section 5.9.

Chapter 1: Introduction

1.1 Context of thesis

One in 500 people have Parkinson's[1] in the United Kingdom (PD UK 2015), and whilst it is not a life-limiting condition, the experience of living with Parkinson's affects every aspect of the lives of those with the condition and all who surround them.

Everyone's experience of living with Parkinson's is different. The varied nature of symptoms has led to a tapestry of methods and strategies to manage the symptoms for, and by people with the condition. One such method that is receiving growing interest and popularity is dancing. This has taken many forms, from the structured and stylised genres of ballet, tap, jazz, Irish, Latin American and ballroom, to more creative, improvisational, modern and contemporary styles.

Since qualifying as a physiotherapist, I have worked closely with people with Parkinson's (PwP) on both an individual and group basis, running a weekly dance class specifically tailored for PwP, where I encourage when possible, therapeutic gain through a dance genre. This focus has predominantly taken the form of 'modern dance' with an eclectic mix of dance styles, creative improvisation and vocal work, rather than the specific genres of ballroom and Latin American dance that will be used in this study. Irrelevant of the dance style, it has become evident from an anecdotal perspective that the opportunity to move and engage in an activity that has its primary focus within the paradigms of socialising, enjoyment, physical achievement and aesthetic reward, has an ability to provide a release from the physical boundaries that the condition dictates, which is worthy of further research.

I have experienced a release from the pressures of daily life through dancing and am aware of the opportunities that dance presents in exploring new movement behaviour. It appears to allow the participant to explore a personal

[1] The term "Parkinson's" will be used throughout this thesis rather than "Parkinson's Disease" as it is the preferred term used by the Parkinson's community in the UK. It emphasises Parkinson's as a condition that one lives with rather than a disease.

journey of movement and expression either as a solo performer or within the supportive and enriching environment of group dance.

The personal challenges I have faced through my practice as both a physiotherapist and a dance teacher comes from amalgamating the scientific and often medical paradigm of physiotherapy with the creative and explorative paradigm of dance. In an effort to achieve patient-centred goals in a truly biopsychosocial approach, I became interested in exploring the complex interplay between the ‘arts and the sciences’ further.

The drive for evidence based practice in physiotherapy and the emerging research base for the benefits of dance for PwP led to the development of a research project focusing on the therapeutic effects of ballroom and Latin American dancing for PwP. A grant was awarded to the Rehabilitation Research team at the University of Southampton by the National Institute of Health Research (NIHR) - Research for Patient Benefit (RfPB). Working as a research assistant on this project, I was able to make an original contribution by designing and undertaking a PhD study to investigate the effects of ballroom and Latin American dancing on turning performance in PwP.

Whilst there is a growing body of evidence for the use of dance as a rehabilitation tool in PwP, the purpose of this PhD study is to investigate the effects of a 10-week ballroom and Latin American dancing programme on turning ability in PwP. Turning is often associated with significant physical difficulties and injury for PwP, such as freezing and falling (Stack & Ashburn 2008). In addition, as an integral component of everyday activities, it is fundamental that an improved understanding of the deficits in turning for PwP is reached in order to develop mechanisms to support and manage these deficits.

In addition to the specific influences of dance for PwP, the experience of delivering the class from the teacher’s perspective is also yet to be considered. Therefore alongside the quantitative exploration of the effects of ballroom and Latin American dancing on turning, the experience of delivering a dance intervention for PwP from the teacher’s perspective will also be presented.

It is anticipated that both of these studies will contribute to the development of a Phase III definitive clinical trial investigating the effects of ballroom and Latin American dancing on PwP, alongside the findings from the larger NIHR RfPB study.

"For dance and for rehabilitation medicine, movement is both method and result. In the rehabilitation paradigm, movement is medicine. In the dance paradigm, movement is art. Often a single movement can be both. Perhaps, through this phenomenon of movement, the arts and medicine are more interdependent than we previously imagined" (Worthen-Chaudhari 2011).

1.2 Overview of thesis

Given the relatively new emergence of dance as a form of rehabilitation for PwP, there are many areas that have little or no previous research. The gaps in knowledge range from understanding of the implementation and delivery to the potential physiological effects and outcomes. In addition to the broad variety of topics yet to be investigated, I felt it was important for my own development and understanding of the processes of academic knowledge generation, that I undertake research in both the quantitative and qualitative paradigms.

This thesis begins with a description of the context in which the research was undertaken, including an introduction to Parkinson's and review of the literature surrounding the use of dance for PwP, followed by an overview of the RfPB study of Ballroom and Latin American dance for PwP, in which this thesis is nested (Chapter 2). The broader implications of dance for PwP are then considered through a qualitative exploration of the implementation of new classes from the perspective of the dance teacher (Chapter 3). From an increased understanding of the implications for implementation of dance classes for PwP, it is then essential to explore the possible impact on performance that dance may have on the symptoms of the condition, in particular the difficulty of turning. The current literature on the difficulty in turning for PwP and the possible role of dance in the treatment and management of this difficulty is discussed in Chapter 4. As a result of a small feasibility study (summarised in Appendix 3), suitable quantitative methods to assess the impact of a ballroom and Latin American dance class on turning performance in PwP were designed and selected, which are described further in Chapter 5. Results of this study are presented in Chapter 6 and then discussed in Chapter 7. Finally, the impact of both the qualitative findings of the expectation and experience of teachers delivering a dance intervention, and the quantitative findings of the impact of the intervention on turning, alongside possible future directions for research are discussed in Chapter 8. The components of this thesis are summarised in Figure 1.

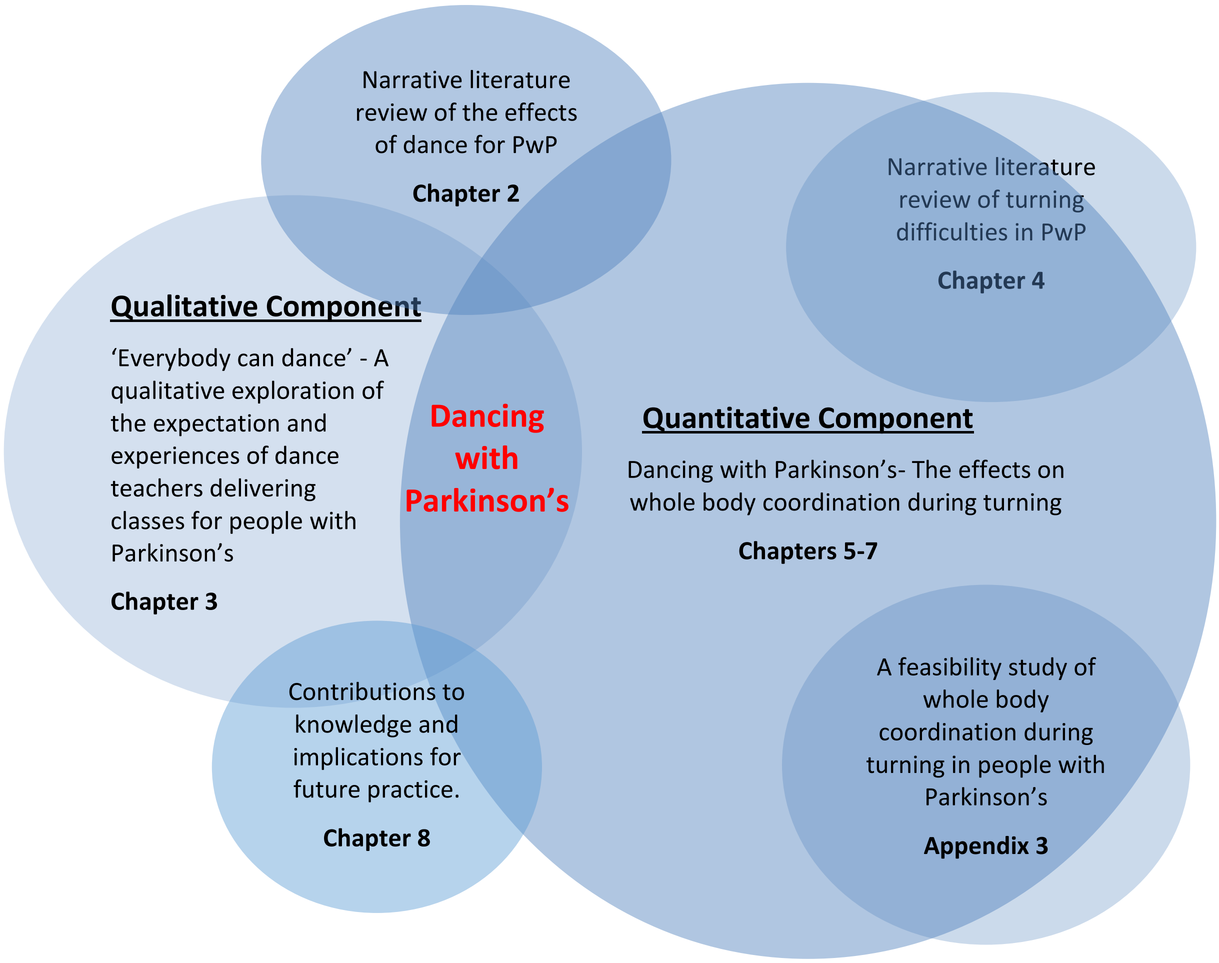


Figure 1 – Representation of the components of the thesis 'Dancing with Parkinson's.

Chapter 2: The effects of dance for people with Parkinson's.

A general overview of Parkinson's and the role of dance in the treatment and management of some of the symptoms associated are presented in this chapter. The content will provide an understanding of the background used in the development of the RfPB study of the effects of ballroom and Latin American dance for PwP, within which the research studies included in this thesis were nested. A brief summary of the RfPB study will also be included to provide context.

2.1 Introduction to Parkinson's

2.1.1 Prevalence

Parkinson's is a common, progressive, neurodegenerative movement disorder of the central nervous system, presenting with particular impairment of the motor systems as well as the autonomic nervous system and state of mind.

Parkinson's is estimated to affect one in 500 of the population in the United Kingdom, totalling an estimated 127,000. Whilst prevalence increases with age, 1 in 20 who present with the condition are under the age of 40 (PD UK 2015). Using lost productivity as a measure, the estimated cost of Parkinson's in the United Kingdom is approximately £449 million annually, with the majority of the expenditure being a result of loss of independence requiring institutionalised care (Findley 2007). Therefore, to ensure best value and utilisation of resources, rehabilitation research should focus on maximising quality of life and minimising the impact of the disease progression, to retain independence. This will become even more important as the population ages, as Parkinson's is likely to become more prevalent, with more than 40 million people worldwide predicted to have movement disorders secondary to Parkinson's by the end of 2020 (Morris 2000). This presents a personal, social and economic need for development of the long-term treatment, including self-management of this condition.

2.1.2 Clinical presentation

People who are diagnosed with Parkinson's experience movement disorders that if not managed, can lead to "considerable disability" (Morris 2000). Physically, PwP experience: bradykinesia, a slowness of movement; rigidity, a resistance to movement; freezing episodes, a sudden interruption of on-going movement; resting tremors and involuntary movement, as a direct result of the disease process, with abnormalities of postural reflexes that occur with increasing disease severity. These motor deficits commonly lead to poor performance on measures of balance and functional tasks, and have been associated with generalised deficits of attention and falls (Ashburn et al. 2001).

Clinically, PwP tend to adopt stereotypical movement patterns such as a "shuffling pattern" of walking with a forward lean, increased flexion of the hips and thoracic spine, increased posterior pelvic tilt, loss of plantar flexion and heel strike at the ankle during gait (Nieuwboer et al. 2007) and particular difficulty in turning, often described as moving 'en bloc' (Crenna et al. 2007; Akram et al. 2013a) i.e. 'nearly simultaneous rotation of head and trunk and decreased relative head excursion after the second turning step' (Crenna et al. 2007).

The variability of symptoms and limitations of performance between PwP is high and un-predictable (Keus et al. 2014). In practice, the Hoehn and Yahr score (H&Y) (Hoehn & Yahr 1967) is used to give an indication of disease progression and clinical presentation (Table 1).

Hoehn and Yahr Score	Description	Phase
1	Unilateral involvement only usually with minimal or no functional disability.	Early
2	Bilateral or midline involvement without impairment of balance.	Early

3	Bilateral disease: mild to moderate disability with impaired postural reflexes; physically independent.	Complicated
4	Severely disabling disease; still able to walk or stand unassisted.	Complicated
5	Confinement to bed or wheelchair unless aided.	Late

Table 1 – Hoehn and Yahr Score (Hoehn & Yahr 1967).

However, it should be noted that this is a tool specifically recommended for demographic representation of physical symptoms as it does not include non-motor function and is not linear (Goetz et al. 2004).

The clinical presentation of Parkinson's is varied and multi-dimensional, which is most likely due to the complexity and intricacy of the pathophysiology of the condition. There is a wealth of literature available discussing the likely mechanisms and pathophysiology of the symptoms, the scope of which is not appropriate to discuss here, however an overview of which is presented below in order to give context to future discussion.

2.1.3 Pathophysiology

The pathophysiological mechanisms of the symptoms of Parkinson's are related to a reduction of dopamine production due to loss of dopaminergic nerve cells in the substantia nigra of the brain, located within the basal ganglia (BG) (Heisters 2011). Dopamine is necessary for the relay of messages in the BG and motor cortex to enable coordinated movement (Goodwin et al. 2008). Globally, the BG are thought to play a role in the initiation of voluntary movements, with facilitation of some and suppression of others, and a comparison of motor commands with a feedback system from the movements produced (Bartels & Leenders 2009).

The models used to describe the role of the BG in the literature continue to emerge as understanding of its function develops. It is however, useful here to describe the classical model to provide a basic understanding of the function of the BG and the development of motor symptoms.

Alexander (1986) initially described the classical model of the BG as a network of parallel loops that integrate the cerebral cortical regions (associative, oculomotor, limbic and motor regions), BG nuclei and the thalamus. The motor circuit within this complex exist of cortical motor areas that project to the striatum, especially the putamen, then as part of the 'direct pathway' (Figure 2), connect to the substantia nigra reticulate and the globus pallidus pars interna. This pathway provides a direct inhibitory effect (GABA-ergic) on the neurones involved, thus reducing their inhibitory effect on the thalamus and thereby facilitating movement.

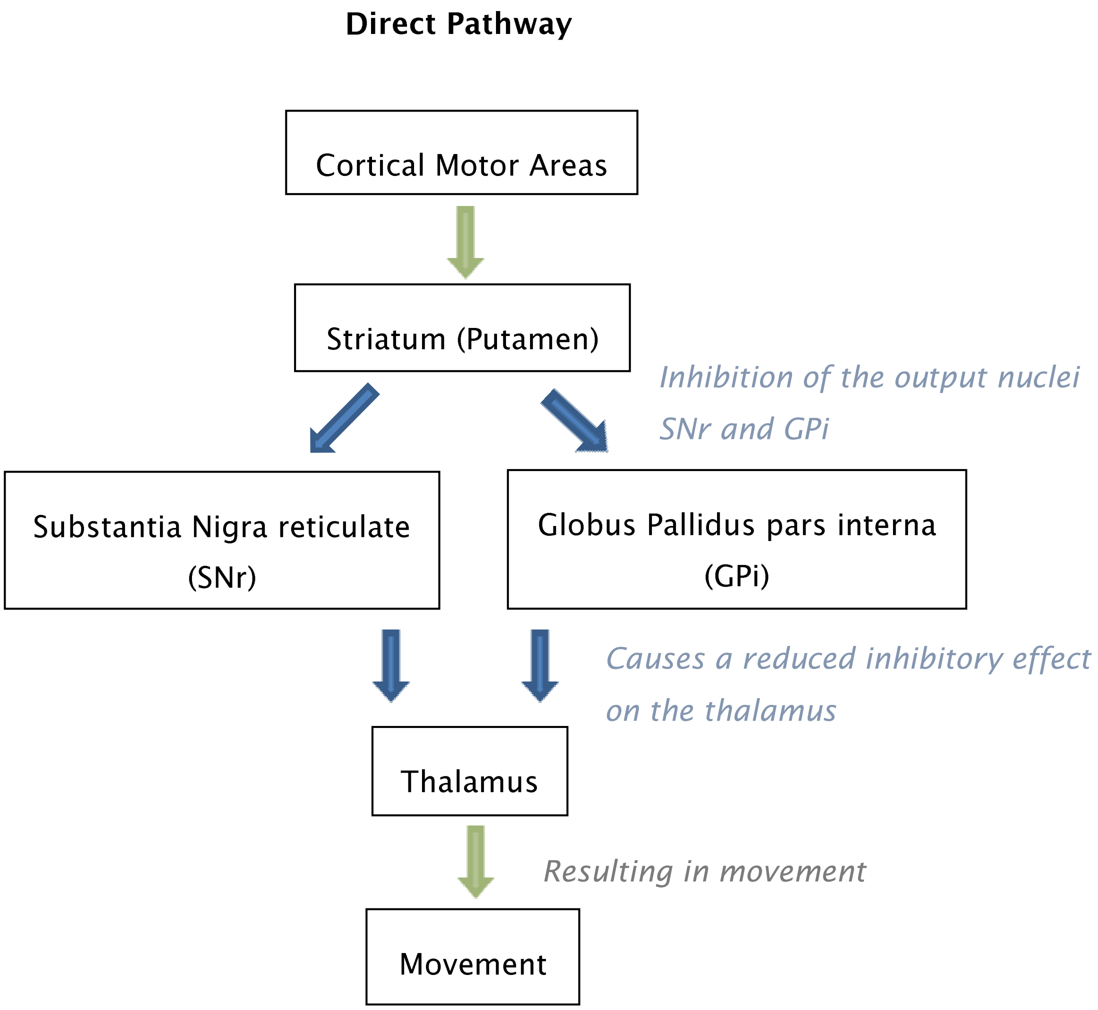


Figure 2 – Representation of the 'direct' movement pathway, synthesised from the literature.

The ‘indirect pathway’ (Figure 3) connects the putamen with the output nuclei via the Globus Pallidus pars externa (inhibited) and the Subthalamic Nucleus (disinhibited) and excitation of the ‘direct pathway’, thus enhancing the pathway and thereby supressing movement.

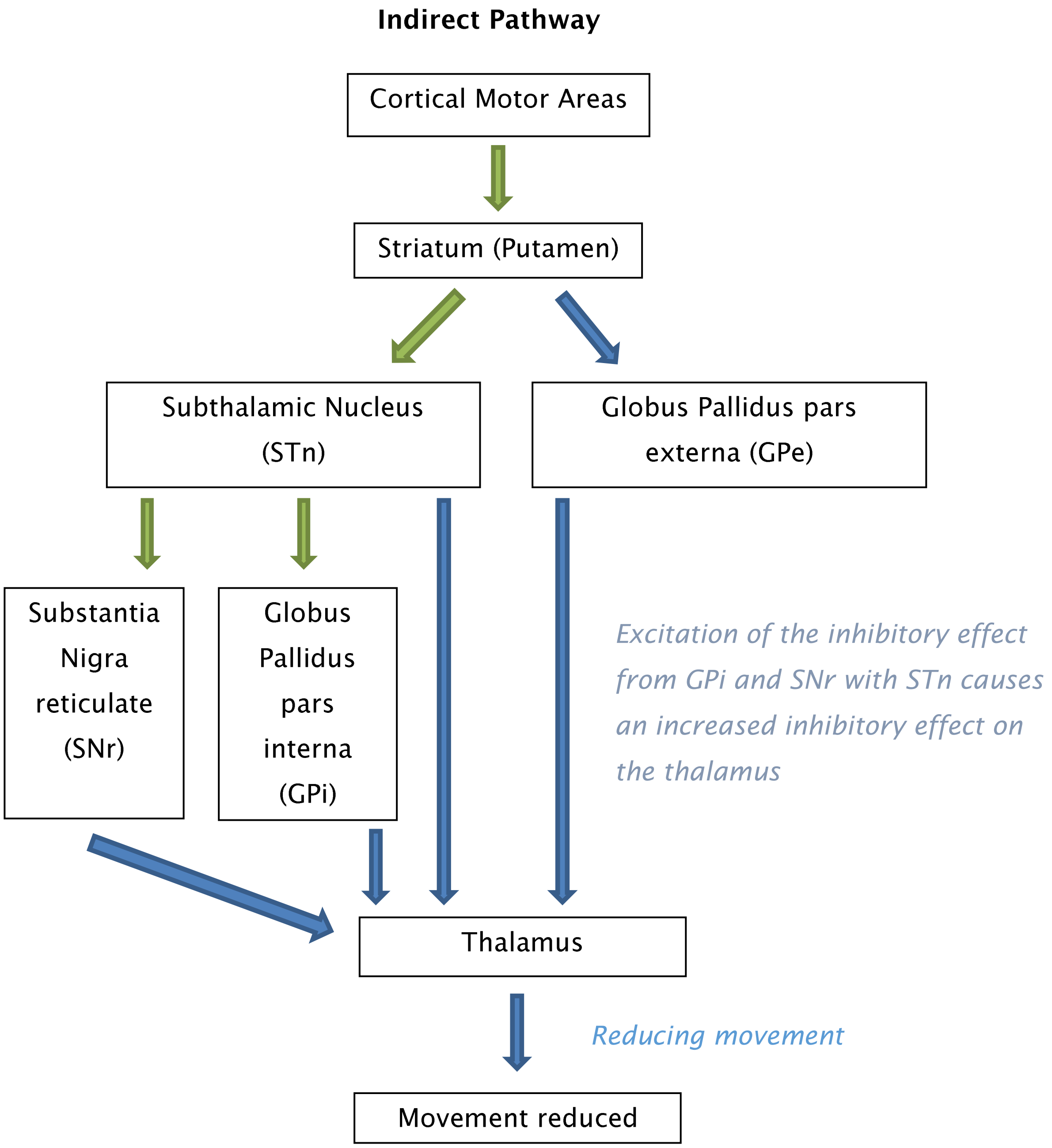


Figure 3 – Representation of the 'indirect' movement pathway, synthesised from the literature.

According to the 'classical model' of direct – indirect pathway regulation, dopamine deficiency leads to reduced inhibition of the indirect pathway and reduced excitation of the direct pathway, with the net result of supressed movement and a cause of the symptoms of bradykinesia and akinesia experienced by the majority of PwP. Symptoms become apparent once approximately 70% of the cells are lost, with further slow reduction of dopamine over time presenting with progressive symptoms (Heisters 2011).

There are several developments of this model available in the literature, giving suggestions for the pathophysiology of the specific motor abnormalities for PwP, as different aspects of Parkinsonian motor symptoms and non-motor symptoms cannot be explained simply as a result of the augmentation in the inhibitory output from the BG (Bartels & Leenders 2009). However, further explanation of these developments is beyond the scope of this thesis.

As well as slowness of movement, people with bradykinesia also have difficulty in performing sequential movements (Marsden 1994). Current studies suggest that the motor command governing movement may be normal, but the dysfunctional basal ganglia are unable to maintain or match the required amplitude of movement when relaying the motor command to the thalamic nuclei and brain stem (Farley et al. 2008). This leads to a progressive decline in movement size during sequential actions, known as 'motor instability' and can be clearly seen in people with gait hypokinesia, in whom the footsteps become shorter the further they walk (Morris 2000). All aspects of movement are scaled down including spatial (step length), kinematic (joint angle) and kinetic (joint moments and power) variables.

Whilst the pathological causes of these symptoms are documented, current literature focuses on specific deficits and possible treatment options in isolation to each other. The exact relationship and effects each deficit have on each other with regards to functional performance are less well understood, but may hold greater clinical relevance when considering treatment options for efficient and safe participation in daily life as a whole. With an appreciation of this, the impact of the specific deficits experienced in turning in PwP are considered in detail in Chapter 4 of this thesis, and the possible impact that dance may have on turning performance as a whole is reported.

2.2 The current treatment and management of Parkinson's and the role of dance.

2.2.1 Current care plan for the treatment and management of Parkinson's

Due to the multi-dimensional aspects of Parkinson's, current treatment provision for PwP is complex and multi-modal as medical intervention alone is not sufficient (Keus et al. 2014).

Management of symptoms tends to include a combination of medication (levodopa) and occasionally surgery (deep brain stimulation), alongside multidisciplinary therapy (Heisters 2011). Pharmacological and surgical management target mainly the motor system, but are not sufficient during later stages of the condition (Heiberger et al. 2011) or without side effect and great economic expense (Findley 2007). Activity limitations and symptoms restricting participation such as freezing, impaired balance or cognitive impairment respond poorly to medication and in some cases may be worsened (Keus et al. 2014).

The overall goal of Parkinson's management is to optimise activities, participation and quality of life, by considering functional, personal and environmental factors (Keus et al. 2014). To date, whilst medical intervention can help manage the symptoms of Parkinson's, there is no evidence for modifying effects of the condition for any medical intervention (Keus et al. 2014). Historically physiotherapeutic models have utilised compensatory strategies as the basis of their management (Sharp & Hewitt 2014), however emerging evidence that exercise improves cortico-motor excitability in PwP, suggesting potential neuroplasticity, has been shown (Fisher et al. 2008). In addition, animal studies have demonstrated behavioural recovery and an increase in dopamine synthesis as a result of exercise (Tillerson et al. 2003). The role of exercise for the treatment of both the physical and psychosocial symptoms has been advocated throughout the literature, most recently in the development of the European physiotherapy guidelines for Parkinson's (Keus et al. 2014). In reviewing 70 clinical trials, the guidelines suggest strong evidence for the role of specific physiotherapy intervention for improving transfers, balance, gait, physical capacity and movement functions (Keus et al. 2014).

Whilst exercise is the primary scope of practice for physiotherapy with PwP (Keus et al. 2007), questions remain surrounding the optimum content (Goodwin et al. 2008). An evidence-based literature review of physical therapy for PwP suggested four components are required for effective rehabilitation. These being; 1) cueing strategies to improve gait; 2) cognitive movement strategies to improve transfers; 3) exercises to improve balance; and 4) training of joint mobility and muscle power to improve physical capacity (Keus et al. 2007). Furthermore, the European guidelines suggest five core areas as the main focus of physiotherapy for PwP, being physical capacity, transfers, manual activities, balance and gait (including posture) (Keus et al. 2014). A recent systematic review of physical activity on functional skills showed strong level one evidence (consistent results from well-designed and well-conducted studies) that development of motor and sensory perceptual performance skills (strength and balance) in PwP are supported by multi-session, repetitive physical exercise and activity training (Foster et al. 2014). Dual task activity performance, particularly related to balance, has also been shown to be responsive to training in which both cognitive and motor performance skills are integrated within the activity (Morris et al. 2010). Finally, the use of multimodal activity intervention has been shown to have a positive benefit for cognition, especially executive function in PwP (Tanaka et al. 2009).

A recent Cochrane review stated the overall aim of physiotherapy intervention is to optimise independence, safety and wellbeing, thereby enhancing quality of life, however the intervention that is most effective at achieving this remains unclear (Tomlinson et al. 2014). Limited resources and the need for long-term physical interventions within the National Health Service have required consideration of novel and motivating ways of encouraging rehabilitative activities that can be offered within the lifestyle and social sectors; maximising quality of life and minimising the impact of the disease progression to retain independence. One example of such an activity for PwP is dance.

2.2.2 The role of dance for the treatment and management of Parkinson's

Considering the latest European guidelines for physiotherapy in PwP (Keus et al. 2014), the use of dance as a form of treatment and management of PwP can demonstrate considerable suitability by meeting each of the core areas suggested. In addition, a recent review of the clinical evidence for complementary and alternative therapies in Parkinson's found sufficient evidence that dance therapy is safe, enjoyable and effective for improving gait and balance in PwP (Bega et al. 2014). Specifically, dance techniques for PwP are designed to encourage postural extension, head and trunk rotation with repetitive turning, ankle movements, stepping strategies, enhanced balance mechanisms through safe and supported challenge and increased exercise capacity, all shown to be of deficit in PwP (Nieuwboer et al. 2007). The specific nature of dance training for these deficits is supported by the findings that improvements in physical performance is most responsive to task-specific compared to task non-specific training (Kwakkel et al. 2007).

Dance not only challenges physical function but also autonomous and emotional expression by stimulating many sensorimotor systems through whole body movement (Batson et al. 2014), thus enhancing somatosensory and vestibular feedback, alongside visual and verbal cueing from the teacher or auditory cues from the music. All of which have been shown to successfully regulate loco-motor movement (Lohnes & Earhart 2011), whilst enhancing cognitive function (McKee & Hackney 2013), owing to the dual task nature of the intervention.

To explore these effects further, a narrative review was undertaken to summarise the effects of dance in PwP. A detailed description of the search can be found in Appendix 2 ('Literature search terms for the effects of dance for people with Parkinson's'), with an overview displayed in Figure 4.

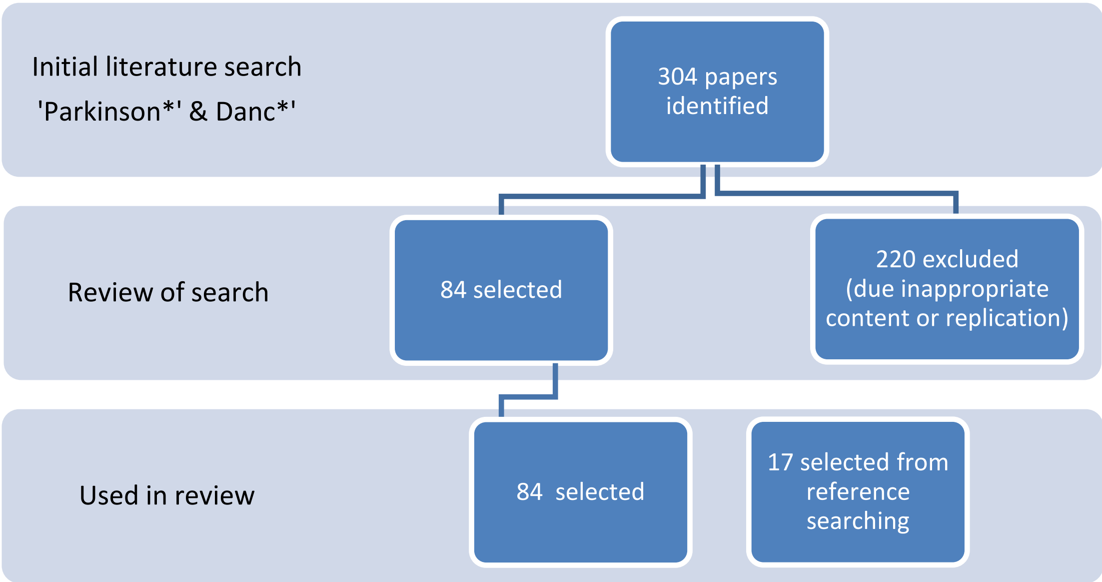


Figure 4 – Literature search results for the exploration of dance and Parkinson's.

2.2.3 Literature review of the effects of dance for people with Parkinson’s

Dance is a choreographed routine of movements, usually performed to music (Hui et al. 2009). It is a multi-dimensional activity, offering auditory, visual, and sensory stimulation, musical experience, social interaction, memory, motor learning, emotional perception, expression and interaction (Kattenstroth et al. 2010).

The overall impact of dance for PwP has been considered in a recent systematic review and meta-analysis, including five trials. Results found dance significantly improved motor scores on the Unified Parkinson’s disease rating scale (UPDRS), Berg balance scale (BBS) and gait speed when compared to no intervention in PwP, with improvements in the BBS and quality of life (PDQ-39) also found to be significantly greater in dance compared to other exercise interventions (Sharp & Hewitt 2014). Whilst this provides consolidation of literature to demonstrate the overall impact of dance across studies and across dance disciplines, caution should be taken as methodological quality of the trials included was considered poor, owing to risk of bias, with a lack of details reported on the blinding and monitoring of other activities or interventions, and lack of trials showing the long-term effects of dance for PwP. However, the inclusion of trials including ballroom, Argentine tango and Irish dance provides an overview of the global effects of dance across the disciplines.

Despite an increasing number of studies investigating all forms of dance for PwP such as Ballet (Houston & McGill 2013), ballroom and Latin American (Hackney & Earhart 2009a; Hackney & Earhart 2009b; Hackney & Earhart 2009c; Hackney & Earhart 2007a; Hackney & Earhart 2007b; Hackney & Earhart 2010a; Hackney & Earhart 2010b; Duncan & Earhart 2012; Duncan & Earhart 2014), contact improvisation (Batson 2010; Marchant et al. 2010; Heiberger et al. 2011) and Irish dancing (Volpe et al. 2013), the majority of dance research for PwP has been conducted in the genre of ballroom and Latin American dance, in particular the movement sequence of Argentine tango. This dance involves frequent movement initiation and cessation, spontaneous directional changes, foot strike patterns (heel-toe footsteps), balance challenges such as weight transference with and without the partner and a wide range of movement speeds (Hackney & Earhart 2009a) that target movement initiation, turning and bradykinesia respectively. Many of the step patterns used in Argentine tango also mimic those used to target the rehabilitation of ‘freezing of gait’, such as stepping over a partner’s foot.

When comparing Argentine tango to a standardised programme of strength and flexibility exercises, Hackney et al. (2007b) showed significant improvements in the UPDRS, in both groups after 20, one-hour sessions. In this trial however, the Argentine tango group also improved significantly in the BBS, demonstrating a 3-4 point change, which is considered to be clinically meaningful (Keus et al. 2014). A trend towards improvement in the Timed up and go test (TUG) and half the group continuing to dance post intervention, with the exercise group also changing to Argentine tango was also demonstrated. The primary outcome measure was not stated, but the feasibility of participants being capable of participating in tango and showing improvements in functional mobility in both groups was suggested. Without stating the primary outcome, it is not possible to determine whether the study was adequately powered, and with a small sample size of only 19 in total, it may indeed have been underpowered.

Using the same trial design, the authors also reported in a separate paper (Hackney et al. 2007a) that PwP in both the exercise and Argentine tango groups increased balance ability, measured using the one leg stance and functional reach tests, but increases in balance confidence were only shown in the Argentine tango group, using the falls efficacy scale and activities of balance confidence scale. These results are difficult to comment on further as no indication of the significance of the comparisons was reported. However, a significant difference was reported in perceived balance ability in favour of the tango group through an exit questionnaire, asking participants to rate the statement ‘my balance has improved since starting this programme’. Whilst this could be considered a ‘leading question’ causing bias, it was the same for both groups, and therefore the significant difference found suggests Argentine tango classes had a greater effect on balance confidence than exercise alone.

It is important to note in this instance, the findings of a meta-analysis, demonstrating benefits gained as a result of physiotherapy were generally diminished after cessation of the intervention (Gage & Storey 2004), in addition the ever-tightening constraints of the health care setting in delivering preventative therapy for long term condition management. Both of which suggest the delivery of dance for PwP may be suited to an intensive initial period, later supported in the social setting. The majority of the studies of Argentine tango for PwP have been conducted over a 10-week period of 20, one-hour classes, however similar effects have been found from short time periods and more frequent classes. Hackney and Earhart (2009c), found significant improvements in the BBS, UPDRS and the percentage of time spent in stance phase during gait, from a two week programme of 10, 1 ½ hour Argentine tango classes. Unfortunately this study was limited by a small sample size (n=14), and was a non-randomised design, presenting the possibility of bias. However, the results do suggest the feasibility of a high dosage, intensive tango class intervention, which may, with further research, have implications when considering its possible delivery as an intensive treatment programme in the health care setting. This is further supported by the findings that participants wished to continue with regular classes after the research study had finished, and those not allocated to dance chose to take up dancing (Hackney et al. 2007a; Hackney et al. 2007b) as an independently accessed community-based healthcare option, which suggests dance may be suitable in this context.

Working towards this model, Duncan and Earhart (2012) studied the effects of a 12 month community based Argentine tango programme for PwP. They found a significant 28.7% (12.8 point) reduction in their primary outcome measure of the UPDRS for those in the Argentine tango class from baseline to 12 months, in comparison to no change in a control group. There were also significant group by time interactions in the secondary measures of balance, gait and endurance. These results were also replicated in a subsequent study over two years by the same author using the same design, showing the improvements to exceed the minimal detectable change and minimal clinically important difference (Duncan & Earhart 2014). Unfortunately, participants were only assessed when they had withheld from medication, thus limiting the findings in the functional setting when medication is taken regularly. The design also did not control for the effects of socialisation and attention, as the controls received no intervention. However, a large sample number (n= 62) and the use of validated outcome measures over time, gives this study a more robust basis to suggest long term intervention through dance has the potential to modify disease progression in PwP.

It is not only Argentine tango that has shown significant improvements in motor deficits for PwP as contemporary dance styles have also been studied (Westheimer 2008; Marchant et al. 2010; Heiberger et al. 2011). Contemporary dance can be considered a more expressive form of dance, creating movement through experimentation and collaboration of new movement rather than set standards or defined styles. It offers a free-form improvisation-based dance technique in comparison to the structured, stylised and aesthetic demands of Argentine tango. It integrates tactile, vestibular and visual feedback generated simultaneously by both partners or independently by the forces of motion and gravity, without the need for high physical or cognitive ability (Marchant et al. 2010). One such type of contemporary dance that has been used with PwP is contact improvisation (CI). CI has shown improvements in the BBS and gait measures of stance and swing time, plus backward step length (computerised 'GAITRite walkway'), alongside high levels of enjoyment, after 10, 1½ hour sessions over two weeks (Marchant et al. 2010). Whilst this study gives indication of the potential of CI as a dance genre for PwP, particularly for those with severe movement and cognitive difficulties, the research was of low methodological quality. There was a small sample size of 11 and historical Argentine tango data was used as a comparison rather than a control group. It is therefore difficult to distinguish whether these results are due to the specific components of dance or the intensity of the intervention as a driver of neuroplasticity and motor improvement.

Batson (2010) demonstrated an intensive three times a week, for three weeks, modern dance class to significantly improve balance scores in 11 PwP. The outline of the class describes a format of modern contemporary techniques with CI. Interestingly, results showed differences in balance scores during dynamic and multitasking items such as changing level, and multitasking with vestibular perturbations (walking with head turns), neither of which were practiced in the class. This demonstrates a degree of performance cross-over from dance to functional tasks. Unfortunately, due to the primary purpose of this study being to assess the feasibility of a modern dance class for PwP, the research was of low methodological quality, using a convenient sample of participants who were already exercising in a social group, and no control comparison, limiting the further application of the findings of this study.

In support of the findings by Batson (2010) and Marchant et al. (2010), the use of contemporary and free-form styles of dance with a less intensive programme of once-weekly for eight months showed significant improvements in rigidity scores (Heiberger et al. 2011). Significant changes in UPDRS scores were shown in hand movements, finger tapping and facial expression. Again, these activities were not specifically trained during the dance, thus suggesting a change in the motor control and neural circuitry of the brain, possibly through activation of the emotional motor systems, bypassing the affected basal ganglia (Heiberger et al. 2011). This further supports the argument of neuroplasticity brought about through dance. Although particularly interesting, the lack of significant change in gait (TUG) or balance (semi-tandem stance test), small participant numbers (n=11), lack of control and no specified primary outcome measure mean these results should be treated with caution.

To study the effects of different dance genres in the same study, Hackney and Earhart (2009a) compared Argentine tango and American ballroom (social waltz and foxtrot) to a non-intervention control. Participants were randomised into both dance groups, completing 20, one-hour sessions, twice a week over 13 weeks. Results indicated that both intervention groups improved significantly in measures of balance (BBS) and gait (Six-minute walk and backwards walking), with no improvement and expected functional decline in the control group. Although not statistically significant, measures of gait speed (TUG) and gait freezing ('freezing of gait questionnaire') also improved more in the Argentine tango group than ballroom group. This study was of reasonable methodological quality, with a sample size of 58, blinded hypothesis to participants and assessors, with consideration for teacher bias. Despite many of the changes not reaching statistical significance, they may have been clinically meaningful. For example, a 0.1m/sec change in gait speed is required to be clinically substantial (Steffen & Seney 2008), which was achieved in backward walking by both forms of dancing and nearly reached in forward walking in Argentine tango. A possible reason for the lack of significant results may be the selected outcome measures, which may have lacked sensitivity to the effects of the dance class, thus further research to investigate the specific mechanisms of dance, such as body segment rotation and stepping are required.

The effects of Irish dance (Volpe et al. 2013), Ballet (Houston and McGill 2013) and Tai classical dance (Khongprasert et al. 2011) have also all shown positive effects on motor performance including gait, balance and motor disability in PwP. All trials were feasibility studies with small sample numbers and therefore lacked significant power to generalise the findings, but they do demonstrate the need for larger randomised clinical trials to ascertain the effectiveness of all dance forms for the treatment and management of the symptoms of Parkinson's.

In summary, the majority of research has focused on the use of Argentine tango, however it appears contemporary dance, modern, Tai, Irish set dancing and ballet may also demonstrate a potential in the rehabilitation of PwP. It could be suggested that the stylised and specific nature of Latin American, ballroom, Irish, ballet and Tai techniques encourages changes in motor control through mechanisms of neuroplasticity and physiological change (Brown et al. 2006). Whereas, the expressionate and unstructured nature of contemporary and modern dance styles allow participants to explore their own unique movement parameters. Both forms of dance may lead to increased body and emotional awareness, improved body image and a renewed sense of physical and emotional well-being.

2.2.4 Additional influencing factors in dance for people with Parkinson's

The multi-system and holistic nature of dance allows not only an individualised personal experience of movement, but also the interaction of movement created with and alongside others in a unique environment. This interaction may be in the form of collective group movement or small groups and pairs, to a shared music and rhythm depending on the genre of dance investigated.

Considering the influence of a shared experience, the use of an able-bodied dance partner for PwP has been raised in the literature, with both physiological and psychosocial justification. A partner may firstly allow PwP to explore new and perhaps more challenging movement sequences with the confidence of support. This can be demonstrated by a case study of an individual with severe Parkinson's (H&Y stage 4), who primarily used a wheelchair for transportation, showing a 10-week, twice a week hourly Argentine tango class improved his balance, endurance, functional reach, balance confidence and quality of life (Hackney & Earhart 2010b). The participant was only able to participate with the assistance of his caregiver as a dance partner. Whilst this is a case study and therefore has limited generalisability, it does clearly demonstrate the essential role of the partner in allowing those with more advanced symptoms to access the effective rehabilitation of dance.

To specifically investigate the effects of the partner, Hackney and Earhart (2010c) compared 20 partnered and non-partnered Argentine tango dance classes in 39 PwP over 10 weeks. In comparison to the above case study, participants in both partnered and non-partnered groups had a median H&Y

score of 2.5 and 2 respectively, suggesting a less severe disease presentation and thus less likely to require the support of a partner for safety reasons. No significant difference in the movement parameters of gait and balance between the groups was found. Although significant participants were recruited to achieve adequate statistical power, the attrition rate was high, with only 12 partnered and 15 non-partnered participants completing all data collection. The majority of the reasons given for this were unrelated to the intervention and the authors used an intention-to-treat analysis, with data being extrapolated from the last available data point to analyse their results, considered a less robust method of data collection and analysis with a potential to influence the results.

The role of the partner as a multisensory cue may also be fundamental when considering the importance of cueing to movement initiation in PwP (Morris 2000). A partner's physical movement may offer a visual, proprioceptive and tactile cue, alongside their instruction and encouragement being a verbal cue.

During dance, the use of such external cues when being led may improve motor performance, through bypassing the dysfunctional basal ganglia to alternative neural pathways (Brown at al. 2006). In order to follow without restriction, focus must be held on simple concepts of direct, rotation, distance and speed, responding to the smallest external movement cue of the leader from moment to moment. Conversely, taking the lead in a dance partnership requires internal cueing to determine step length, velocity, single support time, and partnered trajectories (Hackney & Earhart 2010c). This suggests there may be a rehabilitative model for both internal (independent or partnered-leading) and external (partnered-led) cueing, hence the lack of difference between partnered and un-partnered Argentine tango found by Hackney and Earhart (2010b). This may also be the case when comparing the use of "stylised" Argentine tango requiring specific, counted steps to fixed rhythms and external cues to 'free-form' styles such as CI, with fluidity and flexibility in performance driven from internal cues.

Although Hackney and Earhart (2010b) did not find a significant difference in movement parameters between partnered and non-partnered dancers with Parkinson's, an exit questionnaire completed by both groups, showed partnered dancing to elicit greater enjoyment and willingness to continue. This is an essential component when developing a rehabilitative programme, not only to promote adherence but also to enhance the potential for neuro-plastic change driven through motivation, saliency, regular practice and intensity (Farley et al. 2008), all of which are more likley to be achieved with partnered dance compared to non-partnered.

In addition to the role of the partner, the use of music and rhythm as an external influence for movement generation during dance is likely to also be fundamental. The use of music-based movement therapy has been widely investigated in the literature and full discussion is beyond the scope of this review. However, a recent meta-analysis of six randomised controlled trials of the effects of music on walking ability, balance and quality of life in PwP concluded significant summary effects sizes in favour of the use of music for all domains (de Dreu et al. 2012). It is likely that the use of music as an accompaniment of dance will contribute to the efficacy, as the temporal musical structure may act as a rhythmic cue (Nieuwboer et al. 2007). This is consistent with the general functional perspective of rhythmic cues enabling and facilitating precise synchronisation of movement (Madison et al. 2011). In addition to this, music has been found to elicit emotional responses, as moving to music activates endorphin release (Blood & Zatorre 2001), with the act of dancing to music promoting an enjoyable and distracting activity from the possible sensations of fatigue and thus allowing PwP to gain a higher level of physical activity than movement without music.

In summary, it appears the use of the partner and the influence of music and rhythm may not be purely for physical support or accompaniment, but as an integral component of the dance experience, offering a multi-sensory cueing model that leads to enhanced movement facilitation in PwP.

2.2.5 Psychosocial influences of dance for people with Parkinson's

It is important to note that it is not only the motor symptoms that have been shown to be affected by dance but also the psychosocial benefits of participating in a socially engaging, potentially uplifting and collectively challenging experience.

The psychosocial benefits of dance for PwP have been reported favourably in the majority of papers (Hackney et al. 2007a; Westheimer 2008; Earhart 2009; Hackney 2009; Hackney & Earhart 2009b; Young-Mason 2009; Hackney & Earhart 2010d; Marchant et al. 2010; Soriano & Batson 2011; Lewis et al. 2014; Mandelbaum & Lo 2014), supporting the notion that motor systems should not be the sole focus of care for PwP. Dance has been demonstrated as enjoyable and socially engaging, increasing motivation to start and maintain a programme of exercise, possibly bridging the gap between social activity and therapeutic exercise in PwP (Rabbia 2010). In addition to the consequences of the physical symptoms of Parkinson's, such as social isolation, withdrawal and low self-esteem, PwP may also experience a decline in their mental status, including depression and disturbances in memory and cognition (Hieberger et al. 2011).

To investigate the complex interaction between motor and non-motor symptoms, Houston and McGill (2013), used a mixed method design studying the effects of a 12-week Ballet project in 24 PwP. Significant positive changes in balance, stability and rigidity (average increase of four points of the Fullerton advanced balance scale (FAB)) were found, with qualitative analysis of film footage, interview scripts and diary reports also showing increased fluency of movement, increased stride length and use of coordinated upper and lower limb movements, supported by comments of increased functional performance. Importantly, an increase in confidence to try new movements was also reported, with corresponding evidence of larger outward projected movements from film analysis and ability in the re-stabilisation task from the FAB. Finally, there were reported improvements in feelings of wellbeing, over and above that gained from the Parkinson's support groups and 100% adherence, with evidence of development of social interaction through film analysis. Whilst the purpose of this paper was primarily action research to enhance the development of the Ballet programme, with clear limitations in sample size (14 interviewed, four kept diaries, six completed the physical assessment measures, with only two completing all aspects) and a biased selection, the results do highlight the multidimensional qualities of dance for PwP and support the role of dance in improving health-related quality of life (Duncan & Earhart, 2012), activity participation (Foster et al. 2013), mood enhancement (Westbrook & McKibben 1989; Lewis et al. 2014) and socialisation (Houston & McGill, 2013).

2.2.6 Pathophysiological effects of dance for people with Parkinson's

The specific mechanisms that underlie the biopsychosocial effect of dance for PwP are unclear. From an overall perspective, the process of moving requires physical attention to neuro-motor feedback loops, sensing force within the body, generating force from muscles, while taking into account gravity, re-sensing and continually adjusting. This feedback system allows a person to perform any movement with reduced conscious control. Dance training of any kind aims to enhance individual awareness of these feedback systems and exert conscious control in key ways to affect physical performance, with the resultant effect of allowing individuals to self-generate novel movement coordination patterns (Worthen-Chaudhari 2011). From the dance perspective, the use of imagery and other creative processes enables the internalization of desired movement and visceral experience of new movement. From the scientific perspective, dance allows participants to utilise explicit control and generate new experiences of implicit processes, all of which are particularly important for PwP who due to the pathophysiology of the condition present, with specific deficits in automatic movement generation (implicit processes), requiring conscious control for everyday tasks. This may represent a possible mechanism of effect not only for the production of movement, but also the experience of producing that movement for the participant and its continued effect in everyday functional tasks.

More specifically, advances in neuroscience have revealed that exercise can inhibit cell death, increase synaptic efficiency, and promote behavioural recovery in animal models with head injury (Kleim et al. 2006). This suggests a dynamic interplay between degenerative and regenerative mechanisms mediated by behaviour, experience, and higher intensities of self-produced activity (Kleim et al. 2004). Current therapies target compensation of functional loss, aiming to bypass the basal ganglia pathology (Keus et al. 2007). This may not make use of the potential gain from neural-plastic changes, such as long term potentiation and synaptogenesis, which may lead to increased ability to engage in more complex behaviours (Hirsch et al. 2008). Dance does share many of the characteristics, suggested by Farley et al. (2008), required to drive neural-plastic change, such as self-produced movement (evidenced in active involvement of participants), saliency and novelty (spontaneous and creative expression of emotion), high intensity and task specificity (practice, motor imagery, repetitions and variation of familiar and new movement sequences) and complexity (free form or set choreographed movement sequences). In addition to this, Jeong and Hong (2005) reported dance movement therapy enhanced the concentration of serotonin (pre- compared to post-12 weeks of dance movement therapy), suggesting a positive effect on feelings of happiness and increased body awareness (although this was in adolescents with mild depression rather than PwP). Finally, motivation is considered essential to motor learning (Farley et al. 2008), for which dance has shown to have a positive effect in PwP (Westheimer 2008).

In an effort to quantify the neuro-physiological effect of a community based, improvisational dance class, Batson et al. (2014) reported a functional magnetic resonance imaging (fMRI) case study of the participant who demonstrated the highest functional gains in balance over a three-month period, scanning before and after an additional one week intensive dance programme (five consecutive days of hourly classes). Results indicated increased brain connectivity, particularly between the basal ganglia and cortical motor centres. The exact mechanisms for this neuroplasticity are unclear, but possible theories include the influence of multisensory cueing, increased attention to walking and more automatic movement patterns (Earhart 2009). Whilst this may be the case in dance forms such as Argentine tango, where the emphasis is on timing and stepping patterns, it is less likely to be the case in improvisational dance, where the emphasis is more towards movement flow, quality and experience.

As well as adaptive change, it is likely that taking part in a dance class facilitates the activation of ‘Mirror Neurons’ which are active during the performance of an action and the observation of the same action (Rizzolatti et al. 1996). It is possible that observation of the teacher performing functional movements that therefore have stored motor-programmes for the participant may activate mirror neurons, even if the functional task is now not possible for the participant due to deterioration. Furthermore, mirror neuron activation is thought to be greater if the movement is considered aesthetic (Calvo-Merino et al. 2008), suggesting dance may have a greater effect than functional practice alone.

Whilst the effects of specific components of dance in PwP have not been investigated, task specificity states that in order to improve in a task, one must practice that task (Hubbard et al. 2009). The components of dance incorporate many functional movements that are particularly difficult for PwP (Earhart 2009), such as walking backwards and sideways, turning, rotation of the trunk, repetitive movement pauses followed by initiation, and movement fluidity (Keus et al. 2007). Furthermore, dance fundamentally requires the participant to multi-task between the steps, bilaterally use their upper limbs in coordination with their lower limbs, and respond to the musical cues and other dancers in the room. The repetitive practice of these problematic components in a safe and supportive environment may be a contributing factor to the improvements seen in gait (Hackney & Earhart 2009c; Hackney & Earhart 2009a; Hackney & Earhart 2010b; Hackney & Earhart 2010c; Hackney & Earhart 2010a). Training of turning steps through dance may also be linked to the argument for neuro-plastic change and subsequent motor improvement (Farley et al. 2008), as greater effect on balance (BBS) and functional gait (TUAG) have been shown in tango than exercise alone (Hackney et al. 2007b), possibly due to the rotational aspects of the dance that traditional exercise therapies rarely include (Keus et al. 2007).

In summary, the mechanisms of dance for PwP are relatively un-investigated; however the evidence presented suggests the fundamental use of imagery and other creative processes enables the internalisation of desired movement and visceral experience of new movement, with enhancing effects on neuro-motor feedback loops. This may have an effect on driving neuro-plastic changes, such as long term potentiation and synaptogenesis, which may promote behavioural recovery and lead to increased ability to engage in more complex behaviours that have become challenging as a result of the disease progression.

In addition, increased brain connectivity, activation of ‘Mirror Neurons’ and increased cognitive attention have all been suggested, owing to the unique effects of multisensory cueing alongside task specificity and repetitive practice of problematic movement, in a safe and supportive environment.

Finally, it appears the effects of encouraging body segment rotation about either a fixed environmental, or an internal body part axis may also be a unique component to dance, often overlooked in the rehabilitation of PwP.

2.2.7 Summary of dance for people with Parkinson’s

In summary, it appears from the evidence presented, that dance classes for PwP are a suitable and effective treatment option for the management of a diverse range of symptoms. It is not just isolated motor symptoms of gait and balance that have shown improvement after dance, but owing to the way dance is taught with an emphasis on aesthetics and personal experience, improvements in body awareness, proprioception and quality of movement have also been seen, with the unique qualities of dance providing a strong base for social and emotional development for PwP.

A variety of teaching methods and thus learning experiences, alongside the possibility of driving long-term neuro-plastic change has also been suggested, with the integral use of imagery and personal experience inherent in dance, creating opportunities for new physical knowledge to generate movement solutions.

The breadth of evidence presented has enabled the novel development of the two studies presented in this thesis. Previous literature informed the design of the dance intervention used in the quantitative component as well as the exploration of the teacher’s expectations and experiences through the qualitative component. Both components draw on the evidence presented throughout the discussions, enabling a depth and breadth of understanding from the findings presented alongside current best evidence. A summary of the key studies used to inform this thesis is provided in Table 2. However, it is important to note that the expanding literature base for the effects of dance for PwP is diverse and extensive with many additional papers being discussed through this literature review and subsequent discussions.

Paper	Study design	Aim	Findings of interest	Contribution to areas of this thesis
Shanahan et al. 2015	Meta-analysis Included studies of tango (partnered/non-partnered), waltz, foxtrot, Irish	To provide information on the frequency, intensity, duration and type of dance for PwP.	Two one-hour dance classes per week, over 10-13 weeks may have beneficial effects on endurance, motor impairment and balance in PwP.	Evidence of the intervention design required to demonstrate a change in function. Supported the design of intervention used in the RfPB study (therefore this thesis).
McGill et al. 2014	Literature review of dance for PwP.	Proposal of the ICF classification of function for dance for Parkinson's research.	Necessity to use the ICF model to show the multimodal effect of dance for PwP.	Consideration of the literature across the ICF framework to identify the gaps in research that are supported by this thesis.
Mandelbaum et al. 2014	Literature review of dance for PwP.	Provide review of the sample size, dosage, frequency, intervention, class size, comparison or control groups, outcome measures and effect size.	Identified essential components of intervention design.	Due to date of publication, this paper contributed to suggestions for future studies rather than the design of the study discussed in this thesis.
Hackney et al. 2007b	Randomised, between subject, prospective, repeated measures (pre-post). 19 PwP 20, 1 hour Tango or general exercise classes, twice a week.	Compare the effects of tango dance to general exercise in PwP.	Tango group showed an increase in balance scores (BBS) and trend for increased mobility (TUAG) not shown in the exercise group.	Suggested the additional effects of dance on PwP above those expected by general exercise. Introduced the concept that components of dance may provide unique rehabilitation of the symptoms of PD.
Hackney and	Randomised, between	Compare the effects	Both dance groups improved more than the	Introduced the concept that different dance

Earhart, 2009a	subject, prospective, repeated measures (pre-post). 58 PwP randomised to Tango, ballroom dance or control. Intervention - 20, 1 hour dance classes, twice a week or usual care.	of tango, waltz/foxtrot and no intervention on motor control in PwP.	control group. The tango group improved as much or more than those in the waltz/foxtrot group on several measures.	styles may affect the symptoms of Parkinson's in different ways to differing extents. Evidence of a significant decline in disease severity and gait in the control group over intervention period.
Hackney and Earhart, 2010c	Randomised, between subject, prospective, repeated measures (pre-post). 39 PwP randomised to partnered or non-partnered tango classes. 20, 1 hour, partnered or non-partnered Tango classes, twice a week.	Compare the effects of partnered and non-partnered dance classes for PwP.	Both groups improved on measures of balance (BBS) and mobility (cadence), maintained at one month follow up. Partnered participants expressed more enjoyment.	Introduces the concept that the partner may have both a physical and emotional impact on the experience and effect of dance for PwP.
Marchanta et al. 2010	Uncontrolled pilot study. 11 PwP 10, 1 ½ hour classes, over two weeks.	Feasibility and possible benefits of contact improvisation for PwP.	Improvement in disease severity (UPDRS), balance (BBS) and gait variables.	Other dance styles may also show an effect on the symptoms of Parkinson's. The mechanisms of effect may be different depending on the dance style and delivery.
Soriano and Batson, 2011	Action research.	One teachers process of developing a modern dance class for PwP.	Modern dance offered a multi-sensory experience and opportunity to explore new movement material for PwP. Dance classes need to include opportunity to	Reflective discussion of the experience from the perspective of the teacher, contributing to the qualitative component of this thesis and the concept that dance teachers and health professionals may approach a dance class for

			maximise expressive movement material.	PwP from a different context.
Houston and McGill, 2013	Mixed methods study. Clinical measures of balance, stability and posture alongside ethnographic methods, grounded theory and effort analysis. 12 week dance project run by English National Ballet.	Exploration of research design to capture the multi-faceted effects of dance for PwP.	Motivation to attend and value of the class was expressed. Triangulation of results demonstrated improvements in balance and stability that were supported by qualitative findings.	Identifies the importance of considering the multi-modal effects of dance for PwP through a range of research methods to capture the total effects on the person and their 'world'.
Houston, 2014	Book chapter. Qualitative design Semi-structured interviews of dance teachers already delivering dance classes for PwP.	Examine the engagement of teaching artists with participants living with Parkinson's.	Many teachers adopt the 'person centred approach' to class, often emphasising the importance of the social aspects over the physical effects. Despite the therapeutic effect teachers did not consider themselves as therapists.	Describes the experience of teaching a dance class for PwP from the perspective of the dance teacher, from which to compare results from this thesis.
Demers et al, 2014	Qualitative design. 3 focus groups across 3 rehabilitation units, including 14 allied health professionals.	To address the 'access barriers to knowledge use' of the 'Knowledge-to-action' process.	4 themes concerning the implementation of dance intervention in the health care setting: 1) Clinicians dance experience and training. 2) Interests and personal belief towards the effects of dance for PwP. 3) Support from the organisation. 4) Available resources.	Describes the barriers to implementation and expectations of clinicians to delivering dance in the medical model of rehabilitation.

Table 2 – Summary of literature used to inform the development and discussion of this thesis.

Whilst there is a growing body of evidence to suggest that dance may have benefit for the treatment of both the physical and psychosocial symptoms of the condition, the majority of these studies have been undertaken with small numbers of participants and varying methodological quality. The 'best practice model' for implementing dance for PwP with regards to frequency, duration, intensity and type of dance is still un-clear in the literature with different dance approaches offering differing evidence and views on the effects and purpose. Nevertheless, the preliminary clinical and functional effects of dance for PwP are worthy of further research. This led to the award of a Research for Patient Benefit (RfPB) grant from National Institute of Health Research (NIHR), to the Rehabilitation Research team at the University of Southampton and the subsequent University studentship that enabled the research reported in this thesis.

2.3 Overview of the RfPB study

The purpose of the RfPB study was to determine the feasibility of conducting a phase III randomised controlled trial to evaluate the benefits of dance among PwP. It was a two-group, single-blinded study, including 53 PwP. Participants were randomised to either an intervention arm (n=36) which included 20, one-hour ballroom and Latin American dance classes, twice a week, for 10 weeks, or usual care (n = 15). A greater proportion of participants were randomised to the intervention arm (two: one) to maximise the number dancing and thus data on the feasibility of the intervention itself. Dance classes included three ballroom (waltz, social foxtrot and tango) and three Latin American (cha cha cha, rumba and rock 'n' roll) dances, all of which were danced with a partner (the selection of dances was based on a small pilot study, described in Appendix 3) and were led by professional dance teachers. A battery of assessments including balance, confidence, spinal posture and mobility and health outcomes were completed in the participant's own home at baseline, three months (before and after intervention) and at six months post randomisation. In addition to this, 15 people who completed the dance intervention were interviewed to enable exploration of their experience of taking part in the study.

Results demonstrated feasibility of recruitment and retention, as target recruitment was achieved with 31 PwP completing on average 18-20 of the classes in total. All dance styles included were found to be feasible and enjoyable, with the waltz and social foxtrot being easiest and the cha cha cha and rumba being most challenging. Difficulties reported included the need to take larger steps, turning and transferring weight. No significant differences were found between the groups at three or six months, however subgroup analysis identified that a) previous fallers, b) PwP who had the condition for longer and, c) male participants, appeared to benefit most from the dance intervention, with trends and significant improvements in balance (b and c), balance confidence and spinal posture (a-c).

The overall conclusion of the RfPB study demonstrated the feasibility of conducting a randomised controlled trial to evaluate the benefits of ballroom and Latin American dance, with recommendations for future trials.

Whilst the main aims of the RfPB study were focused on ascertaining the feasibility of a trial for the effects of dance on PwP on a larger scale, it also provided the opportunity to explore other novel research topics within the same trial. This lead to the development of both the qualitative component of this thesis; exploring the expectations and experiences of dance teachers delivering a new dance class for PwP and the quantitative component; investigating the effects of ballroom and Latin American dance on turning in PwP, through 3-dimensional movement analysis. Each of which make a unique contribution to the findings of the RfPB study as a whole and are presented in the following chapters.

Chapter 3: Qualitative component

'Everybody can dance' – A qualitative exploration of the expectation and experiences of dance teachers delivering classes for people with Parkinson's.

3.1 Context of study

With an appreciation of the essential integration of both qualitative and quantitative research in the paradigm of health research, I was acutely aware that acquisition of skills in both domains would be beneficial to my understanding and development within the academic field. Whilst the main focus of this thesis is the effects of dance on turning performance in PwP through 3-dimensional movement analysis, it is important to consider the perspective of the teachers' delivering any future implementation studies, which also provided an opportunity to learn and apply mixed methods in research through the PhD experience.

As a physiotherapist, I began my journey in the field of dance for PwP delivering a class based on the 'modern genre of dance', including structured dance content as well as an opportunity for creative expression. I was keen to challenge my participants by driving physical improvements in their symptoms based on a medical model of treatment. As a result, I found the inclusion of improvisation and creative expression difficult, but appreciated the need to encourage participants to explore their own movement vocabulary.

As I progressed in this field, I worked with a number of experienced community dance artists, some of whom had experience in working with PwP and inclusive dance practice (dance for all ability). I quickly realised that they were approaching the idea of 'dance for PwP' from a completely different perspective. Whilst they did have scientific knowledge of Parkinson's, their drive and focus during the class was not to remove or rehabilitate symptoms, but instead, work with them and around them, including them in the choreography. From this, the participants gained a sense of achievement and an exploration of new movement. It therefore became apparent that we were aiming for the same experience, but the journey was taking a different path.

Whilst I became aware of the need to celebrate the individuality of each dance participant, the role of dance as an expression of the self and an opportunity for psychological and social growth, I also felt a strong need to remain true to my knowledge and experience of physiotherapy and its benefits in helping to rehabilitate the physical symptoms of the condition. The need to deliver both aspects of the class presented a challenge for me in delivering a therapeutic intervention in an artistic paradigm. It was from this that I became interested to see if the opposite occurred – would a dance teacher have a similar experience delivering their art in a therapeutic world? Thus the opportunity to explore the expectation and experiences of dance teachers through the delivery of an RfPB intervention-based research project aimed at improving physical outcomes in PwP, would add new knowledge to the field and further the development of future dance-based research and classes.

3.2 Introduction

> *"Dance is a way out of a rut, a release valve, a health programme, a means of self-expression, a means of self-realisation, a means of belonging, a means of overcoming, a means of being free not in the escapist sense but in the enfolding of all their experience processed through the dance, finding and redefining new ways of being"*
>
> Ken Bartlett – 'The artistic imperative in dance with people with Parkinson's' – Personal communication at the Dance for Parkinson's Network UK meeting 2013, whilst Creative Director of the Foundation for Community Dance.

The importance of dance for PwP in the physical and psychosocial domains is generating a strong and convincing body of evidence (Hackney & Earhart 2007a; Hackney & Earhart 2007b; Hackney & Earhart 2009a; Duncan & Earhart 2012; Marchant et al. 2010; Westheimer 2008; Heiberger et al. 2011; Batson 2010; Volpe et al. 2013; Houston & McGill, 2013; Khongprasert et al. 2011) as discussed in Chapter 2. However, the exact delivery of such an intervention and more specifically, the experience and impact on those facilitating and guiding the movement, has received little attention in the literature. The aim of this qualitative study is therefore to explore the expectations and experience of dance teachers delivering a new ballroom and Latin American dance class for PwP. This knowledge, alongside the investigation of the physical effects by the quantitative component of this thesis and the RfPB study, will work towards building a broader understanding of the implementation of dance for PwP.

A literature search for the exploration of teaching experiences in dance classes for PwP was conducted and is summarised in Figure 5. A detailed description of this search can be found in Appendix 2 ('Literature search terms for the exploration of teaching experiences in dance for people with Parkinson's').

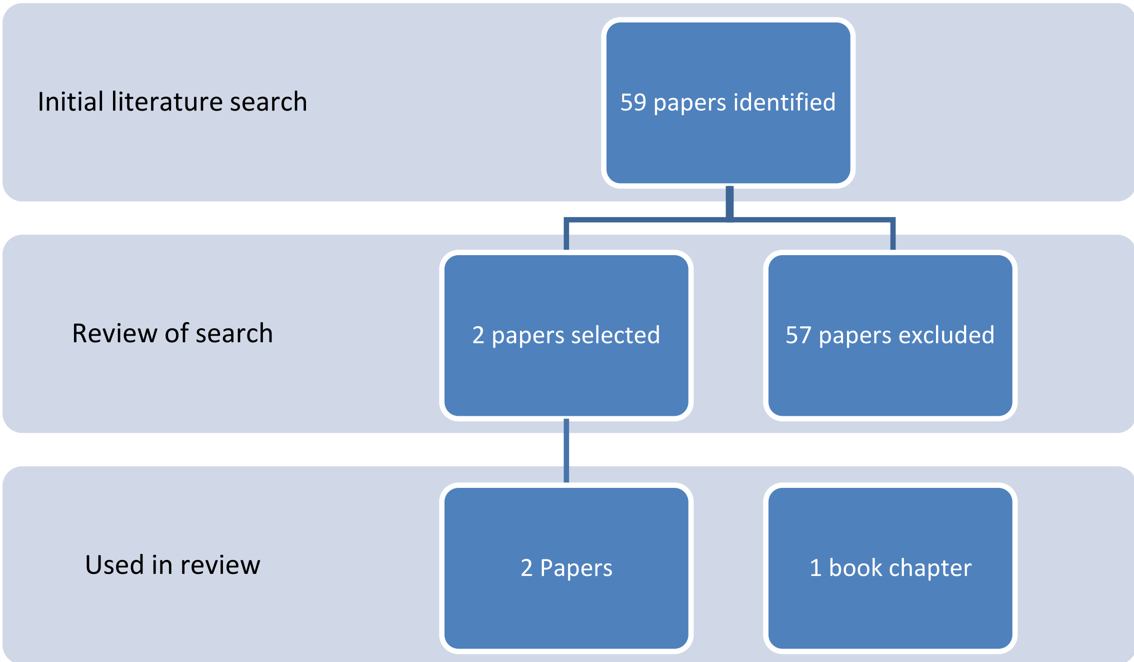


Figure 5 – Literature search results for the exploration of teaching experiences in dance for people with Parkinson's.

Using the search terms danc* and teach* in a selection of databases covering the medical and arts paradigms, a total of 59 papers were identified (17 from database searches and 42 from hand searching), excluding duplicates. The majority of these papers were related to the implementation and practical delivery of the class, rather than the experience of the teacher, with only two papers and one book chapter commenting on the teachers' experience, through the delivery of community dance for PwP specifically. Whilst the components of community dance are considered different from ballroom and Latin American dance (please see ‘Definition section’ of this thesis for a description of each), the insights they provide in the process of delivering dance for PwP specifically, warrants their discussion.

Current community dance classes for PwP offer a wide variety of dance genres and teaching techniques, including contemporary, modern, jazz, ballet, musical theatre, Argentine tango, ballroom, Latin American and improvisation. The majority of classes not only invite people with the condition, but also those who support them and thus also ‘live’ with the condition, and it is for this reason that classes are tailored for those living with Parkinson’s as a whole.

The novel and explorative nature of dance for people living with Parkinson’s has enabled its delivery to merge the professional boundaries of teaching artists and healthcare practitioners. Those currently facilitating practice and involved in the ‘Dance for Parkinson’s network UK’ have a diverse skill mix and background including professions such as dance artists with professional training or vocational qualifications, dance therapists, music therapists, physiotherapists and doctors (Steering group members of the Dance for Parkinson’s network UK), all of which bring differing and varied teaching aims and styles.

Despite the eclectic mix of dance and healthcare backgrounds, it appears that teachers share in a collective goal; that classes are not viewed as ‘therapy sessions’, despite the fact that there can be therapeutic outcomes and it is not offered as a means to an end, but as an artistic practice in which people living with Parkinson’s can participate (Houston 2014). Core principles have emerged from the ‘Dance for PD’ programme in New York, including innovations, creativity, artistic excellence, collaboration, inclusiveness, community, mutual respect and enjoyment (Brooklyn Parkinson Group 2012). The artistic nature of the work is emphasised in that it offers an enjoyable activity, away from the medical commitments that often structure and guide the daily routines of those living with the condition.

Houston (2014), explored the experience of dance teachers already facilitating classes for people living with Parkinson's, through semi-structured interviews, questionnaires and notes from fieldwork with teachers within the UK network 'Dance for Parkinson's network UK' and in the New York programme 'Dance for PD', as well as semi-structured interviews with Parkinson's disease support charities. Teachers expressed the fundamental need for a person-centred approach to their class, giving participants confidence in their ability and ownership in the movement they create, stressing the importance of differentiation, where structured dance material could be adapted to meet individual needs of all the participants. In an extension of this, Houston (2014) also found the person-centred approach expanded to include the lives of the dance teachers in the development of social relationships with their participants, including fostering a community and encouraging friendships around and outside of the class itself. Whilst the use of a grounded theory approach to data interpretation demonstrated the importance of a 'person-centred approach', featuring in many of the extracts from the interviews included in the text, the development of this theme over the three years that Houston collected the data is not commented on. Indeed the perspectives of one particular teacher with a background in physiotherapy did appear to change, stating she initially strove primarily for improvements in physical performance, which over time emerged to a greater importance being placed on the overall personal experience of the dance class. This suggests not all teachers initially had a truly 'person-centred approach' as described by Houston, and thus not all teachers may fit in the approach suggested.

It appears that it is not only the teachers' perspectives, beliefs and values that may be affected by the person-centred approach, but also their personal and emotional experience, with teachers "being touched" by emotional comments and "deeply moving" choreography from participants, alongside a natural compassion for the loss of movement and physical challenges. Teachers reported the emotional experience for both themselves and the participants as a result of the class, in both a positive and negative way. Feelings of cathartic release, togetherness and confidence were reported by the teachers on reflection, but also an acquired sense of responsibility for participants' challenges and difficulties, which may push them to care beyond that which they have training to deal with, such as counselling or social work skills (Houston 2014). The level of emotional and physical support is reported to go beyond what is normally expected in teaching a class, suggesting that working through dance with people who move differently leaves a mark on those who lead, with a high emotional investment (Houston 2014). Again, it is not clear from Houston's paper how the participants were selected or the number reached or sought. The choice of sample describes teachers across both the UK and America, however, it is possible that those consenting to take part may have had a greater 'emotional journey' than those who did not volunteer for the study and thus the sample may have been biased by those motivated and passionate to describe their experiences. Therefore, it is not possible to ascertain if the emotional investment experienced by the teachers in the study by Houston (2014) are typical experiences for all teachers of dance for PwP as no indication of redundancy or theoretical saturation of data was made. In addition, whilst the experiences are insightful of the emotional and personal investment of the teachers of already established dance classes for PwP, it does not provide insight or understanding of the expectations of those that are yet to deliver a class as potential teachers or the new experiences of teaching a class for the first time, both of which will be explored in this study.

The experience of a new teacher to dance classes for PwP is described by Soriano and Batson (2014), detailing the process of one dance teacher's construction and development of a modern dance class for PwP. The teacher was invited to develop the class as an example of action research over a two-week pilot project, to determine the feasibility of the structure and content for prospective studies. The process of honing her enquiry into the dance choreography for this specialised population is presented in the teacher's own words, describing the rationale and structure of the decision making process in the development of the class.

Whilst the focus of the paper is on the content of the class and the experience for the participants, description of the teacher (the author's) expectations, beliefs and influences on this process are discussed. These include: a concern that her inexperience or lack of scientific background would inhibit her ability to work with and best serve this specific population; the need to create a stimulating and valuable class; the difficulties of feeling that she needed to pre-plan and research the material; in contrast to the difficulty in pre-planning owing to the fact that she did not know the participants' level of function until the first class. Conversely, the author also discussed the comfort that she found from knowing the strengths that she had as a dance instructor in general knowledge of the body and movement, ability to listen to participants and their bodies during the class, and remain fluid enough to allow for changes in content as the need arose. From these expectations, the author set an aim to enable her participants to generate their own movement, finding new expressiveness, engendering confidence and ability, rather than merely attempting to copy movement vocabulary from a syllabus-driven content. She was particularly keen to stimulate a class environment that she hoped would nurture a sense of self confidence and self-efficacy in ways that would foster bodily expression, in an accessible and enjoyable way, which was not unduly fatiguing. The author describes the measures she took to accommodate and adapt her 'normal dance practice', making it accessible and achievable whilst remaining true to her notion that the participants could be expressive and creative movers in their own right.

As well as the expectations of the class and its development, Soriano and Batson (2011) also described the teacher's reflections of the two-week pilot study. Here she highlighted her pride in the range of movement that was created and her exhilaration of the problem-solving atmosphere of acceptance and non-judgement, giving freedom to explore movement without habitual association. Her one lesson learnt, was to appreciate genuine simplicity of expression, the breaking down of movement to its simple functional components became the vehicle for psychophysical communication and a means of connecting self-self and self-others. Whilst the thoughts and experiences of the one teacher described in this study are interesting, the purpose of the papers was to 'stimulate dialogue' on designing a community-based dance programme and thus the single case-study design has limited application across the spectrum of dance genres and styles.

Both Houston (2014) and Soriano and Batson (2011) give valuable insight into the experience of teaching and planning the generation of explorative and evolving dance material in the ethos of ‘community dance practice’, but it is important to note that this can be considered in contrast to the structured and syllabus-driven ethos of the set technique and step routine-based class, traditionally taught in the genre of ballroom and Latin American dance, and the focus of this study.

Finally, the thoughts and experiences presented are from dance teachers specifically, however the use of dance as an innovative intervention in rehabilitation in the clinical setting has been advocated (Demers et al. 2014). Therefore there is potential for dance classes for PwP to fall within the paradigm of rehabilitative medicine and thus delivered by therapists, rather than dance teachers. The growing body of evidence to support the role of dance for the treatment and management of Parkinson’s supports its use from the perspectives of evidence based practice (Bega 2014), however knowledge and understanding of the processes of implementation are limited. The first step of a multiphase mixed method study, exploring the transfer of knowledge on the therapeutic use of dance in the healthcare setting, demonstrated four emerging themes from focus groups with allied-health professionals; 1) the clinicians’ previous dance experience and training; 2) their interest and personal beliefs towards using dance as a potential intervention; 3) the support from the organisation and institution in which they work and; 4) their available resources. Interestingly, all clinicians felt it was essential to have both dance and healthcare training in order to deliver dance as a form of rehabilitation, with limited experience in either domain considered a barrier by all. This is not a situation that is prevalent in the dance community at present (from personal experience), with only two of the 24 classes for PwP, currently running across the UK, having direct teaching from a healthcare professional (Dance for Parkinson’s network UK, 2015 personal insight). This raises an important point when considering the generation of classes to date are solely a result of community dance artists, with no class being established through the healthcare system. Thus, it could be considered that the reliance on healthcare skills and experience expressed by allied health professionals in this research is not reflected in community dance artists, as the majority are already practicing without the need for such collaboration. Whilst this research may present a biased view of the necessary skills required to deliver a dance class for PwP, it raises the important point of the potential for differing aims and objectives of a dance class for PwP, between the artistic paradigm of community dance and the medical paradigm of dance for rehabilitation. If the delivery of classes are to successfully engage both disciplines, further research into the expectations and experiences of both are required.

In summary, the growing body of research investigating the physical and psychosocial effects of ballroom dance practice for people living with Parkinson's is establishing a strong clinical justification for the promotion of dance for PwP. However, the expectations and experience of those likely to be delivering and facilitating the intervention has not been explored. With a growth in teachers willing to lead sessions, evidenced from subscription on the 'Dance for Parkinson's' two-day summer school held by the Dance for Parkinson's network UK in 2013 and 2014 (personal insight as a facilitator of the course), the importance of exploring the expectations and experiences of such teachers in this field is evident and pressing. An enhanced understanding of these pre-conceptions will help facilitate and support this emerging discipline for people living with Parkinson's for the benefit of all involved, and supports the proposal of the research question for this study being:

> 'What are the expectations and experiences of dance teachers delivering a new ballroom and Latin American dance class for PwP?'

3.3 Methodology

The research question and methodology for this study were chosen to allow a broad exploration of the experience of teaching dance classes for PwP. With minimal previous understanding of the issues that may be faced, it was essential that openness and flexibility were maintained.

A number of methodologies were considered, however, the small opportunity for data collection and size of the study suggested the data analysis method of bracketing and reduction, often used for phenomenological analysis and the repetitive sampling required to reach saturation in grounded theory concluded both these approaches were not appropriate for this study. In addition, both methods have minimal opportunity to recognise the impact of the researcher in the analysis process and the impact this may play in the interpretation and generation of themes. The interpretation of conversation and language in both conversational and discourse analysis respectively was also considered not appropriate as it was not the interaction between the teacher and the researcher that was the focus of the study, rather the content of their conversation and their own reflections of their experiences. The use of narrative psychology was not appropriate owing to the lack of a known 'story', rather an exploration of the expectation and experiences of the teachers. The data collection method of ethnography was also not suitable for the size and depth of this project, due to limited opportunities to include all dance teachers delivering a new dance class for PwP, rather a small convenience sample based on the RfPB study design. In addition, the issue that the researcher of this study attended the dance classes as part of the research team for the RfPB study, with responsibilities for participant safety and logistics, also prevented the researcher being able to fully observe and integrate herself in the group, as required for ethnographic methods. Finally, the use of case study analysis was initially considered appropriate, however the explorative research question posed was focused on generating insight into the overall experience of teaching the dance class, rather than that of individual cases in their specific context. In addition, case study also often requires data collection from different sources to collate a global overview of the case, which was limited to only one dance centre being included in the RfPB feasibility study in this case. Finally, the influence of the researcher on the data collection and interpretation of the results is also acknowledged to a less extent in the process of enquiry in a case study approach. Therefore, from consideration of all suitable methodologies, a thematic analysis informed by the principles of Interpretative Phenomenological Analysis (IPA), using a framework approach to manage the data was considered most appropriate.

Developed within health psychology by Johnathan Smith in the 1990's, IPA primarily considers the individual that experiences something is the expert about their experience, with the meanings and insight being central to the process (Smith 2008). It is not about testing a hypothesis, but is about understanding personal experiences. Owing to the lack of research in this field to date, an inductionist approach such as this is important, as there is little indication of the potential experience from which to generate a hypothesis.

As suggested by Howitt (2010), there appear to be three areas of influence in IPA; 1) Symbolic interactionism, defined as a focus on the interactions between people and the symbolic meanings and interpretations people attach to their social actions (Ormston et al. 2014). This suggests the experience, and the meaning that is taken from that experience, is related to the actions and relations of the person in the world around them, therefore being dynamic to the interactions that they encounter; 2) Phenomenology, defined as the meaning people attach to a particular phenomenon, concept or idea (Ormston et al. 2014) and can be considered the systematic study of the conscious experience, with the notion that reality and the experience are interdependent, with reality being made up from experiences and experiences understood in relation to that perceived reality; and finally 3) Hermeneutics (both empathic and questioning), defined as an appreciation of the conditions under which a human encounter was produced in order to interpret the meaning (Ormston et al. 2014) and concerns the method of analysis and the meaning that is placed on the text, created through the researcher's interpretations as a process of critical deconstruction. All of which suggests the suitability of IPA as a basis from which to address the experiences of the teachers in this study.

How an individual experiences phenomena and the psychological interpretations of these experiences is a key concept of IPA (Ormston et al. 2014), and thus, will allow an exploration of the meaning the teachers give to these experiences. With influence from a symbolic interactionism perspective, IPA assumes that people attempt to make sense of and give meaning to their experiences from both the ideographic (being the individual) and nomothetic (shared) perspective and from this it also gives account to the process of cognition and the mental process involved throughout the stages of interpretation (personal, researcher, reader). It will therefore not only provide the opportunity to give an account of the experience of the dance teachers, but also their interpretation of these experiences in the context of their lives and environment.

The opportunity to acknowledge the dynamic role of the researcher in both empathic and questioning hermeneutics in their interpretation of the text and the perspective they place on the context was also important in this study. The researcher has previous experience in the field of teaching dance for people living with Parkinson's and therefore felt it would not be possible to isolate this from the process. This presents a double hermeneutic, with the participant making sense of the experience and the researcher making sense of that spoken experience, within their individual social contexts and realities, both of which can be acknowledged through the process of IPA. This also suggests that the process will not be truly intuitionist, as the researcher has prior knowledge and experience that will be guiding her in the initial selection of interview topics to explore. However, awareness of this, the need to be un-biased in the process of topic selection and the potential impact on the research will be considered.

Due to the small target population of this qualitative study, being specific to the ballroom and Latin American classes delivered as part of the RfPB study, the methodological underpinning of this component needed to allow for detailed descriptions of the individual experience, rather than general conclusions of the population of dance teachers. The process of IPA however suggests a two-phase analysis, being the ideographic approach to the personal lived experience, as well as the inference and categorisation of the experience into the wider context by both the researcher and the reader. In an effort to simply reflect the lived experience for the teachers in this study rather than implying generalisation, the researcher refrained from conducting a literature search until after the analysis of the data, and thus avoided influencing the theme selection based on the literature in the field. This method is in keeping with those suggested by Silverman (2010) when conducting qualitative research.

3.4 Method

Having selected IPA as an underpinning approach to the study, the most appropriate data collection technique was semi-structured interviews before the classes started and after all classes had finished (approximately one year later).

3.4.1 Recruitment

Permission to contact the dance teachers involved in the delivery of the RfPB dance classes was sought from the Principal of the dance school. Information sheets (Appendix 4) were provided to three teachers identified by the Principal, who would be teaching the classes. Teachers were asked to use the reply slip (Appendix 5) to indicate their willingness to be contacted by the researcher. Following receipt of the reply slips, the researcher telephoned the teacher to discuss the research further and provided an opportunity to ask questions. If verbal consent to the study was given, a convenient time and location for the researcher to meet with the teacher to complete written consent and the interview was arranged.

3.4.2 Measures

Topics to be included in the pre-class topic guide (Appendix 6) were discussed within the research team, with inclusion of broad, open-ended questions and focus on depth interviewing skills.

Development of the post-class topic guide (Appendix 7) took place after framework analysis of the pre-class transcripts by the researcher and discussed with the research team.

3.4.3 Data collection

At the request of the teachers, all interviews took place in the waiting area at the dance centre. The interviews were conducted in an informal and relaxed manner, which occasionally led to interruptions and significant background noise.

On arrival, the researcher again explained the purpose of the study. The teacher was given further opportunity to ask questions and written consent was obtained (Appendix 8). In case of malfunction, two audio recording devises were used (Sony ICD-BX 140 Voice recorder and a Samsung Galaxy Mini Voice recorder). Both were sound-checked prior to the start of the interview. The first question of the interview was broad and open, to give the teacher and researcher an opportunity to relax into the interview process. From this, depth interview skills were used to probe areas of interest and to maintain a conversational flow.

Interviews lasted approximately one hour, with both teachers given the opportunity to discuss any other topics or issues they felt to be relevant at the end. After the audio-recording was stopped, the researcher thanked the teachers for their time and clarification of the need to interview them again at the end of the dancing intervention was made. On one occasion, the teacher began to discuss further comments relevant to the interview topic, and the researcher re-started the recording with consent of the teacher.

Audio-recordings were transcribed by a research administrator. The transcript format followed the presentation style recommended by Smith (2008) with wide margins and central text as well as line numbering. Both teachers were identified by an ID number. All transcriptions were then checked by the researcher against the audio-recording.

3.4.4 Analysis

Following transcription of the pre-class interviews, the researcher read the transcriptions in full, making notes of the topics discussed. From this, appropriate themes were identified for the framework analysis. Framework analysis is a tool that supports the key steps in the data-management process, including indexing and sorting data into descriptive themes, sub-divided into related sub-themes, which are identified by familiarisation with the original data (Spencer et al. 2003). This enables display of common data and summary across the themes of each participant and between them.

Through this system, all text from the pre-class transcripts was allocated to a relevant theme with the use of a framework in the computer programme, Excel. These themes were used to guide the topics for the post-class interview schedule and discussed with the research team. Post-class interviews followed the same method of data collection and analysis, leading to the generation of post-class themes.

The final stage of analysis involved discussion within the research team of the themes generated through both the pre-and post-class transcripts and the subsequent interpretation by the researcher. Interpretation of the possible interactions between the themes and appreciation of the context of the research was also considered.

Presentation of the themes and their interpretation was supported by examples from the interviews.

3.4.5 Ethical approval

Ethical approval was granted from the National Research Ethics Service Committee South Central – Southampton A (2nd October 2012, Ethics ID: 12/SC/0355).

3.5 Results

Two of the three teachers approached consented to participating in the study. The third teacher had been given the information sheet, but failed to return the reply slip. This teacher was contacted by email and telephone answer-phone message to confirm their decision, but no reply was received. It was felt unethical to continue to contact this participant, however on later discussion with them during the classes, they told the researcher that they had not been able to find the time to reply, but would have been happy to participate. Unfortunately it was too late to recruit them as the classes had already started.

Categories used in the framework analysis (an example of which is shown in Appendix 9), their components and corresponding emerging themes for both pre-class (Table 3) and post-class (Table 4) interviews from the two teachers are outlined below. Pseudonyms have been used to preserve anonymity of the participating teachers and gender, however with only two teachers in a specific field of study, it is highly likely that either teacher will be able to identify comments made by the other teacher and thus anonymity may be lost between them. Both teachers were made aware of this at the point of consent and were happy to continue.

Details of dance steps discussed are shown in Appendix 10.

3.5.1 Demographic detail of participants

Due to the need to preserve anonymity between the teachers it was not thought ethical to provide a detailed description of each teacher individually, as those familiar with the dancing school would easily be able to identify each teacher by this description.

However, as a general overview, the teachers were related and worked at the same dancing school full time. Both had under-taken professional teacher training at a high level. One had extensive experience in teaching ballroom and Latin American dance over many years and through this, had taught the second teacher, who was also experienced in teaching but with less years of experience owing to their younger age. Both teachers had been successful nationally as dancers themselves but neither were competing at the time of the study. Both teachers had previous experience of teaching dance to people with learning disabilities and one teacher had previously taught someone with Parkinson's in their standard class setting for several years.

3.5.2 Pre-class interviews

The following categories, components of those categories and overarching themes were collated from the pre-class interviews:

Category	Components	Overarching themes
Prior Knowledge of Parkinson's	- Physiological (medical based) - Functional (practical issues) - Psychological/social - Where knowledge was gathered from	1) Preparation - Prior knowledge - The need for adaptation but reducing barriers - The role of the teacher
Previous experience of	- Outside of dance - Within the dance environment	2) Expectation

working with PwP		– Challenges – Impact
Expectations of the class environment (delivery)	– Physical (medical based) – Practical – Psychological/social/cognitive	
Expected Impact of dance on PwP (outcome)	– Physical – Psychological/social/cognitive	

Table 3 – Pre-class transcript categories, sub themes and overarching themes.

3.5.2.1 Pre-class theme – 1) Preparation

Prior knowledge

Both dance teachers' knowledge of Parkinson's was based on previous experience from people they had worked with inside the dance environment as well as friends and family. Examples were focused on the physical symptoms:

> *"So like movement wise, so they would be a bit shuffly with their feet and swaying movements they do and just a little bit slower in like their facial expressions…not very good at sort of minor motor skills, like doing up buttons and writing." (Jamie)*

> *"I know that she has difficulty walking and turning round seems to be a very major problem." (Sam)*

Both teachers had some knowledge of the pathophysiology of the condition and the medical implications; however one did not feel that it was necessary to have this level of knowledge in order to deliver the class:

> *"I'm not a medical person, I'm purely a dancing teacher, I have no idea really, I know that it is something that happens in the brain…sparks off from mini strokes…but I don't know what that does…once she started on medication it seemed to improve." (Sam)*

> *"I think there are two types of Parkinson's aren't there, one where they shake and one where they don't." (Jamie)*

As well as the physical limitation associated with Parkinson's, one teacher was also aware of the cognitive symptoms of the condition:

> *"They might become a little bit slower and have to take more time thinking about things, but the basic personality is not changing is it." (Sam)*

The role of adaptation from past experience

From their previous experience of PwP and those requiring additional support due to musculoskeletal injuries, both teachers commented on the need for adaptation during a class in order to achieve the best from their dancers. Adaptations were reported across the technical and performance domains of dance.

Adaptions from a technical perspective as a result of someone not being able to physically perform the steps included:

> *"We do all the steps, but I just don't go into as much detail, as the sort of technique" (Jamie)*

> *"…nothing too difficult that they can't grasp…if we pitch it at the right level then its fine and I think they would be fine with it." (Jamie)*

Adaptions from a performance perspective, suggest that there was a stronger focus on the technical development of the steps as a means of progression, rather than the performance and quality of the dance produced and included:

> *"…we focus more on steps and learning different steps and that's how he progresses…so we do more complicated steps rather than making what he already knows more beautiful." (Jamie)*

> *"You would still try to correct him, but it became increasingly more difficult and obviously the standard of dancing was deteriorating." (Sam)*

Both teachers also discussed the adaptation of their teaching style to the learning needs of the class, particularly from their experience in teaching people with learning difficulties:

"…can't spend too long a time on them because their attention span disappears, need to keep changing things." (Sam)

"… not all people are going to learn things at the same speed…you find the average and work from there." (Sam)

"…try to make sure it is all light-hearted and nothing too serious…" (Jamie)

Whilst these previous experiences highlighted areas where adaption had been necessary, both teachers felt that pre-planning adaptation of the class content or teaching style for PwP was not an appropriate teaching strategy:

"I think the trick is to treat everyone as normal and not to pussyfoot around it all too much -you know if you treat them as normal and then they come up against certain difficulties, then you work your way around those rather than thinking oh they won't be able to do that from the 'get go' and not exploring that avenue at all." (Jamie)

"Well I think in some respects, it's too easy to say I'll change what I'm going to do, I'm not putting that there as an option at the moment, as far as I'm concerned, I'm going to do it in the same way as I would do for anybody else and then we'll see how it goes you know." (Sam)

Extending the idea of a reactive teaching style being preferable, both teachers in fact felt that pre-planning adaptations would be detrimental to the class:

"…that's what being a dance teacher is all about because we adapt all the time…I don't try to plan too much in advance because it always goes out the window…I tend to play it by ear and modify as I go along all the time…this is where teachers go wrong a lot of the time because they've sat at home and choreographed the routine and that's their plan…whether you like it or not." (Jamie)

"…if you put something there and say well this is going to cause me a problem, what you do is you put the barrier there yourself instead of waiting to see if they can overcome the barrier, you put the barrier in place in the first place." (Sam)

For one teacher, the ability to adapt and be responsive was linked to their experience, suggesting those with experience of a wide variety of teaching styles are better able to adapt to the needs of the class:

> *"…here there's about 13 of us that all teach and I've had that experience all my life, of seeing other people teaching and observing other teachers and how they work and how they do their classes, so I've got quite a wide knowledge of dance steps and I've got quite a wide knowledge of how to make a class work I think." (Jamie)*

Both teachers felt that the ability to be responsive to the needs of the class was essential in being a good teacher, from both a physical perspective in helping all abilities to achieve the steps and the social perspective from encouraging achievement through enjoyment:

> *"…always try and hit the middle ground so, we try and get the lesser able ones to keep up with the rest of the class and vice versa." (Jamie)*

> *"I mean for me, a lot of it is the interaction with people that's what we do as dance teachers, it's all about people." (Sam)*

> *"…if you make it fun, then they're going to get an enjoyable experience from it. If you make it rigid and you've got to do it, then it's not going to be so much of an enjoyable experience and really that is it at the end of the day you know. They are not going to do well if they're not enjoying it." (Sam)*

The role of the teacher

Both teachers felt that a key role of the teacher was to encourage the social aspect of the class and emphasised the importance of this in the overall outcome of the class. Above all, both teachers felt that their role was to ensure it was enjoyable, which was also used as an indicator of the success of the class:

> *"I know a lot of people that come here and literally we are their social life…that is their life and so they don't have any other interaction with*

other people really much apart from when they come here, so I think that's good and gives them a real social life and purpose." (Jamie)

"…they've been coming for years and they love it and that's really, as I said at the beginning, really to me that's what's the vital thing…are they going to do it and are they going to enjoy it you know and if they get enjoyment from it then that's a lot of what it's all about." (Sam)

3.5.2.2 Pre-class theme - 2) Expectations

Expected physical difficulties

Despite the wish to remain responsive to the class needs and adapt as situations arose, both teachers identified a number of areas that they expected to be a physical challenge and that might require adaptation as the classes progressed.

These included:

The pace of the music

"…things are not quite the same and things might go at a slower pace and the music might not be normal speed…" (Jamie)

Working in hold

"…work in a hold so that they've got somebody to stabilise them, because balance might be an issue so if they are being stabilised by an able bodied person then that's fine." (Jamie)

"…standing another person in front of you immediately puts a barrier there doesn't it and with able- bodied people, it's very difficult to actually get them to move as one unit, It will be interesting to see…putting another body in front of them is that going to help them or going to hinder them?" (Sam)

Specific turning steps

"I'm not sure about spins if they would be too tricky for the lady but again we can adapt that and do other things." (Jamie)

Weight transference

"…cha cha might be quite quick and it's got that chassis which is like a side-close-side which might be quite tricky to do moving sideways…" (Jamie)

Both teachers also commented on the cognitive challenges that they expected the participants to experience:

"…with Latin, it's a lot more like, the men do one thing and the ladies do another…so I think that might be a bit confusing." (Jamie)

"…tango might prove a little bit tricky, but again that can be modified to make it simplified…to a repeatable sequence." (Jamie)

"I would say, you are probably going to need to be perhaps a little bit more patient you know, take your time about it." (Sam)

Despite acknowledging possible difficulties, both teachers' felt that the class did not need pre-adapting and were clear in their expectation to start the class as a 'standard beginners class' adapting as they felt necessary:

"I think that it will be very similar to a beginners' class that we take already…as for steps, we are not really modifying that too much at all." (Jamie)

"Well I think the whole thing is going to be a challenge, but you know it's one of those things that you can't really sort of assess beforehand isn't it…but you've got to take it as it comes I think you know because you just don't know how they're going to react." (Sam)

Expected impact

Both teachers indicated that they expected the classes would have a positive multidimensional impact on PwP, across the biopsychosocial spectrum:

"I think the benefits are that it covers a broad spectrum of things really so it's not just the obvious like fitness and like the physical element of it…it's also their social and the brain like you know keeping your thoughts going all the time and socialising with other people and just that sort of interaction I think is really, really good for people." (Jamie)

"Well the great thing about dancing is it's physical exercise combined with mental exercise and so that two things working together is a terrific way of exercising because you know you're helping your mind and your body at the same time, which is good." (Sam)

In summary, the pre-class themes were centred on the teachers' prior knowledge of the symptoms of Parkinson's and their experience of teaching others with specific learning needs. They both acknowledged the difficulties that PwP may face when participating in a ballroom and Latin American dance class, however despite an awareness of these, both teachers were clear in their desire not to pre-plan adaptations and instead, anticipated adapting the class content as necessary. Indeed, pre-planning adaptations of content and teaching styles was considered a less favourable option. Both teachers felt encouragement of the social aspect of the class was essential alongside developing an environment that fostered enjoyment.

3.5.3 Post-class interviews

Post class interviews took place with both teachers after completion of all the dance classes (12 months after the pre-class interviews). Framework analysis of the themes emerging from the pre-class data informed the topics for the interview guide of the post-class interviews. This allowed the researcher to re-visit themes that arose in the pre-class interviews.

The following categories, components of those categories and overarching themes were collated from the post-class interviews:

<table>
<tr><th>Category</th><th>Components</th><th>Overarching themes</th></tr>
<tr><td>Experience of the class</td><td>- Comparison to expectation
- Adaptations</td><td rowspan="4">1) Experience and accommodation of change.
- As expected
- Not as expected and what adaptation was needed.

2) Impact
Therapeutic outcome
- Physical
- Psychological
- Social
- Collective struggle

3) Role of teacher (social facilitator or therapist)

4) Practical application
- Teaching points
- Future plans</td></tr>
<tr><td>Impact that the class had</td><td>- Physical - participant
- Psychosocial - participant
- Global - participant
- Impact on teacher</td></tr>
<tr><td>Role of teachers</td><td>- Physical
- Psychosocial
- General</td></tr>
<tr><td>Future</td><td>- Areas to change and why
- Areas to remain and why
- Aspirations for dance for PwP</td></tr>
</table>

Table 4 - Post-class transcript categories, sub themes and overarching themes.

3.5.3.1 Post-class theme - 1) Experience and accommodation of change.

In relation to expectation

Both teachers felt the class was overall as they expected it to be and did not feel that they had to adapt their normal teaching significantly.

When asked was it what you expected?

> *"Yeah, yeah it was what I expected…it was very much similar to how we would teach a class anyway…" (Jamie)*

"Yeah pretty much I think. Yeah because of the way we work in this school, I mean we encourage people to socialise and I mean we've always worked the school as a dancing school/come social club so therefore we're very tuned to the sort of the social side of it and developing from that aspect. So I kind of yeah, I kind of expected that." (Sam)

However, despite reporting the overall opinion that delivering the class was as expected, both teachers did identify a number of difficulties that they did not expect, which required adaption during the class, all of which fell into two categories; either adaptation of the technical content of the class or adaptations of the teaching style.

Not as expected and requiring adaptation

Physical adaptation

Despite acknowledging in the pre-interviews that PwP may face challenges with the technical content of a ballroom and Latin American dance class, when asked about un-expected adaptations, both teachers commented on the technical areas of the class that had been a challenge:

"It was normally in the jive, the ladies go one way and then they come back the other way, so they're not making a full 360 they're sort of doing 180 and then back again and I think that threw them quite a lot." (Jamie)

"Like the waltz was quite complicated for them and the tango was quite complicated…[Sam] realised that that spin turn wouldn't happen so [he/she] put the whisk and chasse in instead which was perfect, which worked really well." (Jamie)

"On the first course, actually working out what they were going to be capable of doing was quite challenging really because of the whole turning round…" (Sam)

"When we did the tango and doing the promenade and getting people to step across was actually a little bit difficult to start with…" (Sam).

> *"The worry is where when we introduce like in the rumba, we introduced the underarm turn for the lady, for a lady with Parkinson's… what we tried to do was in effect straighten it out so we wouldn't refer to it as you're 'gonna' turn, we said you are going to take a forward step towards the end wall and then you take a forward step in the other direction with the other foot and then a step to the side so trying to do it so that we had actually changed the sort of the basis of how it works really." (Sam).*

Adaptation to teaching style

Both teachers also commented on specific adaptations to their teaching style, that they did not expect to make, with use of various teaching skills, including:

Persuasion

> *"We did turns in the rumba and the jive, uhm they weren't as easy as I thought they were going to be and I mean they all did it but they took a bit of persuading to do that and I think that was yeah that was a bit difficult." (Jamie)*

Leeway

> *"One chap, he couldn't put his foot across his body and put his weight on it, that was just a physical barrier that wasn't happening but that was fine you know, we just carried on with him you know attempting to make those movements and we knew that wasn't going to happen and so yeah, we let him carry on as he was." (Jamie)*

Changes to expectation level

> *"You've got to get your expectations on the right sort of level and it kind of does depend on the level of disability doesn't it, so yeah so perhaps you would have to lower your expectations to a certain degree but not much though. As far as I'm concerned as I said earlier on you know that's what you're 'gonna' do and you make them do it – end of." (Sam)*

Flexibility

"It was guess work and we developed it in the first one as we were going kind of, but having done that the other groups that followed were much easier to do because you knew exactly where you were going." (Sam)

Tolerance

"We had one guy in the last course who really challenged me as a person and a teacher because he would not accept help, he wouldn't try and he had his own idea about what he was meant to be doing which was totally off and we had to just stand back and let him do that and that was the hardest pupil, I have ever had…I've never seen anything like it so that really challenged me not to say anything." (Jamie)

The use of partners

"One of the things that I did notice was the fact that if you had an experienced dancer that worked quite well but when you've got somebody…so if the partner never danced before, so when they were using their life partner, that could be a problem because sometimes the partner was worse than the people at picking things up." (Sam).

Adaptations requested by the research team

As well as the adaptations made by the teachers during the classes, there were two specifications requested by the research team from the perspective of safety; starting the class in hold and including a basic walking warm-up at the beginning, neither of which were standard practice at this dance school. These pre-set adaptations did cause some concern for one teacher initially, however they later felt that these were important changes:

Working in hold

"Yeah we had to do it all holding and at first I thought is that 'gonna' work because that's never been done before but that worked fine and that was ok…they did need that hold…I would say it was a luxury but it was also an essential thing you know because otherwise we wouldn't have been able to do it the way we did and it could have gone horribly wrong because you know you could have had more falls." (Jamie).

Walking warm-up

> *"…we had to do this walking warm up which we had never done before and that was quite sort of new and I think for the first couple of sessions, we were all a bit like, what are we doing but actually as you got further along the course, you could see that walking warm up was actually essential for them to do at the beginning because it just got them moving properly. Yeah I think that was quite important in the end." (Jamie)*

Due to the nature of the class being a research project, once the content of the class had been established within the first group of participants, further adaptation throughout the year with subsequent participants was discouraged by the research team. This was in order to maintain consistency in the intervention. Both teachers found this difficult as it was restricting their ability to be responsive to the needs of the class and the individual. This was particularly a problem as both teachers felt the classes could have been progressed:

> *"I was quite relieved that they were a lot better than I think maybe even you guys had anticipated. We could have done more with them, definitely could have done more…we could have added probably two more styles I reckon…especially that last block, they were too good really, they needed more." (Jamie)*

> *"I probably wasn't prepared for perhaps the amount that they actually took in really…some of the people that came on, who were in actual fact quite handicapped as they came in, you know developed tremendously." (Sam)*

3.5.3.2 Post-class theme -2) Impact

Both teachers felt the class had a multi-dimensional impact on the participants, this was expressed under three domains, being physical, psychological and social.

Physical effects

The physical impact of the class for the PwP was described by one teacher as a literal change in the participant's ability to perform the dance steps:

> *"At the beginning she wasn't really doing much of the routines we were teaching, by the end she'd picked it up enough…ok not exactly as we would have liked but she was doing moves that were very similar to the routines that we were doing, which I think was phenomenal as she was struggling to even stand." (Jamie)*

> *"…they stood up straight, their walking [was] clearer if that makes sense…" (Jamie)*

In comparison, the other teacher discussed the physical effects with respect to the participants' ability to take part in the class in general and dance around the floor:

> *"I think there is a general thing going through the classes and I think that the amount they actually achieve over the period of time was really quite rewarding because they went from nothing at all, most of them, to in the end being able to get on the floor and dance and at the end we're just putting on the music and they're just getting up and doing the dancing so that to me is a huge achievement." (Sam)*

Psychological effects

As well as the physical impact of the class, both teachers felt an increase in confidence was a key positive change and that this in turn had an influence on their physical performance:

> *" One of the great things about dancing in general is that it gives people confidence and I think that showed up in the fact that people started off a little bit wary of it all, but then their confidence levels grew and so therefore they seemed to achieve more as they were going on." (Sam)*

"I think the biggest one was confidence. They seemed more confident in moving you know just general movement by the end of it than they did when they came in and they first started." (Jamie)

Social effects

Despite the difference in the perceived physical outcome by both teachers (one being specific to performance of steps and one being participation in the class), both teachers felt that the social aspect of the class was fundamental:

"I think that social aspect is in some respects, is as important as doing the dancing really..." (Sam)

"You know it's a bit more of a support group and they find people who are similar to them in the same situation and they realise they're not alone with it and that people are going through the same things." (Jamie)

Finally, one teacher also felt that the impact on the class across all of the domains (physical, social and psychological) depended on the level of difficulty that they had in achieving the steps, with those struggling more at the beginning receiving a more positive impact than those who found the class less challenging. This also affected the impact that the class had on the teacher, enabling them to build a better relationship with those needing more help:

"I think when people struggle with something, it brings out their personality because they... feel like they have to make up for what they're lacking in their dancing ability...when groups were of a mixed ability...there was a bit more of a camaraderie about it, whereas the groups that didn't struggle, they didn't have the same impact on us as teachers. Because they were good, we didn't have to help them so then you're not building that one to one relationship with them...you're just a sort of support there, whereas the ones that I have had to help along the way so I've seen that really, on a one-to-one basis, that development." (Jamie)

3.5.3.3 Post-class theme 3) The role of the teacher

As a development from the pre-class analysis, the role of the teacher was discussed further in the post-class interviews. Both teachers saw themselves as 'social facilitators' in the class (as described by one teacher) rather than purely teaching the dance components or technique and acknowledged their role in the therapeutic outcome of the class from both the physical and psychosocial perspective:

> *"You're happy with being a…not being a therapist but obviously you are driving a therapeutic outcome…" (Jamie)*

> *"I would have said it was therapeutic yeah just because of the way it sort of nurtured their needs emotionally and physically so they were getting that emotional support and connection with the group you know...We're only a small part of that, I think that was more led by them themselves than us...I think that was a natural outcome rather than something that had to be staged or you know put on by us" (Jamie)*

> *"I basically see my role as being…obviously I've got dancing skills but I see myself as an entertainer more than, yeah I don't see myself as…I wouldn't know enough to be a therapist of some sort you know because that's not what I do. I basically teach people to dance and I entertain them as well. That's how I see myself." (Sam)*

Both teachers found their roles to be rewarding and again this mirrored the perceived physical impact of the class, with one teacher gaining reward from enabling participants to achieve the steps:

> *"I would say it is quite a rewarding dance class because you're feeling the effects of people…going from not being able to put two feet in front of each other to…competent dancers by the end…that's brilliant…" (Jamie)*

The other teacher gaining reward from the enjoyment of the class:

> *"Well I think it has been very rewarding because I think that they've picked up the work and the fact that they've all enjoyed it. To be honest I have enjoyed it as well because they've been a really good group of*

people to teach you know and this last week I've missed them you know." (Sam)

3.5.3.4 Post-class theme 4) Practical application

The teachers' experience of the practical application of the class was also discussed. This information was investigated in order to refine the delivery of the intervention for future trials.

Both teachers felt that the class design and delivery was effective in general, however both felt the class could have been more challenging; with either more dance content or a shorter time period.

> *"Adding the two different styles...would have just added a bit more interest to the ones that were eager to learn more and I think you know it would have just filled the time a bit better… maybe if you made it an eight week block then you would not have to." (Jamie)*

> *"…adding in quickstep and samba might be a possibility you know for a future one so that we've actually then covered all the standard eight dances." (Sam)*

In addition to this, both teachers felt a number of teaching skills were fundamental to the success of the class including:

Acknowledgment of participants' difficulties but not giving up:

> *"…we just carried on with him you know attempting to make those movements and we knew that wasn't going to happen and so yeah, we let him carry on as he was." (Jamie)*

> *"…with the cha cha, we said it was difficult but we never gave up on it, we still did it…because you could have just taken it out and said we won't do that but I feel that you know, ok they found it difficult to start with… but then you know, they overcame that." (Sam)*

Music selection

> *"...the music plays an important role too doesn't it you see and we found right from the word go that they all seemed to latch on to the music and perform better once the music was introduced." (Sam)*

In summary, the post-class themes included the experience of the class being as expected from the pre-class interview; however adaptations including changes in the class content and the teaching style as well as those requested by the research team were discussed. Both teachers commented on the impact of the class from a physical, psychological and social perspective, and felt their key role was fostering enjoyment, whilst enabling the social aspect of the class to flourish. Finally the practical application of the class was discussed, both agreeing that the design and delivery were suitable; however an increase in dance content was necessary.

3.6 Discussion

3.6.1 Researcher's background

In addition to the data generated from the interviews of two teachers, the researcher acknowledges the influence of her experience in the field. The researcher is currently co-teaching a dance class for PwP and sits on the steering committee of the 'Dance for Parkinson's network UK'. She has experience in teaching dance artists wishing to establish dance classes for PwP and is a clinical physiotherapist with a special interest in Parkinson's. In addition to this previous experience, the researcher also attended all the dance classes of this study as part of the RfPB study research team. This was to ensure safety of the participants and advise on adaptations necessary from the perspective of limitations due to the symptoms of the condition. She is particularly aware of her previous experience as a physiotherapist entering the dance environment and the challenges she faced in merging the two disciplines, which led her to be interested in this area of study initially. Whilst every effort was made to reflect the data in a true and un-biased way, the researcher's interpretation of the data will undoubtedly be influenced by her background and thus important to consider through the discussion of these results.

3.6.2 Research design

Dance is becoming increasingly popular as a complementary exercise for PwP, and is recommended by many patient associations (Keus et al. 2014). This has helped to generate interest for the development of new dance classes for PwP; however, to date, no research has reported the expectations and experiences of the dance teachers who are likely to be delivering the class. Through semi-structured interviews, and a thematic analysis using a framework approach, informed by the principles of IPA, this qualitative research study enabled an exploration of the expectations and experiences of two teachers before and after teaching four new groups of PwP and their partner's, ballroom and Latin American dance classes, over a one year period.

Due to the dynamic nature of the method, themes that emerged during the pre-class interviews were further explored and focused on during the post-class interviews, therefore discussion of overarching themes across the time frame will be made.

3.6.3 Role of planning and adaptation

Throughout the pre-class interviews, both teachers expressed a strong desire not to pre-plan adaptations of the class dance content or teaching style, wishing to treat PwP the same as any other dance pupil, irrespective of their possible symptoms. Both teachers felt adapting the class as difficulties arose was preferable, suggesting pre-planning adaptations created a barrier to the content and expectation of what could be achieved, and was considered a less-favourable teaching style. The wish to remain fixed to their established teaching style is in contrast to the concern raised by Soriano and Batson (2011), who through their exploration of the process of designing a modern dance class for PwP, did make comment on the teacher's concerns regarding her ability to teach the class, owing to her lack of experience and scientific background with this population. Neither teacher in this study demonstrated a depth of scientific knowledge and indeed felt this was not necessary, however both had previous experience of working with people with special learning needs and discussed methods that they had used to adapt their teaching style.

It may be that previous experience, although not with PwP, enabled both teachers to feel at ease with their ability to adapt in the moment as difficulties arose. Thus limited knowledge of the possible difficulties that may be faced meant preconceptions were not created, whereas a lack of previous experience by Soriano and Batson (2011) instilled concerns. This suggests previous experience to be more important in this case than prior knowledge of the condition.

When discussing if the class was as expected during the post-class interviews, both teachers initially felt that it was, however, further questioning revealed a number of adaptions that had been made and areas that were not as expected. It is interesting that neither teacher felt that the class should have been adapted prior to starting and agreed with this on reflection of the class; however both were able to give examples of where the class did not go as expected and required adaption. It was also interesting to note that the areas where adaptations to teaching were required, such as a participant not being able to achieve the step, or the research team asking for a warm-up and participants to dance in hold, were considered challenging for one teacher. However, this teacher also subsequently felt that all such adaptions became essential to the outcome and safety of the class. In contrast, the other teacher did not experience such difficulties in adaptation, and despite discussing areas where they had adapted and changed the content of the class, they still felt that it was as expected. This may be due to this particular teacher having a greater experience of teaching PwP.

It appears therefore, that the class was as expected and thus the adaptations made as a reactive process to the class needs were also expected, being managed through flexibility of the teaching style. This supports the model of a reactive teaching style rather than a pre-planned adaptation, as expressed in the pre-class interviews. However, those adaptations that were not expected or were imposed by the research team were considered more challenging for the teacher that had less experience and thus possibly less flexibility in her teaching style. This again suggests previous teaching practice influenced the experience of managing adaptation and change for each teacher in this study.

3.6.4 Context of the class

Despite the perceived lack of scientific knowledge by the teachers with regards to Parkinson's, both were able to identify a number of possible challenges in teaching a dance class for PwP. Prior to the class, challenges were focused on the physical symptoms of the condition such as a potential loss of balance, slower movement, difficulty in transferring weight and turning, with both teachers suggesting techniques that they might use to assist with these, as required. Difficulties discussed on reflection during the post-class interviews focused on achievement of specific steps of the class, such as the turn in the jive (Rock 'n' Roll) or the chassés in the waltz. This again demonstrates the teachers' awareness of the specific needs of teaching a dance class for PwP, but their wish to maintain in a reactive teaching style and adapt as difficulties arose. When considered in the wider context, the awareness of difficulties but the desire not to pre-plan changes highlights the possible difference in participating in a dance class from a social paradigm compared to a medical paradigm. In the social paradigm, the aim is focused towards achieving dance participation and performance in the general attendance of the class. This can be compared to a therapy class in the medical paradigm, where the aim is towards disease modification, measured against pre-planned outcome measures and includes a selection of evidence based activities. The Chartered Society of Physiotherapy (CSP) outlines the need to be accountable, measured and justified in the treatment and management of patients' (CSP, Code of Professional values and behaviour) (Chartered Society of Physiotherapy 2014), arguably placing the focus on achievement over participation. This difference in focus was also demonstrated by both teachers opinion of the primary impact of the class being multidimensional and their role as 'social facilitators' and 'entertainers' rather than driving a physical change. This is in agreement with the findings by Houston (2014), where the collective goal of the teachers suggested classes were not viewed as 'therapy sessions', despite the fact that there may be therapeutic outcomes, but as an artistic practice in which people living with Parkinson's can participate (Houston 2014). The reported barriers of a lack of previous dance experience or ideas for dance content discussed by Demers et al. (2014) when interviewing allied health professionals, also supports the differing focus of the class, as all those interviewed felt both medical and dance training was essential to deliver an effective class, indicating a focus on content rather than participation. Therefore, it can be suggested from Demers et al. (2014), that those from the medical paradigm of therapy may approach the context of a dance class for PwP from a different perspective to those from the social paradigm of dance, as seen in this study. Despite this difference in focus, both contexts place the use of dance for PwP within the original definition of dance movement therapy, being “use of movement as a process which furthers physical and emotional integration of an individual” (Sandel 1975 p. 439) and thus whilst separate approaches, both in fact work towards a collective goal for the participant.

The strong emphasis on the role of the teacher to drive the social aspect of the class also supports the notion of the teachers’ perception of the class context, as both teachers saw themselves as a facilitator of the social process rather than an instigator or instructor, with the group support and comradeship to be the strongest driver. The importance of socialisation is also discussed by Houston (2014), from her interviews with dance teachers experienced in teaching dance classes for PwP, suggesting classes are about fostering community, encouraging friendships and support networks between each other. In the genre of community dance practice, the importance of listening to each other is often encompassed in the dance practice itself. However in the genre of ballroom and Latin American dance there is comparatively less opportunity for improvised expression compared to other dance forms such as contemporary and thus, dedicated social time during and surrounding the class may be essential in developing the socialisation of the group.

Finally, the socialisation of the class was also driven by the notion of a ‘collective struggle’. One teacher described the situation where those that struggled more appeared to gain greater support and friendship from their peers, than those for whom achievement was easier. In addition, those individuals who struggled had a greater impact on the teacher, as she took them on a journey from ‘non-dancer to dancer’ and thus gained greater satisfaction and reward compared to those needing less assistance. This feeling is echoed in the thoughts of dance teachers interviewed by Houston

(2014) in relation to finding 'lost movement' through dance, and has the consequence of building the group into a collective of people, with whom everyone feels a sense of sharing. Thus, both results highlight the influence of social support to the class outcome and a collective achievement in the participation of dance.

3.6.5 How achievement is measured and the influence of the teacher

In addition to socialisation, both teachers felt the participation and enjoyment of the class was brought about by the achievement of steps, for which prior adaptation or pre-planning did not allow flexibility and would therefore result in pupils not achieving. This is in contrast to the concepts of inclusive dance practice in community dance, where achievement is based on adaptation of the content to suit the body of the dancer, rather than achievement of steps (Charnley 2011). It is also in contrast to the improvisational movement content created by the pupils in the study by Soriano and Batson (2011). It is interesting that, despite the wish to drive participation and enjoyment, neither teacher in this study wanted to pre-plan adaptation or make pre-conceived allowances for the possible reduction in physical achievement of dance steps by PwP. It may be that this formed from a positive outlook of the 'ability for all to dance' and a reduced understanding of the physical difficulties present in PwP. Or, it may be a direct result of the difference in the delivery of a stylised, syllabus-driven dance genre such as ballroom and Latin American dance, compared to the more explorative and improvisational nature of contemporary styles, traditionally used in community dance practice with PwP. Therefore, enjoyment brought about by achievement of specific steps or ability to join in with the class in unison (with reactive adaptation to individual needs) was emphasised, rather than pre-conceived adaptation of the class content. Thus, effort was made to drive a perception of achievement, but possibly at the expense of the correct dance step being taught. In this way the teachers remained true to the genre and content of the dance being taught and their wishes to treat the participants 'like any other class'.

When considering the notion of achievement during the post-interviews, both teachers judged achievement on a spectrum: One teacher judged achievement as the participants' ability to join in with the class and 'make it around the room', whereas the other teacher judged achievement based on the participants' ability to complete the taught steps in the correct order. These differences in judgement were also mirrored in the teacher's interpretation of the impact of the class – being the impact of participation on the person as a whole, or the physical impact of completing the steps. The reasons for the difference in perceived outcome are unclear; however it is possible that the depth of experience in dance teaching and greater involvement in the study initially, by the teacher judging achievement by participation, may have changed their expectations of the class. Indeed, this is commented on, suggesting it is important to get the expectation correct at the start. The teacher with less experience and less involvement in the study in the developmental stages treated the class as a standard beginners' class, where achievement of the steps is typically necessary for dance progression.

It is possible that the differing goals of the teachers, being 'achievement' or 'participation' driven may influence the outcome of the class, as dance pedagogy research has repeatedly demonstrated that individual goal orientation of class participants mirrors that of their teacher (Andrzejewski et al. 2013). The task orientated goal of 'achievement' may be driven by the need for all to complete the steps correctly and in comparison to others in the room. Whereas the process focused goal of 'participation' drives the need for the class to be able to collectively 'move around the floor together'. It is possible that the two types of teaching pedagogy and goal orientation for the class were empirical in the judgement of achievement and the process of adaptation, with both teachers tackling the class with a different agenda. The resultant effect on the participants is unclear as both teachers covered the class equally, however the effect on the teachers' experience is apparent.

The differing method of judgment was also mirrored in the justification of confidence being the main impact of the class. The teacher judging by 'achievement' described the increase in confidence as being a physical change such as posture and stepping. However the teacher judging by 'participation' described the increase in confidence as a general improvement in themselves and ability to join in with the class. It is interesting to note that an improvement in confidence is also related to the person-centred approach of inclusive dance practice in PwP, where the purpose is to give PwP a sense of confidence in their ability to dance and ownership over what is created, by creative decision-making (Houston 2014). This is unlikely to be the cause of increased confidence in this class, as the content was not created by the PwP themselves. However the adaptation by the teachers as a reactive process during the sessions, differentiating movement for different abilities, allowed a sense of communal motivation as all were achieving together and thus grew in confidence. It therefore appears that both the improvisational practice of community dance for PwP previously reported in the literature and the stylised and structured practice of ballroom and Latin American dance for PwP in this study, whilst extremely different in content and delivery, both enable the participant to grow in confidence through involvement and achievement.

3.6.6 Practical application

It was important for the purposes of future studies, that the experience of the practical application of the class from the perspective of the teacher was also researched, and was therefore included in the topic guide during the post-class interviews.

In addition to the lack of evidence discussing the experience of teaching dance classes for PwP, there is also limited information on the specific content and delivery of the class, with the majority of literature focusing on the physical and therapeutic outcome. Soriano and Bateson (2011) discuss the development and content of a modern dance class for PwP, giving detail of the class structure as: 1) seated warm-up with isolations; 2) standing locomotion exercises; 3) ballet barre alignment, stability and stretching exercises; 4) improvisation; and 5) collaborative choreography, all of which mirrors the class structure recommended by Westheimer et al. (2008). Owing to the genre of both these classes being ‘modern dance’; the format is not the usual format of that followed by a ballroom and Latin American dance class. Hackney and Earhart (2010d), Earhart et al. (2015) and Hackney & McKee (2014) do elaborate on the content of an Argentine tango class for PwP, giving detail of the implementation and structure of the class, with clinical justification. Their method was developed as a result of research in the area and was used as the basis of the structure for the classes in this study; however expansion of the class to include three ballroom dances (waltz, social foxtrot and tango) and three Latin American dances (rock ‘n’ roll, rumba and cha cha) was taken. Overall, the structure of a day-time class, twice a week, for one hour was considered suitable, however both teachers felt the class could have achieved more in the time, recommending including the samba and the quickstep to the content, which was unfortunately not possible due to the restrictions of the research design. The teachers also commented on the content and structure of the class, stating that the use of music was fundamental to the success and enjoyment, both of which, as previously discussed, have an impact on the overall achievement.

It is not only the practical delivery of the class that is important to the outcome but also the role of the teacher with regards to overall pedagogy. Both teachers highlighted a number of teaching skills that they felt were important for the success of the class. Of particular importance was the acknowledgment of the difficulty experienced by the participants. Both teachers were aware of difficulties but felt that perseverance was important. Whilst neither teacher considered themselves as a therapist, the use of perseverance as a teaching strategy to help participants achieve specific steps is akin to a medical model of neuro-physiotherapy, where strategies to achieve as ‘normal movement’ as possible, through repetitive practice and feedback are often used (Lennon 2004). In such, this provides an opportunity for challenge and achievement and thus progression of physical ability in both dance and neuro-physiotherapy. However, as both teachers stated, it is important to recognise the limits of this model and allow for adaption of the step without the feeling of failure. Thus despite not considering themselves as therapists, the similarities in skills between the teachers in this study and traditional neuro-physiotherapy, in developing movement behaviour, appear to contrast the barriers to delivering dance classes for PwP perceived by allied health professionals, stating specific and different medical and dance skills are required (Demers et al. 2014). It may be that the extensive previous experience of both teachers in this study enabled them to recognise the limits of achievement in each individual case and adapt as necessary. It is important to note however, that a level of adaption such as this may not always be the case if teachers have less experience or flexibility in their teaching strategies.

3.6.7 Summary

In summary, the previous experience of the teachers, rather than their scientific knowledge of Parkinson's, in this instance was more important in promoting reactive adaptation of the class than pre-empting adaptations. It is likely therefore that the strong desire to remain reactive is a consequence of the teacher's experience, but may also be due to the genre of dance, being stylised and content driven, with limited opportunity for person-centred choreography or individualisation of movement. Despite this structured design and differing judgment of achievement, the main aim of the class from both teachers' perspective was on enjoyment and socialisation.

From this, it appears the teachers' overall focus of the sessions was based on participation (either in the class as a whole or individual steps), rather than achieving a change in physical performance, as would be the case in a traditional therapeutic encounter such as physiotherapy. This was again mirrored by the teachers' belief that the main impact of the class was an increase in confidence, rather than a physical change, recommending the use of perseverance in teaching in order to gain achievement. This proposes the role of dance for PwP in the social context rather than the medical, despite the similarities noted between the two in promoting a change in physical performance.

Finally, the structure and content of the class was considered suitable by both teachers, although progression of content was recommended.

3.6.8 Limitations

There were a number of limitations that may have influenced the discussions developed from this study and thus it is important to consider these before presenting conclusions.

The selection of three teachers to be included in this research was made by the Principal of the dance school. Unfortunately one teacher did not take part. In practice, five teachers regularly taught the class, which was an un-expected development over the course of the year that the classes ran. It was not possible to include the additional teachers once the classes had started and therefore the study did not capture the expectations and experiences of all the teachers involved as initially proposed.

Due to the nature of the class being part of a research study, the teachers were restricted in the content and flexibility of delivery for each participant. This is not usual practice and therefore would have altered the experience for the teachers, compared to those with more freedom of content.

The researcher had significant experience in the field and therefore had pre-conceived ideas of the topics that may arise. Whilst every effort was made to remain true to the data, her interpretation will have been influenced by her own experiences and thus may have altered the meaning she created. The researcher was aware of this influence and attempted to maintain an impartial standing during interviews, purposefully not giving opinion or implying an understanding of the topic. On reflection, it may have been better for a researcher with no previous experience or pre-conceived opinions to have completed this research, as the possibility of mis-interpreting or mis-representing the data could have been reduced.

The researcher was also employed as a research assistant on the RfPB study and attended all the classes to advise the teachers on safety and adaption of the class for the needs of the participants. This may have created a situation of ‘power’ of the researcher to the teacher. If present, this may have influenced the discussion during the post-class interview, as the teachers may not have wanted to speak openly about the research process or the impact it had on their teaching. In addition, both teachers may have assumed knowledge and information, knowing that the researcher had been present for all four groups of participants and thus not been as explicit in their discussion as they may have been with a researcher who had not attended the classes. The researcher was aware of this limitation and where possible asked the teachers for clarification of the points raised rather than assuming understanding.

The time between the pre-class and post-class interviews was one year. Whilst this did allow time for completion of the framework analysis after the pre-class interviews and thus maintain focus for the post-class interviews, there is the possibility that the teachers found it difficult to remember their expectations prior to the classes starting and thus found it difficult to link their experience with their expectations. The researcher did remind the teachers of their expectations and asked for reflections of these, but possibly not enough, owing to the researcher's lack of experience in this field of research.

As well as considering the impact of the limitations of this study, it is also essential to reflect on the discussion from the context of the researcher, as this will have impacted the conclusions drawn owing to the interpretation of results as described through the methodological underpinnings of IPA.

3.6.9 Reflections from the researcher

Despite experiencing a conflict of interest between the social paradigm of dance and the medical paradigm of therapy myself, there is little research regarding the experience of delivering a dance class for PwP from the perspective of the teacher so I was clear that I did not want to influence the interview topics based on my experience. I therefore chose broad and open topics to begin the interviews and treated the pre-class interviews as an exploration of ideas. From these, I was able to develop themes and draw interpretation. I made every effort to remain true to the data through the robust process of framework analysis and the impartial generation of themes. The methodological basis of IPA enabled me to draw on the experiences of the teachers, but also appreciate my experience and influence in this process as well. For example, I was able to acknowledge my ideas of a possible difficulty in delivering a 'therapeutic intervention' as a dance teacher. However, despite the process of IPA enabling acknowledgment of my influence in the interpretation of data, on reflection, this was an influential factor and has lead me to feel that I was perhaps not the best person to conduct this research owing to my biases and previous experiences.

Given my experience and the initial basis for the study, I was surprised to find that neither teacher expressed a concern at delivering an artistic dance experience in the therapeutic setting. They did not see themselves as therapist, but merely facilitators of a social activity with physical benefits. It became apparent to me that the challenges I had faced were based on my preconception of what the class was aiming to achieve, again demonstrating the bias that I un-knowingly placed on the interpretation of the data. For these teachers, a dance class is an opportunity to participate in an enjoyable activity with the support of others and in that respect they were already experts. The achievement of a therapeutic or physical outcome was a by-product of this primary aim to be 'able to dance'. However, I was attempting to gain a therapeutic outcome as well as appreciate the psychosocial context of the dance environment and thus felt ill-prepared for this juxtaposition of outcomes.

In addition to the personal reflections from this study, I have also been able to develop skills and a greater understanding of the paradigm of qualitative research, alongside the quantitative skills of movement analysis from this thesis. I was keen to develop skills in both areas of research as a learning process and feel an appreciation of both quantitative and qualitative paradigms are essential when establishing a career in health research.

As a consequence of my experiences in physiotherapy, inclusive dance practice, community dance and the exploration of other dance teachers' experiences from the background of dance rather than therapy with this qualitative study, I have been able to amalgamate an appreciation of all in the development of dance for PwP. It appears whatever one's background or focus for the class may be, the primary goals of enjoyment, achievement and participation are fundamental and relevant to all.

Suggestions of further work and the implications of this study are discussed in Chapter 8 of this thesis.

3.6.10 Conclusion

In conclusion, the methods of semi-structured interviews using framework analysis, informed by IPA allowed the first detailed exploration of the experience of teaching a ballroom and Latin American dance class for PwP.

The impact of previous teaching experience over prior knowledge in maintaining a reactive teaching style has been proposed, with teachers suggesting the primary outcomes experienced to be socialisation and increased confidence. In addition, the perception of a multidimensional impact and differing notions of judgement driving the teachers' experience of class achievement and participation, firmly support the context of a dance class for PwP in the social paradigm. This is particularly important when considering the therapy-based, disease modifying intentions initially proposed for the overall study of dance for Parkinson's.

Teachers' experiences are likely to differ depending on the genre of dance being delivered, however improved understanding of these experiences will provide better support and development of the emerging trend of dance classes for PwP and justifies the need for further research in the area (see Chapter 8 for further details).

Whilst a better understanding of the implementation of dance classes for PwP is likely to help the development of the intervention and support new teachers in the field, it is also fundamental that greater knowledge and understanding of the specific impact and effect that dance may have on PwP is developed. As with the experience of teaching the classes, little evidence is available to suggest the exact impact that a class may have on particular symptoms of the condition. If we are to promote the use of dance for PwP as a form of rehabilitation, it is essential that the implementation (explored in the qualitative component of this thesis) is considered alongside the physiological effects (explored in the quantitative component of this thesis) as depicted in Figure 1 (Chapter 1). The following chapters will explore the specific mechanisms and relationships of the deficits of turning in PwP and the impact of dance on turning ability.

Chapter 4: Quantitative component

The effects of ballroom and Latin American dance on whole body coordination during turning in people with Parkinson's.

In order to assess the impact of dance on turning ability in PwP, it is necessary first to discuss the specific deficits of turning in PwP. Therefore, a narrative review was undertaken to 1) summarise the specific deficits of whole body turning for PwP; and then 2) comment on the relationship and impact that these have on each other, with reference to whole body turning performance. Improved understanding of this relationship will enable a detailed interpretation of the impact of dance specifically on turning performance in PwP.

4.1 Introduction to turning

Turning is a functional activity required many times a day and is an integral component of adaptive loco-motor behaviour (Hong et al. 2009), with almost all activities performed during walking, incorporating a need to change direction. It can be described as a 'change in direction from a standing position that requires stepping and rotation of the whole body around its vertical axis' (Stack et al. 2004). Whilst this is a description of a standing turn only, this is predominantly the type of turn used in the related research, due to its functional relevance and clear beginning and end, making it ideal for assessing in the laboratory setting.

Difficulties with turning around the longitudinal axis are a common and early feature of Parkinson's, and can be present while lying recumbent (Steiger et al. 1996), seated (Schenkman et al. 2001), standing (Vaugoyeau et al. 2006; Wright et al. 2007), or walking (Ferrarin et al. 2006; Visser et al. 2007; Huxham et al. 2008a; Song et al. 2012). The widely-reported loss of movement continuity, postural stability and functional achievement during turning in PwP has been termed as 'dysfunctional turning' (Stack & Ashburn 2008) and could be compensatory to perceived instability, a direct cause of instability or a behavioural decision to avoid risk.

Turning is a complex action, in which head and trunk rotation in the transverse plane are vital, to seek out and align with a new path (Patla et al. 1999). Healthy young and older adults engage in craniocaudal sequences of movement to turn while walking, with head rotation leading, then trunk and then pelvis rotation to re-orientate the body towards the new direction (Patla et al. 1999; Akram et al. 2013b), resulting in inter-segmental reciprocal movements (Huxham et al. 2008b). This is not the case in PwP, who demonstrate a loss of axial rotation of the spine (Keus et al. 2007), with little dissociation between the head, trunk and lower limbs (Akram et al. 2013a), which results in a decreased inter-segmental coordination producing an ‘en bloc’ turn (Crenna et al. 2007; Akram et al. 2013a). Whilst some studies have also found the presence of an ‘en bloc’ turn in the healthy elderly (Akram et al. 2013a), kinematic analysis of body segment movements during turning reveals clear abnormalities within the ‘en bloc’ turn in PwP summarised in Table 5.

Deficit	Associated references
Increased step number	Ashburn et al. 2001; Stack & Ashburn 2005; Stack et al. 2006; Crenna et al. 2007; Earhart et al. 2007; Stack & Ashburn 2008; Hong et al. 2009; Spildooren et al. 2009; El-Gohary et al. 2013
Shorter steps	Huxham et al. 2008b; Huxham et al. 2008a; Hong et al. 2009; Bhatt et al. 2011; Peterson et al. 2012
Altered turn strategy	Stack et al. 2002a; Huxham et al. 2008a; Bhatt et al. 2011; Song et al. 2012
Time to turn	Ferrarin et al. 2006; Stack et al. 2006; Visser et al. 2007; Willems et al. 2007; Mak et al. 2008; Hong et al. 2009; Anastasopoulos et al. 2011
Axial segment rigidity	Steiger et al. 1996; Ferrarin et al. 2006; Franzen et al. 2009; Hong et al. 2009; Earhart et al. 2008
Altered body	Ferrarin et al. 2006; Vaugoyeau et al. 2006; Crenna et al.

segment coordination	2007; Earhart et al. 2007; Huxham et al. 2008b; Song et al. 2012; Akram et al. 2013a; Ashburn et al. 2014a
Altered segment timing	Stack et al. 2006; Vaugoyeau et al. 2006; Visser et al. 2007; Willems et al. 2007; Mak et al. 2008; Hong et al. 2009; Anastasopoulos et al. 2011; Akram et al. 2013a; Akram et al. 2013b
Reduced segment rotation	Crenna et al. 2007; Huxham et al. 2008b; Mak et al. 2008; Akram et al. 2013b

Table 5 – Deficits in turning in PwP from current literature

Globally, the characteristic Parkinsonian turn from a standing start involves at least four steps over two seconds prior to forward gait, the quality is poor with reference to independence, continuity, ground clearance, stability and posture, and differences between turning directions are marked (Stack & Ashburn 2008). As well as being detrimental to everyday life, difficulty in turning is a sensitive predictor of the two key symptoms of Parkinson's locomotion; freezing (Stack & Ashburn 2008) and falling (Stack et al. 2006), highlighting the importance of understanding turning impairments in PwP.

In addition to the physical deficits of turning for PwP, the psychosocial impact is multifactorial, including a reported nine-fold increased risk of sustaining recurrent falls than people without impairment, with average survival reduced by 7 years once recurrent falls are present, due to pneumonia as a result of dysphagia and immobility (Wenning et al. 1998). In a study looking specifically at the circumstances of falls reported using falls diaries by 124 PwP, turning was commonly quoted, with nearly half as many falls occurring whilst turning (69 falls) when compared with walking (148 falls), yet it is unlikely that half our daily steps are turning steps (Ashburn et al. 2008). The authors concluded turning to be the single most injurious fall-related activity in PwP. With reference to injury, Melton et al (2006) found PwP to be 3.2 times more susceptible to hip fractures than those without Parkinson's, and importantly herein, falls during turning are eight times more likely to result in hip fracture than straight line walking (Cummings & Nevitt 1994). It is not only a safety concern, but a concern for efficiency and quality of life with 52-62% of PwP reporting turning difficulties in their daily activities (Nieuwboer et al. 1998; Bloem et al. 2006), even in those who demonstrate minimal levels of functional impairment (Stack et al. 2006). In addition, PwP are more likely to fall when turns are made while performing a secondary task such as talking or carrying an object in the functional setting (Ashburn et al. 2001). All of which highlights the need for greater understanding of the deficits of turning for PwP within the field of rehabilitation research.

4.2 Review method

A literature search was conducted using the search terms 'Parkinson*' and 'Turn*' in the bibliographic databases: Cumulated Index of Nursing and Allied Health Literature (CINAHL), Medline, Web of Science (Core collection), Cochrane and Physiotherapy Evidence Database (PEDro) between January 2000 and March 2015. A detailed description of the search is presented in Appendix 2 ('Literature search terms for turning performance in people with Parkinson's'), which is summarised in Figure 6.

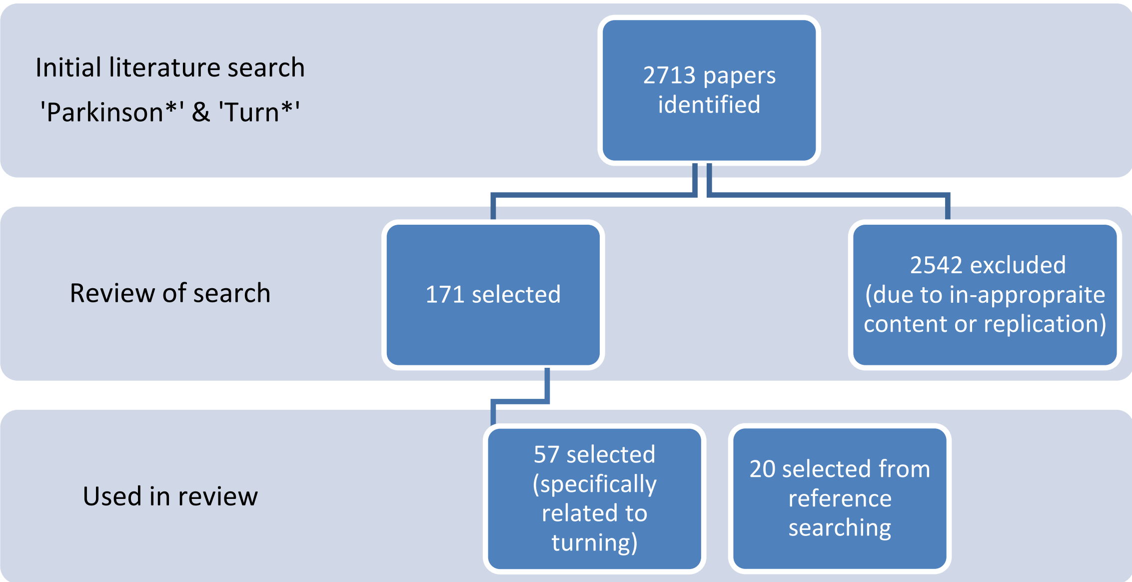


Figure 6 – Literature search for the exploration of the turning difficulties in people with Parkinson's.

From the literature, two hypothetical distinctions in body segments appear to be impacting upon turning ability in PwP, with all turning deficits falling within either the perpendicular or axial body segments. Perpendicular segment deficits can be defined as 'non-optimal movement' occurring in any aspect of the perpendicular areas of the body (being the lower limbs in this case). Axial segment deficits meanwhile can be defined as 'non-optimal movement' of the axial structures of the body (being the head, shoulders and pelvis in this case). Finally, the influence of the environment in which the turn occurs also influences turning performance in PwP and will be considered.

Using the distinction of "axial" and "perpendicular" segment deficits as internal deficits alongside the impact of the external environment, the influence and relationship of each on turning performance and functional outcome can be determined in PwP (summarised in Table 6).

4.3 Perpendicular deficits

The role of perpendicular mechanisms during a turn will be discussed, focussing particularly on the number of steps, the size of steps, the time taken for each step and the quality/type of turn undertaken.

4.3.1 Perpendicular deficit - Number of steps

A greater number of steps to complete a turn has consistently been shown in PwP compared to controls using both clinical measures such as the Standing start 180 degree turn test (SS180) (Stack & Ashburn 2005; Stack et al. 2005; Stack et al. 2006; Stack & Ashburn 2008) and laboratory based 3-dimensional movement analysis (Crenna et al. 2007; Earhart et al. 2007; Huxham et al. 2008b; Hong et al. 2009; Spildooren et al. 2009; Spildooren et al. 2010b; El-Gohary et al. 2013). This appears to be more pronounced when turning to the un-preferred direction (Stack & Ashburn 2008) or in unfamiliar surroundings (Stack et al. 2006).

Interestingly, Stack et al. (2005) compared the ability to turn using the validated SS180 (Stack & Ashburn 2005; Stack et al. 2002b) in 7 PwP (63-85 years) to 16 'younger' (21-39 years) and 15 'elder' (40-83 years) healthy controls. They showed a median of seven steps for PwP compared to five in healthy age-matched controls. Whilst this comparison was deemed to be significant, there was no indication of a power calculation for each group, and with only seven PwP compared to a total 31 healthy controls, thus the possibility of a type-one error (as incorrectly accepting a research hypothesis (Field 2005)) may have resulted in an incorrect conclusion of significant difference.

Further work by Stack et al. (2006), showed PwP who expressed a difficulty in turning took more steps, with a median of six steps to complete a 180 degree turn compared to four in those who did not express a difficulty; values that appear to mirror those of their earlier work in 2005. These values also sit either side of the 'five step count' considered to indicate a difficulty in turning in the elderly population (Thigpen et al. 2000) and thus may represent a great change in functional performance. Furthermore, Stack et al. (2006) showed the number of steps reduced in 57% of participants when assessed in the functional setting of 'making a cup of tea' in their own homes, and again was more pronounced in those who found it difficult to turn. This suggests that those who find it difficult to turn performed better in turning situations that are familiar to them. With a sample size of 75, stratification by H&Y score and use of the SS180 as a valid and reliable assessment tool for turning in PwP (Stack & Ashburn 2005; Stack et al. 2002b), this research accurately depicted the step number in PwP during a turn. What was also particularly important was the use of both functional and standardised assessment measures of turning in this research, in an effort to eliminate the deficits of laboratory-based turning assessments. Unfortunately however, the side of disease onset or differences in ability to turn different ways was not reported, so it is not possible to determine if the difficulty in turning was in both directions or just to the side of disease onset. Indeed, the number of steps is shown to be greater when turning towards the side of disease onset (Spildooren et al. 2012; Spildooren et al. 2010b), which is further associated with freezing episodes (Spildooren et al. 2010a). Both these factors would account for the perceived difficulty, but maybe only in one direction; however the results are presented in a combined direction and thus making it difficult to suggest the possible underlying reasons for the increased difficulty experienced in this sub-group of PwP.

In a later paper, however, Stack & Ashburn (2008) elaborated on these findings, showing 75% of PwP demonstrated multiple step turns to their un-preferred side, compared to 45% in healthy controls. When comparing multiple turn results from the preferred turn direction, 64% had Parkinson's and 17% did not. It therefore appears that turning to an un-preferred direction creates a need for multiple steps in both groups but to a greater extent in PwP. This further exacerbates the already increased step number found in PwP as described above (Stack et al. 2002a; Stack et al. 2006). Although the increased step number is more pronounced in PwP, it also occurs in healthy individuals, suggesting the more difficult someone finds a turn, the greater the number of steps they take. Whilst this research gave a great deal of information regarding comparisons of turn time, type, step count, appreciation of the 95% limits of left and right agreement, functional reach, clinical scores (UPDRS and H&Y Scale) and self-assessed disability scales (SAS) in PwP compared to healthy controls, it is possible that significant findings may have been found by excessive data analysis, as not all results are reported, the primary outcomes are not specified and no statistical adjustments are reported, thus the possibility of over reporting is present.

In support of these findings, using a laboratory-based approach with kinematic analysis, Hong et al. (2009) compared 11 PwP and 12 healthy aged-matched controls, demonstrating that PwP take a significantly greater number of steps in turning, with more than twice the number of steps (13.02 ± 2.86 steps) required to complete a 180 degree turn compared to controls (5.05 ± 0.29 steps). A power calculation for this study enabled the authors to detect a 10% difference between groups using 11 participants. However, during the analysis, the authors grouped each participant's turns by 'turn strategy', defined as the starting foot being either unilateral or ipsilateral to the turn direction. Whilst this was possible due to no significant difference being found for turn direction, it does restrict any analysis with reference to directional preference and side of disease onset, both of which have been shown to influence turn quality (Stack & Ashburn 2008) and perceived difficulty (Stack et al. 2006), making it difficult to draw conclusions for the reasons of increased step number, as turn direction is not specified.

The significant correlation between the UPDRS, SAS and increased number of steps during a turn, for PwP compared to controls (Stack & Ashburn 2008), demonstrates the impact of disease severity on the number of steps during a turn, and furthermore, the degree of difficulty experienced. Although an increase in step number is believed to indicate a difficulty in turning, being less-efficient and of lower quality (Stack et al. 2004), it is possible that a purposeful increase may in fact be useful in order to maintain function. The finding by Stack et al. (2004) supports this, demonstrating that few PwP who fall or have severe Parkinson's use this compensatory strategy.

Clinically therefore, although the results suggest a more advanced presentation of Parkinson's may exhibit a greater step number in turning, the reason for this is unclear. It may be that the strategy of increased turning steps might be a compensatory mechanism for the postural instability and limited axial rotation which is evident in advancing Parkinson's. Therefore, whilst an increased number of steps to turn is considered an indicator of reduced turning performance, as a rehabilitation tool it may be beneficial, particularly in those at risk of falls during turning, in order to maintain functional independence. It is also important to consider the length of the step as this is likely to have a close relationship with the number of steps taken.

4.3.2 Perpendicular deficit - Step length

It is important to note that a reduction in step length is an integral component of turning for all in order to achieve a turn around a point (Orendurff et al. 2006). However, PwP show an even greater step length reduction (37%) compared to controls (22%), alongside a 26% shorter step length during normal linear walking (Huxham et al. 2008a), demonstrating a shorter baseline step length prior to turning.

Using 3-dimensional movement analysis, Huxham et al. (2008a) showed stride length to be a major contributor to turning accuracy. In a study of 10 PwP compared to 10 healthy controls, the healthy controls turned significantly more accurately using a 'three step cross-over' technique about a point to complete a walking turn, compared to the 'wide arc' technique used by PwP. The use of age, gender and height-matched controls in this study is important to ensure that the step length reduction shown is not a result of biomechanical factors, or age-related degeneration but purely the diagnosis of Parkinson's. However, this paper only analysed the three steps prior to and after completing a turn and therefore should be treated with caution, as the shorter and therefore greater number of steps taken by PwP means the two groups would be at different stages of their turn completion for each step.

A reduction in step length and thus speed, and increased step number, have also been shown to be accompanied by hypokinesia in PwP (Huxham et al. 2008a), often resulting in 'freezing' during the turn (Stack et al. 2002a; Bhatt et al. 2011), with one third of turns (19/56 – 34%) demonstrating the feet fail to clear the floor, or one foot clearing the other to place in front (Stack & Ashburn 2008). The tighter the turn the more these spatiotemporal characteristics are affected, with tighter turns electing a systematic decrease in step length and step time variability and velocity (Bhatt et al. 2011). The reduced coordination of step length between feet, measured as an integration of accuracy and consistency of left-right stepping phases, has also been linked to increased difficulty and freezing during turning (Peterson et al. 2012).

Clinically therefore, this suggests that whilst many small steps at a slower speed sacrifices efficiency and may result in freezing episodes, it may be an effort to preserve postural stability and maintain a wider base of support throughout the turn, maintaining the centre of gravity central to the base of support. Therefore, the apparent decrease in step length and speed may be a purposive adaptation to maintain functional balance and safety whilst turning, and thus reducing this in isolation through rehabilitation must be treated with caution.

4.3.3 Perpendicular deficit – Turn strategy

Leading on from step length, PwP have been shown to predominantly use an incremental turn type (turning on-the-spot before walking) as opposed to a toward-type turn (direct advance to target whilst turning) or a pivotal-type (broad-base turn initiating advance to target) used by healthy controls (Stack et al. 2002a; Salmon et al. 2010; Bhatt et al. 2011). This profile appears to change if the turn is not to the favoured direction, as both controls and PwP perform a turn in the un-favoured direction as an 'incremental turn' (Stack et al. 2002a). Although both groups demonstrated this change, it does highlight that, under the more challenging condition of turning to the un-favoured side, the natural motor performance to meet the demand is to adopt an incremental style of turn. This does suggest that PwP adopt this strategy on a more regular basis in order to accommodate for the lack of perceived stability in all turns. It could be suggested therefore that it is not the turn style itself that is causing PwP to have a dysfunctional turn, but the perceived instability, with the change in turn style being a secondary effect. The findings by Stack et al. (2004), that two-thirds of PwP (8/12, 67%) at the severe stages (H&Y 4 – severe disability, still able to walk and stand unassisted, (Hoehn & Yahr 1967)) appeared unstable when completing a turn as assessed by the SS180 and those of Salmon at al. (2010), showing those with greater motor symptoms (as measured by their UPDRS Score) and reduced balance confidence (Activities-specific balance confidence scale) adopt a multiple step pattern rather than a spin turn, supports the possibility of instability causing a change in turn style.

Using 3-dimensional movement analysis, Song et al. (2012) also demonstrated adaption to turning style with PwP tending to use a step-round style (when the change of direction was to the opposite side of the pivot foot) rather than a spin style (when the change of direction was on the same side of the pivot foot) used by healthy controls. In comparison to Stack et al. (2004), the inclusion of study participants with an early diagnosis of less than a year suggests that the presence of turning deficits occur early in the disease progression. The study also reported the influence of turn style on the translation of centre of pressure (the equilibrium point of the distribution of the resultant ground reaction force applied to the base of support) and centre of mass (the position that represents the equilibrium point of the body's mass), showing the step-round strategy to result in greater postural stability. This is likely to occur as a slower step-round strategy allows a greater use of feedback mechanisms whilst turning (Thigpen et al. 2000). The use of 3-dimensional movement analysis in this study may be a more robust measure of turn type and stability during a turn than the SS180 used by Stack et al. (2004), as it removes the need for a judgement to be made as to the quality and type of turn. However, the similar result for both studies supports the use of both clinical and laboratory-based assessments of turning activities in order to achieve accuracy and functional relevance of turn performance and quality.

These results suggest, under more challenging turning conditions, a natural motor performance produces an incremental turn strategy, suggesting dysfunctional turning in PwP may be a result of a lack of perceived stability requiring a secondary adaption to turning style. This again may be a compensatory strategy to gain control of the centre of mass within the base of support, secondary to the impaired postural control and inability to adjust to the functional task demands.

4.3.4 Summary of perpendicular deficits

In summary, perpendicular deficits (reduced step length, increased step number and alteration of turn strategy) predispose those with Parkinson's to experience difficulty in turning. The reason for such changes are less well understood and it is not clear if these are direct responses to the physiological changes as a result of the condition, or secondary effects from a need to gain greater stability and function in turning. In order to discuss this relationship, it is necessary to comment on the axial deficits of PwP during turning and the impact of these on the perpendicular deficits.

4.4 Axial deficits

For the purposes of this review, axial deficits are considered as 'non-optimal movement' of the axial structures of the body, i.e. the eyes, head, shoulders and pelvis.

Structurally, the axial musculature links all parts of the body together, giving support and stability to allow mobility and proximal limb movement. The axial musculature is anatomically and physiologically complex, controlled by cortical and subcortical structures via the descending monoaminergic pathways, particularly the reticulospinal and vestibulospinal motor pathways, also responsible for automatic postural reflexive movements. These are different from the cortico-spinal tracts controlling distal limb/perpendicular and voluntary movements (Lawrence & Kuypers 1968). More specifically here, experimental evidence based on animal studies indicates that supra-spinal structures pertaining to the basal ganglia are significantly involved in the posturo-kinetic changes associated with circling movements, turning and orientating behaviours (Winchmann et al. 2001). It is therefore likely that deficits in normal function in the basal ganglia results in axial motor impairments as well as the perpendicular deficits already described.

Axial deficits are a common cause of disability in PwP, they have been reported to be less responsive to pharmaceutical therapy than perpendicular deficits (Steiger et al. 1996) and occur early in PwP (Verheyden et al. 2007), presenting a significant difficulty in their management. Whilst a degree of tonic regulation (sustained postural control) of axial muscles is necessary to provide a stable base of support for movement of perpendicular body segments to be coordinated and controlled, excessive control as a result of axial motor impairments in PwP leads to axial segment rigidity. Using both functional assessments, such as the Functional axial rotation test (FAR) (Schenkman et al. 2001) and advanced kinematic analysis (Schenkman et al. 2000; Carpenter & Bloem 2011), the presence of 'axial stiffness', 'axial rigidity' and 'en bloc' turning (terms used interchangeably) as a result of axial motor impairment in PwP has been well reported in the literature (Steiger et al. 1996; Morris 2000; Schenkman et al. 2001; Ferrarin et al. 2006; Stack et al. 2006; Vaugoyeau et al. 2006; Crenna et al. 2007; Earhart et al. 2007; Verheyden et al. 2007; Visser et al. 2007; Willems et al. 2007; Wright et al. 2007; Huxham et al. 2008b; Huxham et al. 2008a; Mak et al. 2008; Franzen et al. 2009; Hong et al. 2009; Hong & Earhart 2010; Anastasopoulos et al. 2011; Song et al. 2012; Akram et al. 2013a; Akram et al. 2013b; Ashburn et al. 2014a). As with perpendicular deficits, there appears to be a number of factors that may contribute to axial deficits during turning in PwP, including axial segment rigidity; coordination and timing of the segments of the trunk; rotation of each segment and the role of the eyes. Each of which will be discussed, alongside the impact they may have on the perpendicular deficits already presented.

4.4.1 Axial deficit – Axial segment rigidity.

It appears that disorders of axial movement are dependent on the duration of the disease progression and associated increase in severity due to neurodegenerative properties, demonstrating a more prominent axial rigidity (Steiger et al. 1996).

To demonstrate this, Steiger et al. (1996) assessed the ability of 36 PwP to turn in bed before and after dopaminergic stimulation. Whilst dated, this paper potentially provides a design to compare the same individual at stages of increased and decreased disease severity. Axial rotation was measured using the Kings College Hospital (KCH) rating scale, with the sub-score of axial rotation being a mean of the score rating for rising from a chair, postural stability, axial rigidity and whole body bradykinesia. In total, 19/36 participants demonstrated a difficulty in turning in bed when examined in the 'off' state (medication at its least effective) following a levodopa drug withdrawal, with all but one improving with a levodopa challenge. There was a significant correlation between axial rotation and difficulty turning in bed, suggesting an influence of axial rotation on turning performance. Interestingly, the authors also noted increased use of the upper limbs to help achieve the turn when off medication, suggesting the loss of automatic movement and sequencing of axial rotation may be responsible for the adoption of secondary compensatory strategies in the perpendicular body segments.

Whilst this paper does highlight the influence of axial rotation on improved turning performance, it is unlikely that this is a result of improvements in axial rigidity, particularly as levodopa has since been shown to be ineffective at improving specific axial deficits during turning (Earhart et al. 2008; Hong & Earhart 2010). However, when considering the component of the KCH rating scale for axial rotation also includes measures of perpendicular performance, such as rising from a chair and whole body bradykinesia, this again suggests the influence of levodopa on secondary compensations, highlighting the need to address axial rotation deficits specifically as the disease progresses, medication options become more limited and turning becomes more challenging.

In support of the idea of axial deficits driving perpendicular adaptions, Hong et al. (2009) demonstrated a similar pattern of muscle activation in the lower limbs (perpendicular segments) of PwP compared to controls, but greater variability and reduced rotation of the head, trunk, pelvis and foot. This suggests that Parkinson's may affect the ability to organise and appropriately scale the amplitude of the axial movements of the turn, with muscle activation patterns of the perpendicular segments remaining intact or indeed adopting compensatory strategies in the foot. Unfortunately this research did not collect Electromyography (EMG) readings from the axial musculature, which would have been useful to distinguish the impact of each area.

Finally, Franzén et al. (2009), uniquely demonstrated, using a combination of clinical and functional tests alongside 3-dimensional movement analysis, PwP to have a significantly (43%) higher axial torque compared to controls, which was correlated to their functional performance in turning tasks. Interestingly, again in contrast to Steiger et al. (1996), the authors found no effect of levodopa on axial rigidity, but did show an improvement after levodopa administration in functional tasks (Figure of eight walk test). This again suggests the presence of compensatory perpendicular adaptations when the patient finds the task more difficult (off medication), with an underlying axial rigidity remaining.

It appears from the literature that axial rigidity can be further divided into deficits in the coordination, timing and rotation of the body segments within the axial structure and the influence of eye control, each of which will be discussed.

4.4.2 Axial deficit – Segment coordination and timing

When turning, PwP have consistently shown linked movement of the head, trunk and pelvis in a characteristic 'en bloc' appearance (Ferrarin et al. 2006; Vaugoyeau et al. 2006; Crenna et al. 2007; Earhart et al. 2007; Huxham et al. 2008b; Akram et al. 2013a; Ashburn et al. 2014a). In comparison, healthy young controls demonstrate a reciprocal oscillating pattern of movement, with movement of one segment resulting in coordinated counterbalancing in the next (Patla et al. 1999; Huxham et al. 2008a), which is also retained in healthy older adults during walking turns (Ferrarin et al. 2006; Crenna et al. 2007).

It is likely that a lack of segment coordination will lead to a perception of instability and the possibility of a purposeful adoption of a 'rigid trunk' in order to achieve an adequate base of support from which to move the appendicular segments. Without such control of the trunk, it is often difficult to achieve selective movement of the limbs (from clinical experience). In addition, the adoption of an 'en bloc' turning sequence may be an advantage by reducing the dimensionality of the interconnected chain of axial segments to one degree of freedom in order to simplify the coordination of movement required in the transverse plane (Akram et al. 2013a). This suggests that simplifying the task may be a strategy to cope with the loss of inter-segmental coordination in PwP. The tighter control of the 'en bloc' pattern of turning has also been replicated in healthy elderly when turning with their eyes closed (Akram et al. 2010b) and whilst challenging the vestibular, visual and proprioceptive systems by eyes closed and on a moving platform (Earhart et al. 2007). This suggests a simplification of the control of movement, by reducing the degrees of freedom in the axial segments when turning under more challenging conditions. Recent studies have also found an 'en bloc' turning strategy in healthy older adults when the turn is simple, such as to a predictable direction, self-paced and on-the-spot (Anastasopoulos et al. 2011; Akram et al. 2013a), suggesting an ability to also reduce the degrees of freedom in turning movement when the task is simple; a flexible adaption that may not be possible for PwP, therefore making all turning environments challenging.

It is not only the coordination of the timing of body segments during the onset of turn that is affected in PwP, but also the velocity of the segments during the turn (Visser et al. 2007; Akram et al. 2013a; Akram et al. 2013b) and the total time to complete the turn (Stack et al. 2006; Visser et al. 2007; Willems et al. 2007; Mak et al. 2008; Hong et al. 2009; Anastasopoulos et al. 2011). It has been suggested that the delay in these timing variables throughout the turn may be a result of the bradykinesia experienced by PwP (Morris 2000). However, the findings that those with relatively un-affected walking strategies still present with a delayed 'en bloc' turn, often similar to those with more advanced symptoms (Ferrarin et al. 2006; Crenna et al. 2007), and walking velocity to be un-related to segment coordination in the healthy elderly (Akram et al. 2010a), suggest the perpendicular deficits of bradykinetic gait are unlikely to be the drivers of timing and axial coordination deficits in PwP.

In an effort to distinguish the key features of the deficits in an 'en bloc' turn, a delay in the onset of pelvic rotation has been found (Vaugoyeau et al. 2006; Akram et al. 2013b). Vaugoyeau et al. (2006) studied 10 participants with advanced stages of Parkinson's (H&Y 3-4 and duration of disease ranging from 6-29 years) compared to five age-matched controls, with kinematic variables. In order to assess a functional task that could be achieved by all participants and involve whole body re-orientations, they asked all participants to take a single step at a 45 degree angle. Data were collected on the movement variables of the head, shoulders and pelvis as segments of the trunk. In agreement with Ferrarin et al. (2006), they found a slower initiation of movement of all body segments in PwP compared to controls, irrelevant of the speed that the step was undertaken. More specifically they found a delayed onset of pelvis rotation with respect to the shoulders compared to controls, suggesting a specific deficit in coordination of the shoulders and pelvis rotation and the sequential head, shoulder, pelvis rotation. Although this is not in agreement with the 'en bloc' presentation of previous papers discussed, only the relationship of the head and trunk (as a whole) tends to be commented on in such papers and thus the distinction between the shoulders and pelvis was not described.

The authors suggest a possible reason for a specific delay in the pelvis may be due to the control systems of each segment, with top-down organisation using the head position in space as a reference frame to coordinate shoulder position and a bottom-up control, which when a person is standing, regulates the position of the centre of gravity in space as well as that of the pelvis. Bottom-up control would be mainly related to equilibrium maintenance and thus more severely affected in PwP, owing to the reduced capacity to generate ground reaction forces (Vaugoyeau et al. 2003) as a result of an impaired extensor muscle activity and ankle strategy. A specific delay in the pelvis is also reflected in the recent findings of Ashburn et al. (2014a) and Akram et al. (2013b) who, using 3-dimensional movement analysis to assess standing and walking turns respectively, both show the greatest difference in the onset latency of segments to a turning cue between PwP and healthy controls in the lower body segments (pelvis and feet). A resultant delayed coordination between top-down and bottom-up control may arise (Vaugoyeau et al. 2006), which may also be influenced by the difficulty PwP experience in achieving dual motor tasks simultaneously (Morris 2000).

Whilst onset latency has consistently shown to be significantly slower across all the segments in PwP across the literature, further analysis by Ashburn et al. (2014a), accounting for head velocity, resulted in a loss of significance of the difference previously found. This suggests head velocity to be a key determinant in segment onset latency and supports the theory of 'top-down' organisation of segments driven by the head. However, even if PwP are able to alter their head velocity to accommodate for the delayed onset latency in the upper segments, the 'bottom-up control' would remain deficient. Whilst these findings are interesting and somewhat unique in the field, generalizability is limited to those in the early-middle stages of the condition as only two out of 31 PwP included were H&Y stage 4. Thus the interaction between segments may indeed change as the condition progresses, warranting further research.

These results appear to suggest that adopting an 'en bloc' turning strategy with fewer degrees of freedom simplifies the turn and therefore is adopted by PwP in response to a lack of segmental coordination, but also by healthy, age-matched controls under challenging conditions or conditions that do not require inline adaption such as on-the-spot turns.

4.4.3 Axial deficit – Amount of segment rotation

The 'en bloc' un-coordinated turning presentation in PwP may also result in variation in the amount of rotation each segment achieves about the vertical axis during each foot step of the turn.

Using 3-dimensional movement analysis of a walking turn about a pole, Huxham et al. (2008b) studied 10 PwP and 10 age-matched controls. The results (surprisingly) demonstrated greater rotation in the thorax and pelvis of PwP compared to controls when taken in relation to the corner of the turn (pole). When considered with relation to the axial deficit of reduced intersegment coordination producing an 'en bloc' presentation (closer linking of the segments at each footfall), and the perpendicular deficit of reduced segment rotation when considered over each footstep in PwP compared to controls found by the authors, this again supports the suggestion of axial deficits driving perpendicular changes.

It can be hypothesised that if the trunk and pelvis are moving together as a unit as in PwP, rather than rotating, as seen in controls, then only a limited amount of rotation is possible in the vertical axis before the feet must move, leading to the increased number of steps and decreased step length often observed. Therefore, if the 'en bloc' trunk rotates as much as possible over each foot step to maintain orientation with the head, this may appear as if rotation is greater in relation to the corner of the turn (pole) compared to control participants, who can disperse the rotation through the head, shoulders, trunk and pelvis. This hypothesis leads towards a multiple 'wind-up-release, wind-up-release' presentation; where the body rotates until release of the foot occurs, and suggests a possible reason for the multiple stepping pattern often seen in PwP.

Another possible hypothesis for the increased rotation, as suggested by Huxham et al. (2008b), is the presence of a separate motor command for segment rotation compared to all other aspect of the turn. This may well be the case as supported by the findings of Crenna et al. (2007), showing deficits in head and trunk rotation in the absence of gait and balance abnormalities in 14 PwP with mild clinical impairment. However, considering the direction of this effect it is not likely that the increases in axial rotation seen by Huxham et al. (2008b) are compensating for footstep patterning, but quite the opposite, of axial deficits driving a perpendicular adaptation. Indeed this can be supported by the findings of two companion papers by Akram et al. (2013a; 2013b), showing similar magnitude of segment rotation at the onset of foot re-orientation in 14 PwP compared to 19 healthy, age-matched controls during predictable, self-paced walking turns, but a reduction in magnitude during on-the-spot turns, with both studies showing a delay in segment turning velocity.

These results suggest the motor control of the magnitude of segment rotation may be preserved during walking turns, possibly due to the stepping pattern accommodating for the axial deficit. However, when turning from a stationary position during on-the-spot turns, the delay in segment initiation and reduced turning velocity cannot be adjusted for, thus resulting in a reduction in the amount of rotation seen at each footstep. Interestingly, turns to both 45 and 90 degrees were assessed in both studies by Akram et al. (2013a; 2013b), showing no effect of turn angle/type during on-the-spot turns and worsening segment velocity and magnitude in larger walking turns. This further adds to the possibility of adaption in a walking turn, but with the added influence of motor instability typically observed in PwP, as perpendicular adaptation (stepping) was possible in smaller walking turns, but failed to maintain effect in larger turns. With good participant numbers for variables of 3-dimensional movement analysis, assessment both 'on' and 'off' medication and use of the validated FAR test for axial rotation, both papers provide an accurate measure of walking and static turning performance in PwP. However, unfortunately the authors did not comment on the total number of steps taken to complete either of the turn types, so the impact of a possible step accommodation for axial deficits across the whole turn in standing and walking turns cannot be made. In addition, all turns were to a predictable direction and at a self-selected pace towards a pylon, thus limiting the ability to transfer the findings to real life situations when quick turns to unpredictable directions without the environmental cue of a pylon are most likely to result in turning deficits and consequential falling.

The findings by Mak et al. (2008) go some way to show the deficits in turning in these unpredictable conditions, by again using 3-dimensional movement analysis to assess sudden unpredictable 30 and 90 degree turns to either direction in 10 PwP and 10 age-matched controls. They found smaller total turning angles, slower initiation of the foot step and a narrower step width in PwP compared to controls. This again demonstrates the hypothesis of a reduced rotation magnitude corresponding with an adaption in step strategy, which in this case is step width. The authors also noted the narrow step width to be related to an inadequate force to accelerate the centre of mass towards the turn direction, with a resultant destabilisation effect and axial rigidity. In opposition to Akram et al. (2013a; 2013b), these authors found no difference in measures of different turn angles, suggesting the fundamental problem of turning in PwP to be modification of the motor programme from walking to turning, irrespective of turn angle. It is likely that the difference in findings is due to the unpredictability of the turn in the study by Mak et al. (2008), known to be more deficient in PwP than predictable turns and thus forcing all turn angles to accommodate with the same motor programme.

The results presented appear to suggest PwP have a reduction in the amount of rotation each segment undergoes during a turn, however the variety in methods used to assess this aspect of turning with regards to the point at which the rotation is measured, the use of specific turning angles and environmental cues appears to distort the reported findings.

4.4.4 Axial deficit - Eye control in turning

It is evident that visual information plays an important role in locomotion and turning. Large saccades (gaze shifts) are common in everyday life, in particular turning, and require combined movements of the eye, head, trunk and feet (Anastasopoulos et al. 2011). The deficits of the head, trunk and feet have been discussed and it is therefore essential, for completeness, to consider the contribution of the eyes during turning.

Studies in healthy individuals have shown that the eyes participate in the top-down rotation of sequence (Lohnes & Earhart 2011) as previously mentioned. The initial saccade during a turn, in combination with subsequent head movements, provides a shift of gaze to a position aligned with the direction of travel (Lohnes & Earhart 2011). Gaze shifts precede shifts in centre of mass trajectory during turning, and unexpected perturbations of gaze cause delays in centre of mass movement to steer the body along the desired trajectory (Vallis et al. 2001).

It appears through studies of multi-segment movements during walking, that a task-dependent reduction of the number of degrees of freedom occurs as a way of simplifying the control of complex movements in healthy people and PwP (Courtine & Schieppati 2004). Specifically during turning, this results in a reduction of three mechanical degrees of freedom to two kinematic degrees of freedom for eye, head and trunk (Anastasopoulos et al. 2011).

Anastasopoulos et al. (2011) demonstrated that PwP have normal movement initiation times of the eye, head, trunk and feet, and velocity of the eyes and head, but slow movement velocity of the trunk and feet. These results appear to support the 'top-down' control theory (Vaugoyeau et al. 2006), with the head and eyes maintaining velocity but the trunk, pelvis and feet showing decreases. Using principal component analysis (PCA), the authors demonstrated that PwP showed a significantly greater contribution of their eye-in-orbit to the components of the turn, and a significantly smaller contribution by their head on trunk compared to controls. This suggests that PwP use their eyes more in a turn and their head and trunk less, perhaps to compensate for the slower trunk movement. Using the same method of analysis, the authors also demonstrated high levels of head velocity are required to achieve a single step, with PwP showing lower levels of head velocity. This may provide another reason for the multiple step pattern as previously described in PwP.

The inclusion of mildly affected PwP (H&Y 1-2) in this study, demonstrates eye kinematics to be unimpaired and potentially compensating for the slow movement deficits of the trunk, feet and to a lesser extent the head present at the very early stages of the disease process. These visual compensations however, may begin to deteriorate as the disease progresses and the ocular movements become more impaired (Carpenter & Bloem 2011), and thus requiring a greater input from the deficient sensorimotor pathways, leading to reduced motor performance and function. Whilst the PCA analysis of this research allowed interesting and novel information regarding the impact of each segment to the turn, the data from 10 PwP were compared to that of 10 controls from a previous study. It is therefore difficult to guarantee all participants followed exactly the same protocol by the same researchers, possibly giving rise to external bias and inconsistent results. In addition, the age range of the PwP was much greater (11 years, mean age 58.3 years) than the control group (2.6 years, mean age 52 years), thus the impact of age related changes cannot be fully acknowledged and the results should be interpreted with caution.

The impact of the visual system to the interpretation of the environment in which the turn is taking place has also been discussed. Galna et al. (2012) used electrooculography, synchronised with 3-dimensional movement analysis, to investigate the level of visual scanning whilst completing complex walking and turning tasks in 21 PwP compared to 12 age-matched controls. They found, as expected, that PwP take longer to complete all tasks, with both groups increasing their saccadic eye movements prior to a turn. However, they also found PwP made less frequent preparatory saccades than controls. The study showed robust methodology with variables highly controlled in the laboratory-setting, repetition of all measures at least three times and a high number of participants compared to similar studies using such data collection methods, however it is not clear if the authors expect a similar performance in the home environment, when often PwP perform better and are more familiar with their surroundings. Therefore it may be suggested that impaired visual sampling prior to a complex task may contribute to impaired function, as sufficient visual information and cueing is not obtained, but it is unclear to what extent in the home environment.

In summary, it appears the motor control of the eyes during turning is linked to the top-down control theory. However, in contrast to the reduced amplitude of rotation seen in all other segments during a turn in PwP, the eyes appear to show an increased velocity of movement and contribute to a greater extent to the components of a turn compared to controls. This may be a compensation for the slower and smaller trunk movements, or may be a direct result of the reduced effect from the deficient basal ganglia on the eyes, owing to the fact that they do not compete with postural or voluntary movement. Despite the increased use of the eyes during the turn for PwP, it also appears they do not prepare the body in the same way as controls, showing reduced scanning prior to the turn, which may result in reduced visual cueing and analysis of the environment for complex tasks, both of which are essential for successful execution of the turn.

4.4.5 Summary of Axial deficits

In summary, it is apparent that axial deficits make a significant contribution to the experienced difficulty in turning for PwP. Axial segments appear to present with global rigidity and stiffness in a characteristic ‘en bloc’ movement pattern. Specific deficits have been shown in segment coordination, in particular the shoulders and pelvis, delay in segment initiation time throughout all segments, a reduction in segmental rotation and the use of eye saccades to control and scan for preparation of a turn compared to controls. Most of which have been found to be affected by disease severity, even in the early stages of the disease in the absence of perpendicular deficits and the influence of the direction of the turn performed (preferred/un-preferred).

The exact mechanism of such axial deficits remains unclear alongside their relationship and interplay with the perpendicular deficits discussed in Section 4.3, however suggestions of differing descending monoaminergic pathways (rectiulospinal and vestibulospinal pathways controlling axial musculature and predominantly corticospinal pathways controlling perpendicular), differing global motor control mechanisms (top-down/bottom-up) and direct secondary compensatory effect on each other have been made, but all require further investigation.

It is clear however, that axial deficits should be considered alongside the perpendicular deficits of step number, step length and turn style traditionally used (Keus et al. 2014), which may provide an opportunity to make lasting changes in motor control and the eventual turning performance in PwP. In order to assess the overall performance of turning in function, it is also fundamental to consider the external impact in which the turn is taking place, as only then can you consider the experience of turning performance in context.

4.5 External impact on turning ability in people with Parkinson's

The International Classification of Function (ICF) (WHO 2002) details three fundamental components in the analysis of function and consideration of therapeutic interactions; the impairment, the task and the environment. Physical impairments in the task of turning in PwP have been considered in Section 4.3 and 4.4, however in order to gain a realistic and valuable insight into the experience of turning for PwP, and thus propose interventions for enhancement, it is necessary to also consider the impact of the environment to this task.

In order to enhance understanding of these variables and their role in turning performance for PwP, it was necessary to conduct a secondary sub-literature search, summarised in Figure 7. A more detailed description of this literature search can be found in Appendix 2 ('Literature search terms for external influencing factors on turning in PwP').

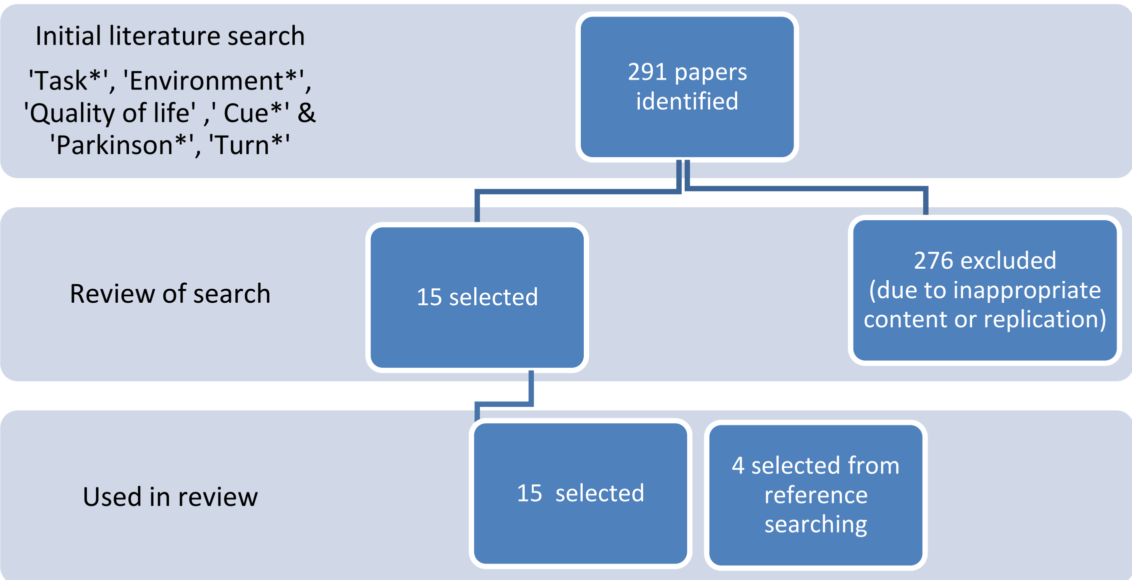


Figure 7 – Literature search for the exploration of the external impact on turning in people with Parkinson's.

Whilst there are obviously many variables in a 'natural environment' that may contribute to the performance of a task, the literature suggests the use of cueing, the environmental setting and the need for dual tasks to all have a significant impact, each of which will be discussed. As previously stated, 86% of PwP who experience difficulty in turning report frequent freezing and falling (Stack et al. 2006), therefore the impact of the environment, task and external triggers to freezing episodes has an impact on turning performance.

4.5.1 External impact – Cueing

Cueing can be defined as ‘using external temporal or spatial stimuli to facilitate movement initiation and continuation’ (Nieuwboer et al. 2007). External cueing can be visual, auditory or proprioceptive in nature and may be beneficial to PwP by utilization of the intact pre-motor cortex of the brain rather than the deficient, supplementary motor cortex and basal ganglia (Morris 2000).

The positive effect of cueing on gait and straight line walking, with an additional task has been well documented (Nieuwboer et al. 2007), showing reduced interference of the secondary task, and reduced variability in step duration (considered a measure of the disturbed automaticity in PwP). However, the impact of cueing on turning is less understood (Willems et al. 2007). As an extension of their previous work on gait, Nieuwboer et al. (2009) investigated the immediate effect of different cueing modalities on turning performance in PwP. During a previous trial, data were collected from 153 PwP, of H&Y 2-4. They completed a home-based functional turning task of walking to a chair, picking up a tray with two glasses of water on and returning, whilst wearing a cueing device on a belt. The device produced a visual cue in the form of a flash of light from a light emitting diode worn on glasses, an auditory cue through earphones, and a somatosensory cue (pulsed vibration) through a wrist band. For those that did not regularly experience freezing, results showed improvements in turn speed with auditory and somatosensory cues, but not visual cues. Auditory cues seemed to elicit the largest effect but were not significantly better than somatosensory cues, except in those who did not freeze. The authors attributed the significant improvements in turning ability from cueing to a more efficient allocation of attention during the task. The mechanism of effect from the external information provided by the cues was suggested to generate the necessary gait pattern for fluid walking, and thereby reduced the need for 'attention' to this aspect of the task. It also allowed increased attention to the speed of the turn and to the secondary task. Alternatively, as the cues were set for baseline walking speeds of each individual, the tempo of the cue may have also sped up the turn in this way. Or, simply raising the participants' awareness of the task or increased sensory feedback from wearing the glasses may have a significant impact on alertness and therefore speed. The exact impact of cueing on turning performance therefore requires further investigation.

The use of cueing further contributes to the hypothesis, that the ability to move is not lost in PwP, rather the person is dependent on cortical mechanisms to activate and sustain movement, with the possibility that this may be achieved by simply raising awareness of the deficits. Strategies that rely solely on this however, may not be appropriate for PwP who have severe cognitive impairment, who may benefit more from external cues and adjustments to the environmental setting.

4.5.2 External impact - Environmental setting and cueing

With regards to setting, the impact of the environment that a turn is completed may impact the performance outcome of that turn. It has been discussed in Section 4.3.1 and 4.3.3 that PwP take more steps to complete a turn and adopt the 'step round' strategy more often that the 'pivotal type' (Stack et al. 2002a), both of which require more space to complete. In the home environment, this may not be possible, particularly in rooms with many obstacles and furniture, or rooms that may be smaller such as bathrooms. Interestingly, with reference to cueing, Willems et al. (2007) failed to show a significant impact on the type of turn using auditory cueing in PwP (ten people who did not freeze, nine people who did freeze) using 3-dimensional movement analysis of a left hand turn about an obstacle. Cueing in fact forced those who did not freeze to adopt the 'wide arc strategy' only seen previously in those who freeze, who also retained this strategy after cueing. This may be a reflection of the tempo of the cue (linked to straight line walking in this study) encouraging a larger step and therefore forcing the 'wide arc strategy'. It may also reflect the need for larger steps by those who often freeze, as an effort to reduce the variability of timing known to be higher in PwP than healthy controls (Willems et al. 2007). Indeed, cueing did reduce the variability of step duration during the turn, which has been shown to have a significant impact on reduction in freezing episodes (Willems et al. 2007). Whilst these effects of cueing on turn type are likely to reduce the incidences of freezing, and therefore potentially falling, the result should be interpreted with caution due to low subject numbers, the artificial tempo of the cue being set to straight-line walking (despite the need of step-asymmetry in turning steps) and the sole use of left turns, not permitting the effects of disease dominance or directional preference to be addressed.

In addition to the space required to make a 'large arc turn', the direction of the turn that PwP may be forced to take may also have a strong relationship to the outcome of the turn. In healthy participants, Courtine and Schieppati (2004) described separate functions of the inner and outer leg during turning, with the inner leg showing reduced step length and swing velocity, and increased stance phase duration, whilst the outer leg continues the on-going movement with decreased stance phase duration, thereby inducing symmetry. It would be plausible to suggest therefore, the necessary reduction of step length, on top of the already reduced step length in PwP as discussed in Section 4.3.2, may contribute to step variability and thus freezing of gait and difficulty turning. Indeed, Spildooren et al. (2012), studied 26 PwP (13 people who freeze and 13 people who did not freeze), completing a 180 degree turn whilst wearing 3-dimensional movement analysis equipment. They found freezing to initiate more often at the inner side of the turning circle (61 cases versus 33 cases on the outside), and conversely participants reinitiated movement predominantly with the outer leg (62 cases outer leg versus 32 cases inner leg). It would be expected therefore, that if PwP turn towards their side of symptom onset and thus more affected side, then freezing would occur more, as the inner leg may already have a shorter step length. However, disease asymmetry was not related to freezing episodes during turning in this study, which is in contrast to a previous study by the same authors showing freezing to be more common on the disease-dominant side (Nieuwboer et al. 2007) and also towards the non-preferred side (Stack et al. 2002a). Possible reason for this discrepancy may be under-powering in the study by Spildooren et al. (2012), as only seven of the 26 participants actually froze during the testing protocol, thus significantly reducing the data for this aspect of the analysis. In addition, participants were tested in their 'off phase' of medication compared to other studies being tested whilst receiving standard medication. There also appears to be confusion in the literature regarding the 'side of disease dominance'. The current study used a classification from the UPDRS, as the side with the greatest symptoms, however Stack et al. (2002) rated it on 'side of preference to turn'. It is possible that these could be different within participants and thus providing conflicting data. These differences in variables tested make extrapolation to the general population of PwP challenging.

It may be possible therefore, that the asymmetrical character of turning itself may be more important than the dominance of the side of symptoms. This may not account for all of the difficulty in turning to un-preferred directions however, as Spildooren et al. (2012) also demonstrated 35% of freezing episodes to occur in the outer leg. A possible reason for this may be the difficulty in transferring the centre of mass onto the inner leg of the turn due to restricted axial rotation (as previously discussed in Section 4.4), resulting in incomplete weight shift and reduced toe clearance causing freezing in the outer leg.

4.5.3 External impact - Dual tasks

As well as the environment that the turn is completed, the purpose of the turn and any co-existing tasks may also have an effect on the turn performance. Gait impairments in PwP are exacerbated under dual task conditions, requiring the simultaneous performance of cognitive or motor tasks (Kelly et al. 2012). Whilst the impact of dual tasks on gait has been well researched, there is little evidence of the impact during turning. However in light of the difficulties in turning discussed already, mirroring complications during gait, it is likely that gait changes during dual tasks are replicated during turning. This link, however, must be treated with caution, and further research is required.

Plotnik et al. (2011) studied 30 PwP, using force-sensitive insoles to quantify the timing of the gait cycles during 80-metre walking trials. Walking was at a self-selected, comfortable pace, under three randomly presented gait conditions; usual walking, walking and dual tasking and walking performing serial three and seven subtractions. Participants were optimised for medication. Results were expressed as a percentage of a single task performance, reported as the ‘dual task cost’ (DTC). The impact of the cognitive challenge of serial three and seven subtractions represented a -17% and -23% DTC respectively with regards to gait speed and -11% and -15% respectively with regards to stride length. Further to this, Lord et al. (2010) measured gait parameters in 29 PwP, who had withheld their medication, wearing accelerometers in their own home, whilst walking 6.5 metres carrying a tray and counting auditory tones. They demonstrated a DTC of -65% with regards to gait speed. The use of the DTC allows these two studies to be compared even though they varied in terms of participant medication cycle, the task and the environment. However, because of these multiple differing factors, it is not clear which has influence on the greater DTC reported by Lord et al. (2010) and thus further research is required in this field. In a review by Kelly et al. (2012), uncertainty was reported as to whether motor tasks or cognitive tasks have a greater impact on gait in PwP, as it appears that the more complex a task, the greater effect it has. The impact of cognition with regards to executive function, attention, memory, language and visuospatial impairments, all known to deteriorate as the disease progresses (Morris 2000), should also be considered, as it is likely to have a greater impact on turning performance in the later stages of the condition.

4.5.4 Summary of external impact

In summary, the impact of external factors has been considered in this section, demonstrating one of the most researched and frequently used environmental triggers of external cueing to show improvement in turning ability in PwP (Morris 2000), thus highlighting its importance when assessing turning performance and designing rehabilitation intervention. Adaption of the environment that the turn is completed in has also been shown to be an important factor in improving turning performance. Complex turns inherent in manoeuvring in the kitchen or bathroom may be compromised even more, due to the defective basal ganglia function hindering the ability to adapt from one mode of locomotion or turning strategy to another. Finally, turning in daily life is frequently accompanied with additional task performance, such as moving with an object and holding a conversation, which may also affect turning performance, and thus should be considered when striving to make rehabilitation functionally relevant.

4.6 Overall summary of turning deficits

The impact of perpendicular, axial and environmental variables on turning performance has been discussed and is summarised in Table 6.

The internal perpendicular deficits of an increased step number, decreased step length and alteration in turn strategy (Section 4.3) have been compared with the axial deficits of increased axial segment rigidity, comprising of reduced segment coordination, timing, and rotation, plus altered eye control (Section 4.4). The possibility of axial deficits driving a secondary response in the lower limb has been suggested, however, it remains unclear where exactly these deficits are located within the axial sections of the body, and indeed the interplay between them. Disease severity appears to be a factor in determining the relationship between the structures, with the possibility that axial deficits are present even in the absence of perpendicular deficits at the early stages of the disease, and thus driving the perpendicular compensatory changes as the disease progresses.

Alongside these internal variables, the impact of external variables such as the use of external cues, the surrounding environment and the functional necessity of the task i.e. to complete a dual task when turning, has also been discussed, all of which also appear to influence turn performance in PwP.

The role of axial and perpendicular deficits, or a combination of both, alongside the requirements of the turn and the environment it is completed in, therefore has significant consequences when designing and justifying rehabilitation packages aimed at improving functional turning ability in PwP. These traditionally include step practice and development of compensatory strategies. However, as it appears axial deficits may be the primary drivers in the deficits of turning performance experienced by PwP, with perpendicular deficits resulting from compensatory strategies or secondary changes, a focus on improving axial movement ability may result in better functional outcomes than traditional limb strategies alone. In addition, consideration of the requirements of the turn, such as the necessity to complete a dual task, and the impact of the environment should also be made.

Thus, further research is required to assess the impact of multi-modal treatment strategies that include specific focus on axial rotation rehabilitation alongside those of the perpendicular body segments and the environment, one of which may be dance.

Table 6 – Synthesis of deficits in turning from the literature

Internal influences Those originating within the individual				**External influences** Those originating from the environment.
Perpendicular deficits		**Axial deficits**		**Impact of cues**
‘Non-optimal movement’ occurring in any aspect of the perpendicular areas of the body (limbs)		**‘Non-optimal movement’ occurring in any aspect of the axial areas of the body (head and trunk)**		**Using external temporal or spatial stimuli to facilitate movement initiation and continuation**
Step number	Increased number of steps to complete the turn.	Segment rigidity	Increased rigidity with disease progression.	Auditory cues elicit the greatest effect with utilization of the intact pre-motor cortex of the brain.
	Step number increased to a greater extent when turning to the un-preferred direction.		Deficit in scaling the amplitude of segment rotation.	Allows increased attention to the speed of the turn and/or the secondary task.
	Increased step number related to disease severity.		Higher axial torque related to reduced axial rotation in turning tasks.	Forces a ‘wide arc’ turn strategy and reduces the step length variation in turning.
May be a useful compensatory strategy.		*Leads to adoption of secondary compensatory strategies.*		**Environmental constraints**
Step length	Reduced step length.	Segment coordination and timing	Linked segments producing an ‘en bloc’ turn.	**The impact of environmental factors that may influence performance.**
	Reduced step length reduces turning accuracy.		Simplifies the coordination of movement to one degree of freedom.	Deficits are dependent on the required direction of the turn.
	Reduced step length is linked to hypokinesia and reduced foot clearance.		Delayed segment onset, velocity and total time of the turn.	Turn strategy is dependent on the available space to complete the turn.

	Tighter turns elicit a greater reduction in step length.		Delay in pelvis and foot coordination possibility due to differing control mechanisms.	Necessity to dual task influences performance.
May be an effort to preserve postural stability.		*Leads to un-coordinated movement of the axial and perpendicular structures.*		
Turn Strategy	Incremental turn strategy rather than spin or step round.	Segment rotation	Reduced individual segment rotation around each footstep in standing turns.	
	Change may be due to perceived instability.		May be a component of delayed segment initiation and reduced velocity.	
	Changes appear to be evident in the early stages of the disease.	*Leads to secondary step compensatory strategies.*		
		Changes in eye control	Increased velocity of movement and use of eyes during turning.	
			Linked to the 'top-down' theory.	
			Reduced scanning prior to turn.	
		May be a compensation for the reduced axial rotation		

4.7 The impact of dance on turning performance.

The effects of dance on turning have not been investigated to date. Considering the difficulty in turning expressed by so many PwP and the fundamental need for successful and safe execution of turning in activities of daily life, there is an urgent and extensive need to develop novel methods of rehabilitation that can be effective, feasible and cost effective for the long-term management of the condition and the particular problems of turning specifically.

Whilst the majority of papers presented in this chapter have looked at individual deficits in turning (Sections 4.3 – 4.5), or the impact of dance on individual symptoms in isolation (Chapter 2), this may be criticised as it diminishes turning and the use of dance as a rehabilitation tool for PwP to the presentation and response of one or two symptoms. Evidence however, appears to suggest a complex interplay of deficits in turning, and a holistic effect of dance on the person as a whole (mind and body), and thus investigating components in isolation prevents a true interpretation of the 'real life' situation.

The use of the International Classification of Functioning (ICF), designed by the World Health Organisation (WHO) to define disability, may help draw together the evidence presented, and demonstrate the impact of dance for PwP on turning ability. The ICF considers disability experienced by an individual to encompass five categories in a hierarchical model including body structure and function, activity and participation, with influencing factors of the environment and individual person (Figure 8).

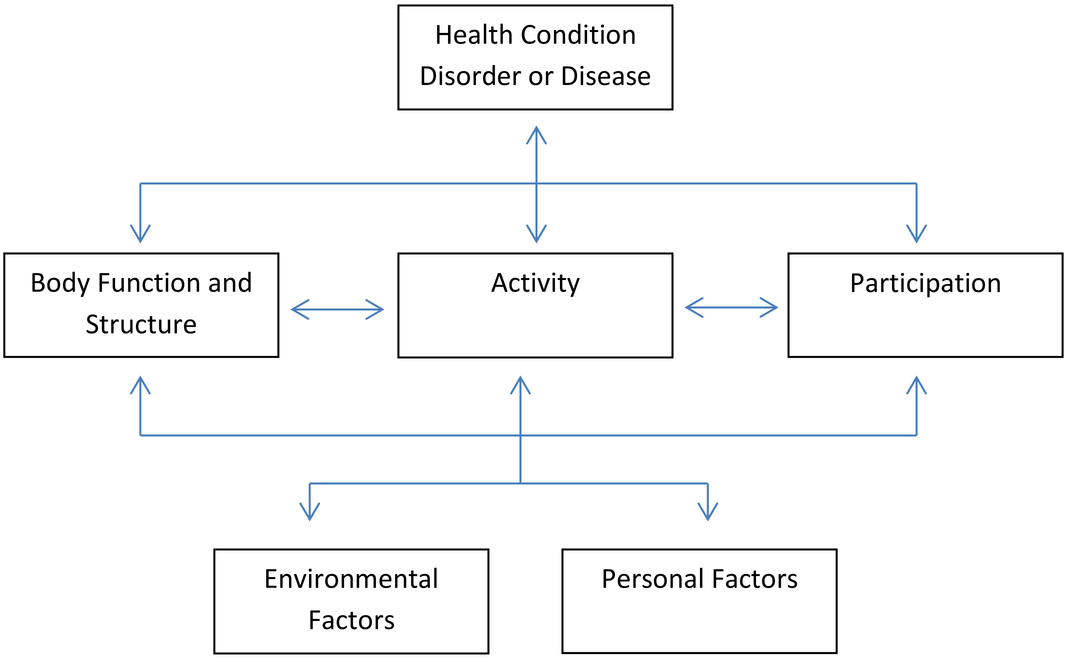


Figure 8 – Representational model of the ICF Framework (WHO 2002).

This represents a biopsychosocial model for disability, and takes into consideration the impaired body and/or mind and as well as the influence of how an individual participates in everyday life activities and situations (McGill et al. 2014).

By using the model, the effects of dance, as discussed in Chapter 2 and the corresponding deficits in turning discussed in Sections 4.3 – 4.5 can be summarised.

Figure 9, synthesises the literature presented using the ICF model of disability to suggest the influence of dance on turning deficits in PwP. Due to a lack of research on the effects of dance on turning in PwP, the effects suggested in the model can only be extrapolated from available research and thus are speculative in this instance.

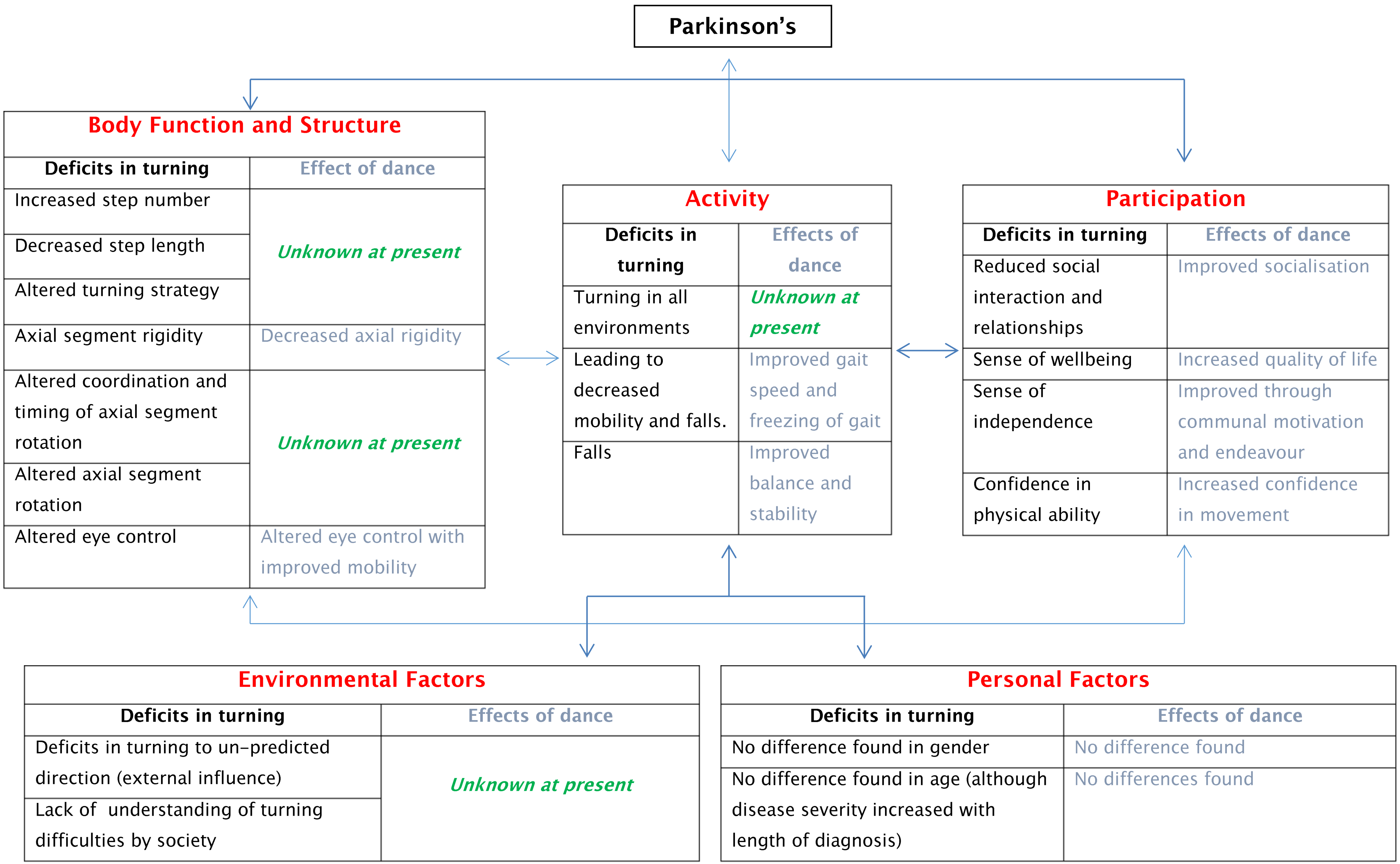


Figure 9 – Proposed influence of dance on turning deficits in PwP using the ICF model.

4.8 Justification for current study

A trend is apparent in the literature to suggest deficits of the axial segments of the body (head and trunk), including increased axial segment rigidity, comprising of reduced segment coordination, timing and rotation, plus altered eye control, may have an influence on the presentation of perpendicular deficits (lower limbs), such as increased step number, decreased step length and alteration in turn strategy, during turning. Whilst current published literature has demonstrated the presence of these deficits, many deficits have been looked at in isolation of each other and therefore the true influence of each on turning ability as a whole is difficult to interpret. The quantitative component of this thesis will therefore investigate the effects of dance on both axial rotation (whole body coordination) and the perpendicular measures of footsteps and turn strategy when assessing the functional performance of turning as a whole. This will allow consideration of the effects of dance on individual turning deficits, but also discussion of the influence of deficits across the axial and perpendicular segments, and thus treating the body as a whole, during a functional performance of turning.

By considering the interaction of perpendicular and axial deficits, the specific effect of dance on turning ability can be suggested. Whilst dance has growing published evidence for its global effects on PwP, such as improvement in balance, gait and psychosocial influence, the specific mechanisms of the effect of dance for PwP are yet to be reported. No studies have considered the effect of dance on turning specifically, despite the functional relevance and importance demonstrated in the literature (Chapter 4). In addition, no previous studies have used advanced measures of 3-dimensional movement analysis to assess the outcome of a dance intervention. In order to fully understand the physiological adaptions during turning, as a result of dance in PwP, it is necessary to isolate movement and look specifically at its components using detailed movement analysis techniques. This component of the PhD will therefore focus on the effects of dance on turning performance using sophisticated measures of 3-dimensional movement analysis, which will allow a detailed assessment of turning performance and the effects of a dance intervention across all body segments.

As demonstrated in Figure 8 (Section 4.7), the ICF considers the impact of Parkinson's on the person and their environment as a whole. It is clear from this model that the specific effects of dance on the deficits considered under 'body structure and function', and the global effect of dance on turning performance in both 'Activity' and 'Environmental factors', are gaps in our current understanding and therefore warrant further investigation.

Integration of results from this study, with the findings from the concurrent RfPB funded study and current published literature, will span across all five components of the ICF model. This will in the long-term, add to the understanding of the use of dance as a form of rehabilitation. Fundamentally, incorporating treatment of the key symptoms of the condition, delivered in an enjoyable and engaging format, and therefore promoting motivation to regularly participate in physical activity; all considered critical for the effective treatment and management of PwP and all of which are included in dance.

Chapter 5: Methods

This chapter describes the data collection, extraction and analysis procedures taken to investigate the effect of ballroom and Latin American dancing on whole body coordination during turning in PwP. A feasibility study to assess the appropriateness of the outcome measures for this study was completed, a summary outline of which is reported in Appendix 3. Aspects of the recruitment and consent process were managed by the RfPB researcher (not the researcher for this PhD) and this has been acknowledged in the text.

5.1 Research aim

To investigate the effects of ballroom and Latin American dancing on whole body coordination during turning in PwP.

5.2 Research question

Are the kinematic measures of body segment latency, body segment rotation and force variables during turning, and the clinical measures of the Standing start 180 degree turn test (SS180) and Berg balance scale (BBS) altered after a dance intervention in PwP?

Based on the findings of the individual results, the changes in the relationship of body segment latency, body segment rotation, force production and clinical measures of turning performance, before and after a dance intervention, in PwP will be discussed.

5.3 Design

This study was a randomised, controlled experimental design to investigate the effects of ballroom and Latin American dancing on whole-body coordination during turning. There were two groups; PwP who completed a dance intervention alongside usual care (intervention group) and PwP who followed usual care only (control). Each participant attended the Gait laboratory, University of Southampton, Faculty of Health Science at the University Hospital Southampton NHS Foundation Trust on two occasions (pre- and post-intervention or control) for assessment of turning ability. Analysis of whole body coordination during turning in PwP who danced was compared to those who did not, using the measures of group demographics, body segment latency, body segment rotation, ground reaction forces, SS180 and the BBS (data collected by the RfPB researcher).

The design followed the process detailed in Figure 10.

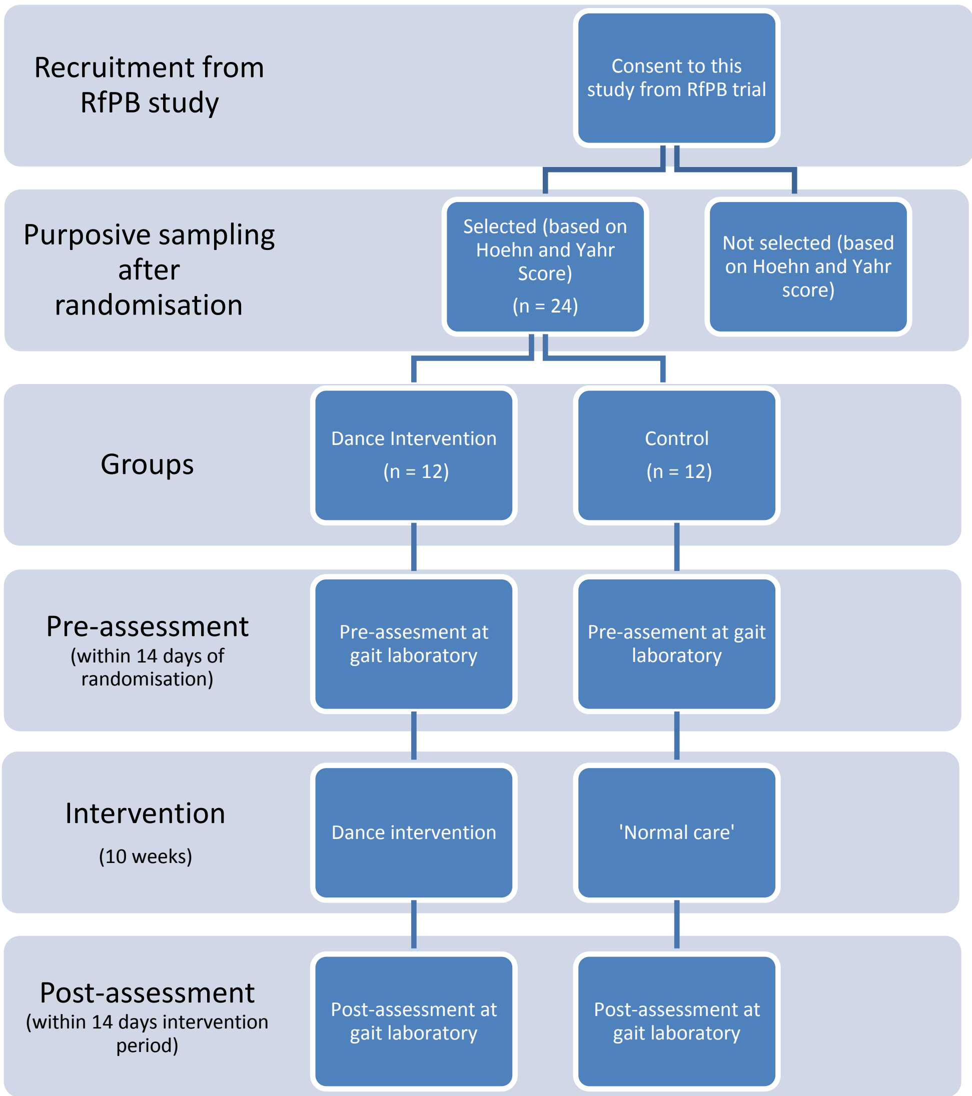


Figure 10 – Research design.

5.4 Eligibility

5.4.1 Inclusion/Exclusion criteria

Inclusion criteria

1. Eligible people had a diagnosis of Parkinson's disease by their Consultant Neurologist.
2. Hoehn and Yahr (H&Y) (Hoehn & Yahr 1967) scale 1-3, which means mild to moderate mobility and stability deficits (Section 2.1.2). Results from the feasibility study found participants with this score were capable of turning and completing the required tasks (see Appendix 3).

Exclusion criteria

1. Inability to follow commands and remember instructions.

During the assessment, participants were asked instructions such as "turn to the light behind you" or "turn to the direction that the arrow indicates". They were required to carry out this command without confusion or the need for clarification.

2. Inability to tolerate the assessment procedure of turning.

The participants were expected to tolerate up to 90 minutes of standing and turning of 180 degrees, however rests were available on request.

3. Musculoskeletal disorders that could affect the participant's ability and performance whilst turning.

This was restricted to disorders with a recent onset (within the past three months) that were still affecting the movement of the participant. Disorders prior to this are likely to have resulted in physical adaption and accommodation and thus not likely to change over the course of the intervention period.

4. Any other neurological conditions such as stroke, vestibular disturbance, vertigo, peripheral neuropathies or any other condition that would negatively affect balance control.

Both musculoskeletal and additional neurological conditions (other than Parkinson's) may alter the ability or performance of the participant to turn.

5. Visual impairments that could not be corrected with glasses or contact lenses.

This was required in order to find the necessary target to turn to.

6. Hearing impairments that could not be corrected with a hearing device.

This was required in order to hear the instructions given without repetition.

7. A recent fall (defined as 'as an event which results in a person coming to rest inadvertently on the ground or floor or other lower level' (WHO 2012) within two weeks as a consequence of turning or of unknown reason, presenting a significant concern for the participant's safety whilst turning.

8. Participants already undertaking dancing classes or had done so in the previous 3 months.

Eligibility criteria were checked informally through the initial telephone screen and formally through the baseline assessment by the researcher for the RfPB study. A subsequent screen was completed by the researcher for this study on attendance at the Gait laboratory for pre-assessment.

5.5 Participant selection

5.5.1 Sample number

No previous study has reported on the effect of an intervention on whole body coordination during turning in PwP, so it is not possible to predict an effect size and thus power calculation for this study.

The sample size (12 dancers and 12 controls) was determined by previous research using 3-dimensional movement analysis of turning in PwP (Mak et al. 2008; Hong et al. 2009; Huxham et al. 2008a; Huxham et al. 2008b; Ferrarin et al. 2006; Willems et al. 2007; Wright et al. 2007). Mak et al. (2008), investigating the sudden directional change during straight line walking in PwP and healthy controls, predicted 80% power (using an alpha level of less than 0.05) from 14 participants (seven in each group). In addition, Hong et al.(2009), studied turning in PwP and healthy controls using kinematic measures similar to this study, indicating a power of 85% to detect a main effect of group (PwP/controls) with 11 participants in each group.

An appreciation of the data collection needs for the qualitative component of the RfPB study was also taken into consideration, with a necessity not to over-burden the participants, in line with ethical recommendations.

5.5.2 Recruitment and consent

Participant recruitment to the study was through invitation to the RfPB study.

Recruitment for the RfPB study was achieved through presentations at local Parkinson's support group meetings, consultant appointments, regional research networks, newspaper adverts and word of mouth. Participants were recruited in four blocks over one year.

After initial notice of interest, potential participants were provided with a participant information sheet detailing all components of the RfPB study (including the current study). Interested participants were contacted by telephone, by the RfPB researcher, and an opportunity for clarification of the requirements was provided. If appropriate for the RfPB study, a telephone screening took place to assess eligibility and make an appointment to gain consent and complete the baseline assessments by the RfPB researcher. Participants consented to all components of the study separately, (RfPB study, RfPB qualitative component and this study).

Those participants who consented to the current study were contacted by the researcher of this PhD, who completed a telephone screening assessment (see Appendix 11), given an opportunity to ask further questions and invited to participate if appropriate based on sampling criteria (Section 5.5.3). Invitation was based on disease severity, rated by the H&Y classification (Hoehn & Yahr 1967) from baseline assessment and group allocation in the RfPB study. This enabled a sample with equivalent disease severity in both groups. All those that consented were then contacted by telephone to either invite them to participate in this study or thank them for their interest if not selected.

5.5.3 Randomisation strategy and sampling

Once recruited into the RfPB study, PwP were randomly allocated to either intervention (dance) or control groups by telephone randomisation with a medical statistician undertaking the randomisation, ensuring the ratio of dancers and controls was met for each dance block (block one: eight dancers and three controls and block two, three and four: nine dancers and four controls). Participants were then informed of their allocation by telephone. From this, a purposive sample based on disease severity from each group was taken for the current study. Therefore allocation to group was at random, but sampling from each group was controlled for by disease severity.

5.6 Group content

Following the pre-assessment, participants entered their allocated group (intervention/control). The details of each are described below:

All participants continued with their usual care as deemed appropriate by health care providers. This usually comprised attendance at medical clinics, medication and visits from Parkinson's disease nurses (based on clinical experience). Participants were requested (but not compulsory) to maintain their lifestyle habits and activities during the ten-week intervention period where possible and inform the researcher if this changed significantly.

5.6.1 Control

Those allocated to the control group continued with their usual care as detailed above. After the post-assessment at ten-weeks and after the final assessment for the RfPB study, all participants in this group were invited to attend a once-a-week dance class for 10 weeks, as detailed below.

5.6.2 Dance intervention

Dance steps were initially selected by the dance teachers in discussion with the research team from the RfPB study (including the researcher for this PhD study). The dance content followed the basic syllabus for beginner classes usually taught at the dance centre, however specific adaptations due to the difficulty of the steps in relations to the symptoms of Parkinson's were recommended where necessary. The dance content was trialled in a pilot study for the RfPB study (and this PhD) and a refinement of the dances was made. The initial selection of dance content and refinement following the pilot is shown in Appendix 3 ('Developmental work').

Following the pilot, those allocated to the dance group received twice-weekly dance classes for 10 weeks (20 classes in total). Classes were one hour long and included combinations of the following dances.

Dance	**Outline of steps**	**Genre**
Walking warm-up	Walking in a circle with hand held support of a dance partner to Paso doble music.	None specific
Social foxtrot	Basic foxtrot step Additional 'step/close' section	Ballroom
Waltz	Basic waltz step – taught as box step initially Additional whisk and chassé	Ballroom
Ballroom tango	Basic tango step Additional promenade	Ballroom
Rumba	Basic rumba step New-York step Ladies' under-arm turn	Latin
Cha cha cha	Basic cha cha cha step New-York step	Latin
Rock 'n' Roll	Basic rock 'n' roll step	Latin

	Ladies' turn Change of hands	
Social Dance	Basic formation dance step	Social dance

Table 7 – Intervention group-dance content.

Further details of each dance step are shown in Appendix 10.

The frequency and duration of classes is in line with previous studies of dance for PwP and the conclusions from a systematic review considering the 'FITT principle' (Frequency, intensity, time and type) of dance for PwP (Shanahan et al. 2015).

Participants were asked to identify a dance partner (spouse/carer) if possible. In addition to this healthy volunteers were also recruited and allocated to those unable to identify their own dance partner. All partners were screened for eligibility and consented to the study by the RfPB researcher. Throughout the intervention, care was taken to ensure that participants always danced with a partner, which often meant participants danced with a number of different partners throughout the intervention period.

The class was taught by two teachers and a research assistant (researcher of this PhD). The research assistant ensured that the class content was suitable for PwP with regards to physical ability and taught instructions, making suggestions for adaption where necessary. The research assistant was also responsible for the safety of the participants whilst completing the intervention alongside the logistic management of the class, ensuring all participants had partners and transport.

5.7 Blinding

It was not possible to blind the researcher for this study to the group allocation, as this was known from the researcher's involvement in the randomisation process for the RfPB study. However, once collected, the subsequent data analysis was re-coded with random numbers by the senior experimental officer. This process allowed blinding of the researcher during the data extraction process. The data were then un-coded for data analysis.

5.8 Assessment

Both the pre-and post-assessment for both groups were completed within 14 days prior to and finishing the 10-week intervention block (see Figure 10). All assessments were completed at the Gait laboratory.

5.8.1 Equipment and laboratory set up

Participants were asked to wear the equipment described below for 12 turns. This permitted the motion analysis software to detect a specific movement in the X, Y and Z axis of the Gait laboratory for each body segment, and thus produce a 3-dimensional image of the movement over time.

Both methods of movement analysis (3-dimensional movement analysis (Coda) and Videonystagmography (VNG) eye tacking systems) have been used successfully in previous research from the University of Southampton within the research group (Ashburn et al. 2014a; Ashburn et al. 2010; Verheyden et al.2007), and measures taken were found to be suitable following the feasibility study (see Appendix 3).

5.8.2 Equipment worn by participants

5.8.2.1 Coda markers

The position of the head, shoulders, pelvis and feet whilst completing the turn were recorded using a Coda motion analysis system (Charnwood Dynamics Ltd, Leicestershire, UK). This is a motion-analysis system that records movement of the different segments of the body from a set origin in the room space around them. It is capable of producing coordinates of each segment in order to construct a 3-dimensional image when collated. Markers on each body segment were required. The markers consist of infrared light emitting diodes (LEDs) (1x2cm) (Figure 11) plugged into lightweight battery packs.

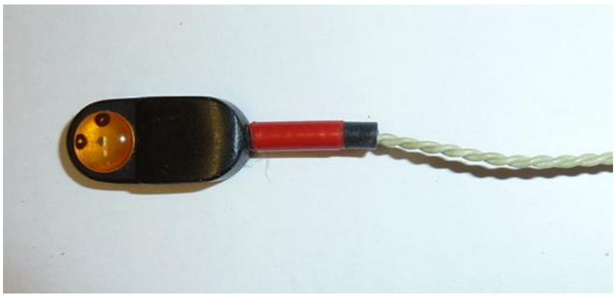


Figure 11 – Light Emitting Diode (LED).

The LEDs were triggered and pulsed sequentially by a computer, permitting automatic identification of each marker by the Coda units. The markers were attached to the participants clothing by double-sided, hypoallergenic tape.

5.8.2.1.1 Marker placement

There were two markers on the shoulders, placed on the upper surface of the acromion on each side, a marker on the sternum and at mid-scapulae level (approximately over T4, as this was considered the mid-point of the thorax segment), all of which were ascertained by surface palpation. Markers were placed over clothing to protect modesty. Whilst this may lead to some movement of markers during the turn, with a possible impact on the amount of rotation of each segment, this was minimised by asking participants to remove loose fitting clothes where acceptable and taping clothing to the skin surface using hypoallergenic tape. Markers were not re-positioned once the testing procedure had started for each visit, with a change in rotation from initiation to the first foot movement being recorded, rather than an absolute angle reached by each segment. This ensured that difference in marker placement at the pre- and post- assessment did not impact on the change in angle recorded and used as a comparison. Four markers for the head position were mounted on a helmet, one above the lateral aspect of each eye and one on each side of the occiput. Four markers were placed on a truncated half-pyramid block mounted on a large Velcro belt around the participant's pelvis. There were two markers on each foot (whilst wearing shoes), one over the first toe and one on the heel at 45 degrees from the midline of the foot with the participant in a natural stance. This was measured by the participant standing in a neutral position with a right-angle measure placed on the floor behind. The point where the right-angle measurer was in line with the heel was taken as the 45 degree point for marker placement. See Figure 12 for marker placement and Figure 13 for the assessment of heel marker position.

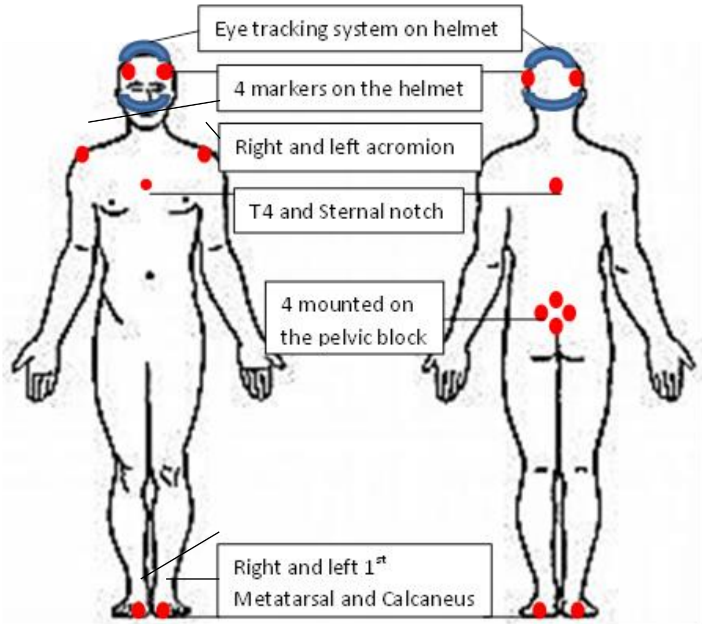


Figure 12 – Whole body marker placement.

Figure 13 – Heel marker placement.

The distribution of markers in this format allowed them to be identified by the Coda system at any point of the turn. The use of more than one marker for each body segment enabled a continuous tracking of the segment, despite loss of sensor identification by the Coda system, by the use of the rigid body software or vector analysis (refer to Section 5.9.3 (data extraction Coda) for more details). This also ensured that not all points needed to be identified, for example the anterior portion of the pelvis as well as the posterior was not necessary as the vector analysis and segment position is a combined reading of the sensors related to that segment, not isolated marker movement.

5.8.2.2 Eye tracking system

To detect the movement of the eyes, the participants were required to wear a lightweight helmet with a high frequency light one-camera system called VNG Ulmer (SYNAPSIS SA, Marseille, France - Visio Goggle) mounted on the front but below the eye line, so not to impede the participants' vision when looking forward. The helmet had adjustable straps to optimise its fit to their head (see Figure 14) and to ensure the camera did not move during data collection. The four Coda markers on the head were also mounted on the frame of the helmet.

Figure 14 - Helmet and camera system with Coda markers.

5.8.3 Laboratory equipment

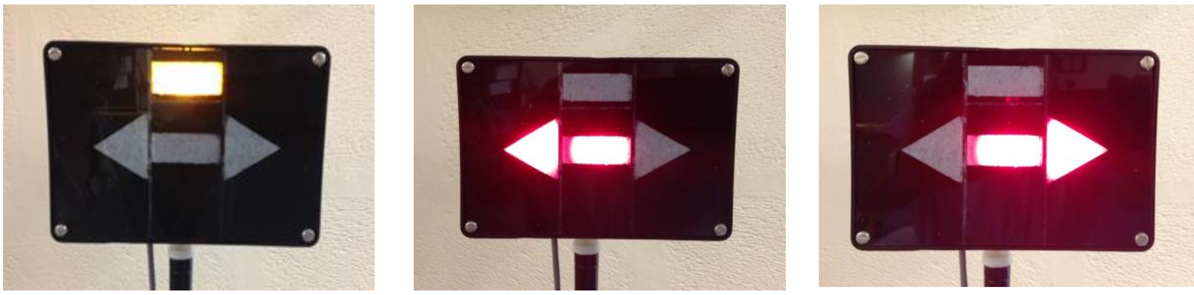
Appendix 11 shows the setup of the Gait laboratory in a pictorial view. This includes Coda movement analysis system, VNG eye tracking system, light initiation system, force plate, video camera, safety belt, chair and ball.

5.8.3.1 Force plate

A Kistler force plate (model No 9281B, Kistler instrumente AG, Eulachstrasse 22, 8408 Winterthur, Switzerland) was positioned in the middle of the room, set into the floor. Participants were asked to turn around on this force plate. The force plate produced data on the centre of pressure before and during the turn, which was later used in comparison to the position of the feet.

5.8.3.2 Light initiation system

An LED light in a light box was mounted on a stand directly in front of the participant (Figure 15). The light box was controlled by the experimental officer via a switch system that was also connected to the Coda system computer. The switch system (Figure 16) had the combinations of arrow directions (central light, left arrow and right arrow), which could be pre-set by the experimental officer. When the switch button was pressed, an orange ‘hold light’ went off and was simultaneously replaced by a red arrow (left or right), which indicated when and which direction the participant was to turn.



Central ‘Hold light’ Left turn Right turn

Figure 15 – Light box indicating direction to turn.

Directly opposite this light (180 degrees) was a red circular LED light mounted on a stand, as a reference point for participants to turn towards. All lights were set at eye level for the participant.

In addition to the activation of the lights, the switch button system also placed a marker point on the Coda angular displacement graph of each body segment. This was later used as the reference point to determine onset latency of each body segment. The marker point indicated the time of the light cue which could be compared to the point of initiation of each segment.

Figure 16 – Light box switch system controlling the cue to turn.

5.8.3.3 Video camera (SS180)

A video camera was placed on a tripod below the circular red light for data collection during the SS180 as standardised by Stack and Ashburn (2005). This was set up to only include the participant from the shoulders down to the feet to reduce the possibility of identification and was analysed at a later date by the researcher.

5.8.3.4 Calibration and synchronisation of equipment

5.8.3.4.1 Defining Coda X, Y and Z axis in the laboratory

Using Coda software routine, the X, Y and Z axis of the Gait laboratory were aligned with the force plate. At the start of each recording, the origin of the room axis was set at the centre of the force plate using a Coda marker.

5.8.3.4.2 Calibration of eye tracking system

Calibration of the VNG and Coda systems followed the protocol previously used for 3-dimensional movement analysis of PwP in the laboratory (Ashburn et al. 2010; Verheyden et al. 2012; Ashburn et al. 2014a). Software supplied with Coda permitted data on timing, position and angle of each of the LED markers throughout the turn to be collected. Software from the eye tracking camera allowed both lateral and vertical tracking of both eyes to be collected. This was achieved by detection of the centre of the pupil by the VNG camera and tracking the movement of both eyes to provide a single displacement output. In this study the lateral displacement of the eyes was considered most important in a turn, however in order to compare this data with that produced from Coda, the VNG eye tracking system needed to be calibrated to change the lateral displacement data into angular displacement during the turn. The calibration of the two systems was achieved prior to turning by the participants following a moving dot with their eyes on a screen placed two meters in front of them. The set distance of the screen, and the dot moving on the screen allowed calculation of the angle that the eyes were tracking. This could then be used to calculate the angle of the eye movement during a turn and the onset latency of eye movement. This method has been used in previous studies of eye tracking in PwP in the laboratory (Verheyden et al. 2012).

5.8.3.4.3 Synchronisation of the Coda and VNG eye tracking systems

The Coda and eye tracking system operated on separate computer systems and therefore synchronisation was required at the point of data recording. The point that the light cue was given was recorded on the Coda system by a marker signal (as previously described in Section 5.8.3.2), however it is not possible to put this marker on the VNG eye tracking system. In order to synchronise the two systems a purpose built signal button was built on the keyboard of the VNG eye tracking system, which also placed a signal on the Coda system. Pressing this button twice at the beginning of the recording produced two marks on both the systems (blue lines on Figure 17). The midpoint between the two marks was taken as a reference to synchronise the two systems (green dotted line on Figure 17). Taking the midpoint enabled the internal computer error of placing a mark on the two screens to be halved. This allowed exact comparisons to be drawn between the data from both systems. The synchronisation also allowed the point of the light cue to be placed on the VNG eye tracking system (red line on Figure 17) and thus initiation of the eyes could be calculated from the light cue.

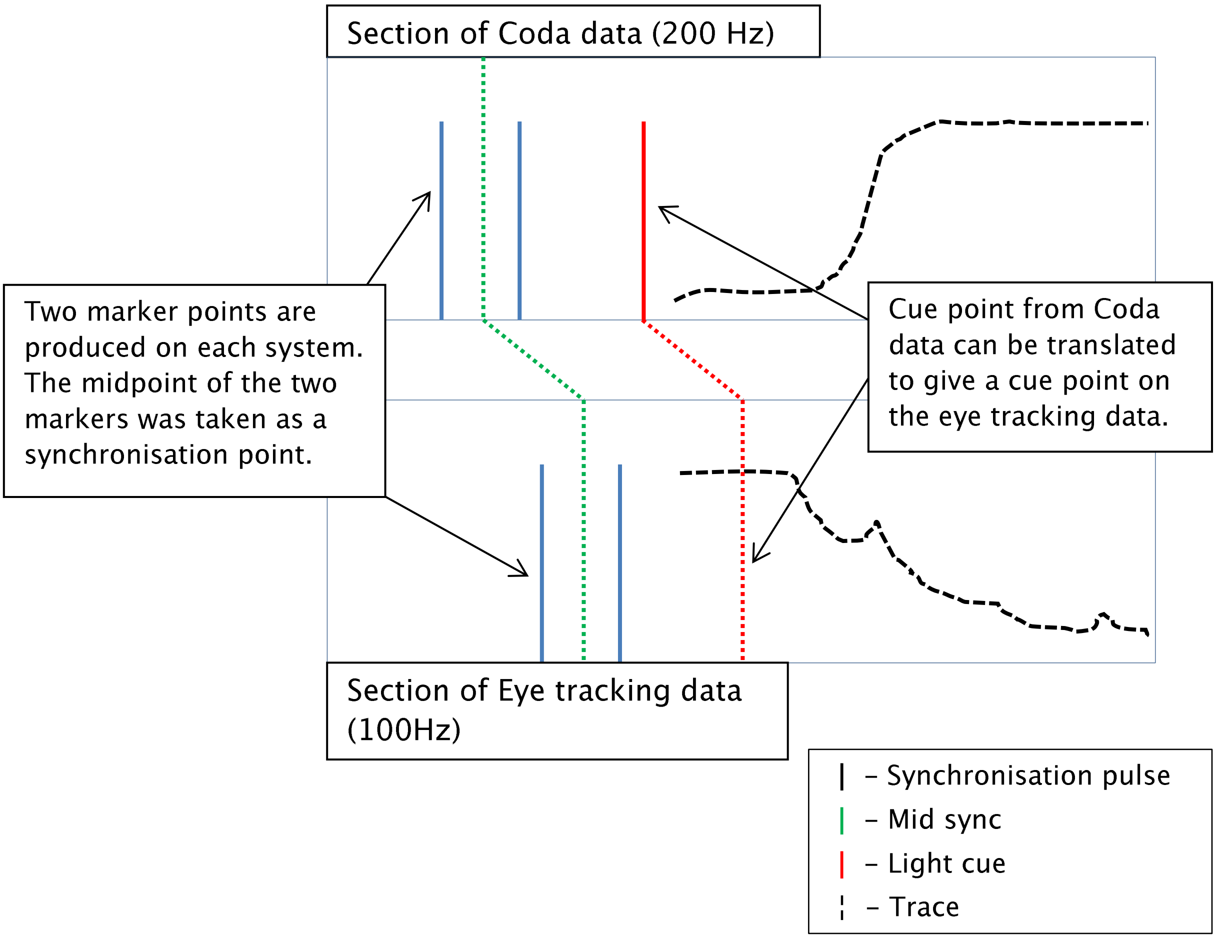


Figure 17 – Representation of the synchronisation process between the Coda systems and the VNG eye tracking systems.

5.9 Data collection

Participants were approached and selected as previously outlined (see Section 5.5).

The researcher gave all instructions and coordinated data collection. The experimental officer operated the computer programs and provided technical support for the set-up of the Gait laboratory. All participants followed the same procedure at both pre- and post-intervention/control periods.

Participants were tested during the time of day that they felt was suitable for them, which was replicated for the post-assessment to reduce the impact of variable medication cycles and diurnal variation plus to ensure optimum mobility (Ashburn et al. 2014a).

5.9.1 Demographic data collection

Once selected and consented (as detailed in Section 5.5), a basic demographic assessment took place (see Appendix 12). This was to enable further analysis of data if anomalous results were found and to ensure that the effect of medication or diurnal variation in symptoms was considered.

This included:

1. Age.
2. Hand dominance (assessed as writing hand)
3. Foot dominance (assessed by asking the participant to kick a small inflatable ball rolled towards them, whilst seated. This was repeated three times and the foot most often used depicted their foot dominance).
4. Any other relevant past medical history (for safety reasons in the laboratory).
5. The side of initial onset of their Parkinson's disease.
6. Year of diagnosis of PD.
7. The symptoms they currently experience from their Parkinson's and how long they have had these symptoms.
8. Their use of anti-Parkinsonian medication – which medication they take, its effect and when it is at its optimum effect.
9. Whether their present symptom presentation (on that day) was typical for them.

5.9.2 Data collection for differing types of turn

Whole body coordination during turning was assessed through 12 on-the-spot turns at a self-selected pace. The selection of 180 degree turns was based on: 1) the high frequency of these turns found in activities of daily living (Glaister et al. 2007); 2) the findings that the greatest difficulty in turning for PwP is seen at 120 degrees (Bhatt et al. 2013), but the need to allow for flexibility of start position; 3) the significant effect of turn type found in 180 degrees, but lost in 270 and 360 degree turns (Earhart et al. 2007); and 4) the need for comparisons to the clinical measure of turning from the SS180.

The use of on-the-spot turns (rather than walking turns) was made due to: 1) many of the falls among PwP occurring whilst making such turns (Akram et al. 2013a) owing to its common use in activities of daily living, such as moving in tight spaces; and 2) the practicalities of gaining data from the force plate.

The use of turns at a self-selected pace removed the influence of a cue for speed influencing turning performance (Nieuwboer et al. 2009). It is also more likely that turns in the functional setting are at a self-selected pace.

Turns were assessed in both preferred and un-preferred directions. This was in response to the findings that turns to an un-preferred direction show greater difficulty than those preferred (Stack et al. 2002a). Turn preference was determined by three turn trials as detailed (Section 5.9.3). This method was chosen due to its likelihood of being an accurate representation of individual turn preference, irrespective of perceived directional preference (self-reported) or in relation to side of disease onset, both of which have been used in previous studies with contradicting results (Ashburn et al. 2014a and Nieuwboer et al. 2007 respectively).

Predicted and unpredicted turn direction was also assessed. This was included to assess the possible influence of pre-motor planning in predicted turns over the automaticity of basal ganglia control in unpredicted turns, thought to be altered in PwP (Huxham et al. 2008a). Differences between predicted and un-predicted turning were also shown in the sub-analysis of the feasibility study (unreported data).

5.9.3 Data collection for 3-dimensional movement analysis

At each visit participants were shown around the Gait laboratory and the data collection procedure explained. Foot dominance was assessed as detailed above.

Participants were then fitted with the equipment as described (Section 5.8.2) and given an opportunity to walk, turn and move in order to familiarise themselves with the feeling of wearing the equipment. Participants then completed the VNG eye tracking system calibration as detailed above (Section 5.8.3.4.2) and subsequently data collection began.

Participants were asked to stand on the force plate in the middle of the Gait laboratory facing the light box. In accordance with the risk assessment, the researcher stood in close proximity to the participant to assist them with maintaining balance if necessary. The researcher gave the participant a number of standardised verbal instructions before each turn, as detailed below.

For the practice turns:

> *" There is a light behind you on the other side of the room, when the orange light in front of you changes to red, please turn around to face the light and stop"*

This was repeated three times and provided an indication of which direction they preferred to turn towards. This also gave the experimental officer an opportunity to check that all equipment was operational.

Participants then received 12 standardised verbal commands from the randomised list allocated for their participant number. This included three predicted turns to their left and three to their right and three unpredicted turns to their left and three to their right. Appreciation of the preferred turn direction, allowed the direction 'left or right' to be changed to 'preferred or un-preferred' direction during subsequent analysis. Three turns were therefore completed for each turn type (predicted/preferred, predicted/un-preferred, un-predicted/preferred and un-predicted/un-preferred). The order of turns was randomised for each participant by the experimental officer using a pre-

prepared balanced randomised list. The combinations of turns are shown in Figure 18.

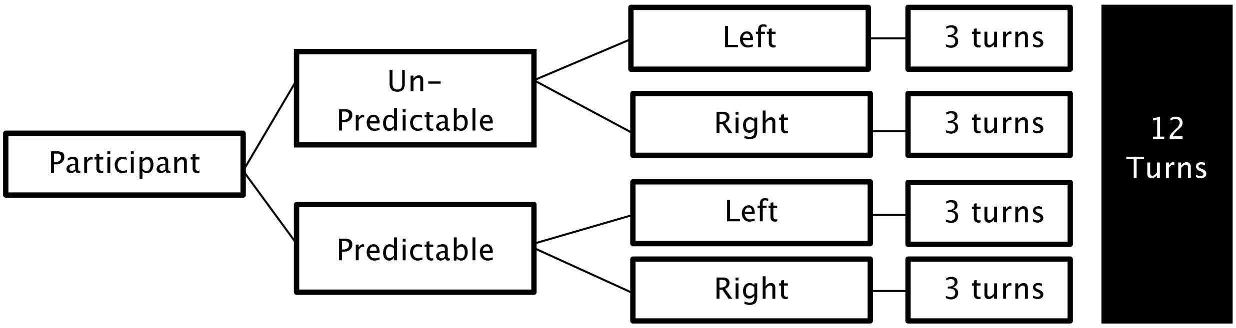


Figure 18 – The 12 turns completed by all participants in a random order (as depicted by the balanced randomisation for each assessment session).

Instructions for each turn were read from the script below:

For predicted turns:

> *"Please look at the light in front of you, when the arrow pointing to the left/right comes up, please turn to the left/right, to face the light behind you"*

For unpredicted turns:

> *"Please look at the light in front of you, I am not going to tell you the direction to turn, but when the arrow lights up, please turn in the direction of the arrow to face the light behind you"*

Whilst the data collection was taking place, the experimental officer was watching on the computer screen to check that all equipment was recording. The researcher was watching that the participant did not step off the force plate before the first foot movement. If either of these occurred the turn would need to be repeated again at the end of the sequence. Once completed, the VNG eye tracking system and Coda sensors were removed from the participant and the SS180 completed.

5.9.4 Data collection for the SS180

The SS180 protocol was explained to the participant as described by Stack and Ashburn (2005). This clinical measure of turning was used due to its validity and reliability at detecting turning performance in PwP (Stack & Ashburn 2005).

Standing on the force plate, facing the light box, participants were instructed to walk towards the camera behind them. A standardised verbal command was given as: *"There is a video camera behind you that I would like you to walk towards when I say…When you are ready, please walk towards the camera".*

The direction in which the participants turned was recorded on the SS180 data collection sheet (Appendix 13). The test was then repeated, asking the participant to turn in the opposite direction from the previous time.

This concluded the assessment procedure. All equipment was cleaned using antibacterial wipes after use with each participant.

5.9.5 Data collection for the Berg balance scale

The Berg balance scale (BBS) (Appendix 14) was used as a recommended measure of balance performance in PwP (Keus et al. 2014). It has been found to be a reliable measure of balance in PwP (Leddy et al. 2011). Standardised assessment followed the instructions as detailed in the European guidelines for Physiotherapy (Keus et al. 2014). This was completed in the participants own homes as part of the battery of assessments for the RfPB study. Permission to use the data in this study was granted by the principle investigator of the RfPB study.

5.10 Data extraction

The results from the feasibility study (Appendix 3), alongside the literature (Chapter 4) supported the collaboration of clinical outcome measures (SS180 and BBS) alongside laboratory based measures ('body segment latency', 'body segment rotation' and 'ground reaction forces'). The variables presented in Table 8 were selected for this study:

Measure	Variable	Body Segment	Output	Data collection method
Latency	Body segment latency.	Eyes Head Shoulders Thorax Pelvis Feet (R/L)	Time (seconds) delay from cue* to initiation of movement for each segment.	Kinematic – Coda 3-dimensional movement analysis and VNG eye tracking system from cue to initiation of movement.
	Total time of turn.	Whole body	Time (seconds) from initiation to shoulder stop.	Kinematic – Coda 3-dimensional movement analysis of shoulders.
Rotation	Change in body segment angle.	Head Shoulders Thorax Pelvis	Angular change (degrees) from initiation to FFM for each segment.	Kinematic – Coda 3-dimensional movement analysis from cue to FFM.
Weight transfer	Medial/lateral weight transference.	Whole body	Distance of POA from right to left as a % of stance (determined by heel/toe markers) from cue to FFM.	Kinematic – Force plate analysis from cue to FFM.
	Anterior/posterior weight transference.		Distance of POA in the anterior/posterior direction as a % of stance from the cue to FFM (determined by heel/toe markers).	
	Total weight transference.		Total distance of POA (mm) in medial/lateral direction from cue to FFM.	
	Position of weight (anterior/posterior)		Weight distributed in either the anterior or posterior position of the base of support at FFM.	

	Stance width.		Length (mm) between the mid-point of the right and left foot.	Kinematic – Coda 3-dimensional movement analysis of foot markers.
Clinical	SS180 – Time.	Whole body	Time from start of turn to first forward step (sec).	Clinical measure with video analysis.
	SS180 – Number of footsteps.		Number of steps to turn (n).	
	SS180 – Type of turn.		Marked as pivotal, towards, lateral, incremental or delayed.	
	SS180 – Quality of turn.		Rated on independence, clearance, stability, continuity and posture (rated/5).	
	Berg balance scale.		Rating of 1-4 on14 balance tasks. Total score (rated/56).	Clinical measure as part of the RfPB study.
	Demographics	N/A	Age Preferred turn direction Leg dominance Hand dominance H&Y score Years since diagnosis	Participant pre-assessment interview.

* A ‘cue’ in this instance is the point at which the light in front of the participant is illuminated, giving the signal to turn

FFM – First foot movement   POA – Point of application

Table 8 – Table of measures.

5.10.1 Data extraction for 3-dimensional movement analysis.

Data were captured and extracted as angular displacement graphs in both the eye tracking and Coda systems, with inertial latencies of each system being accommodated for during the extraction process (Ashburn et al. 2014a; Ashburn et al. 2010). Data was captured at 200Hz from Coda and 100Hz from the eye tracking system. This meant that the greatest potential difference in time due to the different sampling rates was 0.005seconds (s) (0.01s sampling at 100Hz – 0.005s sampling at 200Hz = 0.005s). Therefore the potential error as a result of different sampling frequencies is less than the difference looked and considered in analysis.

5.10.1.1 VNG eye-tracking system

From the time of the two synchronised pulses, the start of eye movement was recorded from the graph using a calibrated scale to measure to the nearest one hundredth of a second (see Figure 19). Therefore the potential error of extracting the exact point of initiation was considered to be +/- one sample point (0.01s).

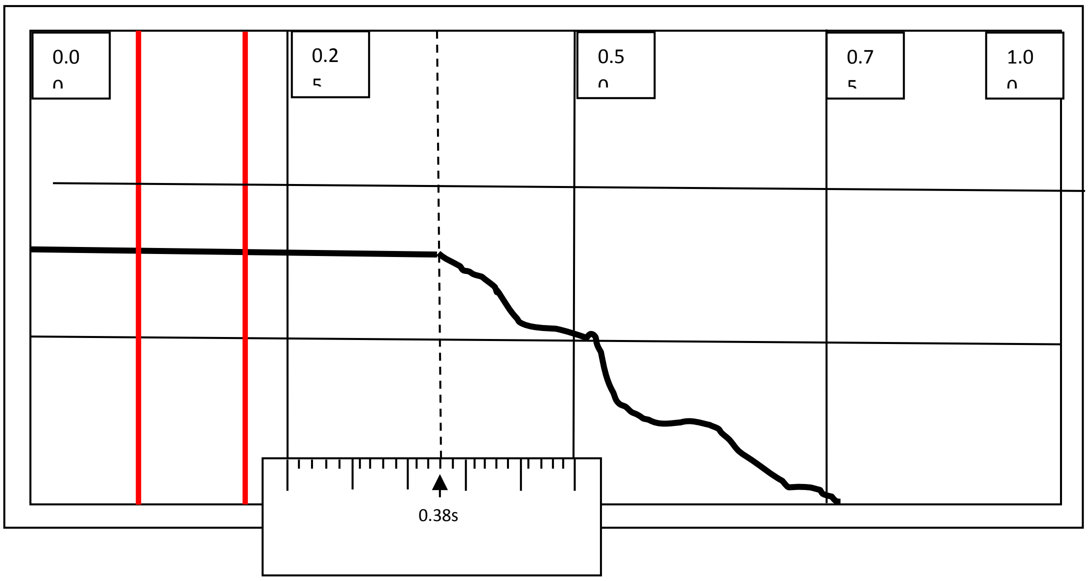


Figure 19 – Extraction process for eye tracking data.

The direction of the first eye movement was defined as the point at which the trace deviated from resting and was determined visually. If this did not correspond with the direction of the related turn, then the first point of eye movement in the direction of the turn was recorded. Filtering of blinks was not undertaken as this presents a potential to create a time shift in the initiation point. Elimination of blinks was however achieved manually by the researcher's interaction with the data for extraction of all points and appropriately identifying initiation of eye movement rather than a blink.

5.10.1.2 Coda movement analysis system

5.10.1.2.1 Synchronisation and cue point extraction

The time of the two synchronised pulses was extracted from the Coda motion output graphs by moving the cursor at intervals of 0.05 seconds and recording the time point. The time when the arrow indicating which way to turn was illuminated, giving a cue to the participant to turn, was also recorded in this way.

5.10.1.2.2 Initiation angle and time of each segment

The angular displacements of each segment throughout the turn were represented both individually and collectively in a graph in the Coda motion software. The point at which angular displacement occurred in all Coda sensors (four head, two shoulder, two thorax, four pelvis, two left and two right foot) was selected from the collaborative graph, including one second before and one second after movement, and extracted at a sampling rate of 200 Hz to a programmed Excel sheet. Using the 'Rigid body software' programme as part of the Coda software, alongside vector programming in excel, the angle of each segment (head, shoulders, thorax, pelvis and left and right foot) was represented. This uses all sensors available to give a single figure for each segment and thus reducing the possibility of erroneous data as all sensors are balanced by the others on that particular segment (four for the pelvis and head, and two for the shoulders, thorax, left and right foot). The initiation (latency) point of each segment was determined as the point where each segments rotational movement exceeded plus or minus three standard deviations of the mean of the previous 0.5 second of data for that segment. This method of extraction followed that used previously in the laboratory for this purpose (Verheyden et al. 2012; Ashburn et al. 2014a; Ashburn et al. 2010) and that used in the feasibility study. Using the movement graphs created in Excel, this point was visually verified as the correct point of initiation. The angle and time at initiation was extracted in this way for each segment for each turn.

5.10.1.2.3 Angular displacement of each segment

The time of the first foot movement (FFM) (either left or right) for each turn was used as a fixed point from which to extract the angle of all other segments. This method was chosen in order to extract data from the same point of the turn for each participant, regardless of the number of steps or time they took to complete the turn plus to avoid the influence of an external cue regulating turn angle or speed. This method also enabled a calculation of 'wind-up' (amount of rotation of each segment) of body segments from start to release of the foot. The identification of the FFM as a point of reference has been used before within measures of turning in PwP (Hong et al. 2009; Mak et al. 2008).

The point of FFM was determined as the point where foot movement exceeded plus or minus three standard deviations of the mean of the previous 0.5 second of data (Verheyden et al. 2012; Ashburn et al 2014). Using the movement graphs created in Excel, this point was visually verified. All data were extracted from the light cue up to the point of FFM. The difference between the FFM angle and the initiation angle was used as a measure of angular displacement of each segment for this time frame of the turn cycle.

5.10.1.2.4 Total time of turn

The total time of the turn was determined by the movement of the shoulders. The difference between the time at the point of initiation (latency) to the time at the last point of movement of the shoulders was used as a measure of the time taken to complete the turn. The last movement of the shoulders was determined as the point where movement of the shoulders did not exceed plus or minus three standard deviations from the mean of the following 0.5 seconds of data (Ahmad 2012; Ashburn et al. 2014a; Verheyden et al. 2012).

The use of the shoulder movement to determine the total time of the turn was selected from clinical experience as it is considered the body segment most likely to reflect the position of the whole body during the turn. The head or feet were most likely to stop at a different direction to the whole body owing to the greater degrees of independent movement, the pelvis is most likely to show delay from the cue, and the thorax may not provide a significant horizontal plane translation to measure stop time.

In addition to these clinical considerations, the feasibility study for these measures demonstrated the shoulders to be the first segment to move in PwP. Therefore recording the start of the turn by shoulder movement using 3-dimensional movement analyses is most likely to reflect the initial movement observed during analysis of the SS180 clinical test.

5.10.1.2.5 Force plate

The measure of ground reaction forces has previously been used in walking turns in PwP (Mak et al. 2008; Song et al. 2012), although using different variables and methods of extraction due to an appreciation of the position of the feet in this study. Ground reaction forces, segment latency and segment angular rotation have not previously been considered together in turning in PwP. The functional relevance of such interaction warrants the inclusion of ground reaction forces in this study and all measures included were found to be appropriate during the feasibly study (Appendix 3).

Determining foot positioning

Data from the point of application in the X and Y axis were extracted from the Coda motion system and imported into Excel as detailed in Section 5.10.1. Using the data from the point of the cue to the FFM, Excel was programed to display a graph with the position of the anterior and posterior foot markers of both feet and the displacement of the force. The foot positioning was determined medial/laterally and anterior/posteriorly. The mid-point of each foot was determined as the central point between the anterior Coda sensor and the posterior Coda sensor. The axis line of the mid-point between this point on the right and left foot determined the anterior/posterior divide of the foot positioning. The mid-point between the right and left toe sensors and heel sensors with an axis point between these two determined the medial/lateral divide of the foot position. The bisection point of the two axes determined the mid-point of the foot position. The position of the point of application of force at the start of the turn and the movement up to the point of FFM with relation to the foot position was recorded. This was used to determine the behaviour of weight bearing forces during this period (see Figure 20).

Medial/lateral weight transference

A measure of the greatest width of medial/lateral weight shift relative to the foot positioning was determined. This was achieved by extracting the maximum and minimum translation point of the point of application in the medial/lateral direction from the force plate, giving an absolute figure for displacement. Using the total width of the foot positioning as previously determined by the midpoints of the foot, this absolute figure was converted into a percentage of the foot positioning for each participant. This allowed comparisons to be made between participants without the need to standardise foot positions and thus influence their preferred stance position.

A measure of the total weight transference over the period of the cue being given up to the FFM was also determined. This was achieved by a measure of the total translation of the point of application over the period, from the force plate in millimetres (mm).

Anterior/posterior weight transference

The anterior/posterior translation of weight was determined by the position of the point of application at the point of FFM (being either anterior or posterior of the midpoint of the weight bearing foot). This was then reported as percentage of the foot position using the same method as that of medial/lateral transference.

Stance width

The total stance width was determined as the length in mm from the mid-point of each foot.

An example of the method used to determine the behaviour of weight bearing forces is shown in Figure 20.

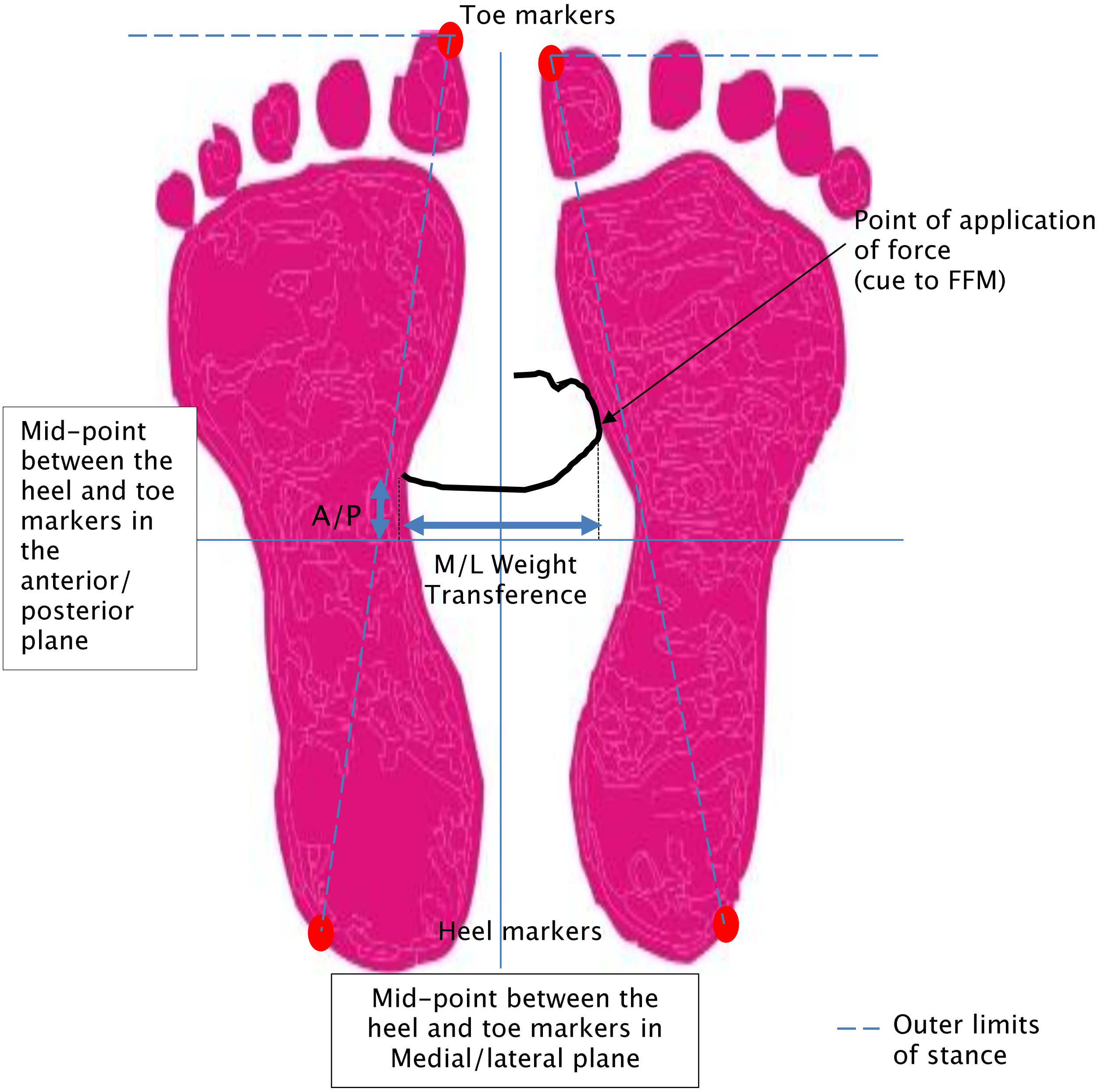


Figure 20 – Point of application (as recorded from the force plate) and extraction of medial/lateral (M/L) and anterior/posterior (A/P) weight transference in relation to the foot position (shown by a dashed line).

Weight bearing position

The position of the point of application at the FFM with reference to the midpoint of the position of the feet determined weight bearing position as either anterior or posterior.

5.10.1.2.6 SS180 data extraction

The SS180 turn test has been proven as reliable and comparable to kinematic measures of a turn in PwP (Stack & Ashburn 2005; Stack et al. 2002b). Data extraction followed the protocol as described by Stack and Ashburn (2005). Training was received from Dr Stack to the ensure data extraction process was as intended by the assessment protocol.

The video clips of each participant completing the turning assessment were watched as many times as was required to obtain all the data. This includes - the total time and number of steps to complete the turn and the type and quality of turn as depicted by five descriptions. This was repeated for both the direction specified and unspecified turns for each participant and recorded on the assessment sheet (see Appendix 13).

5.10.1.2.7 Berg balance scale data extraction

The total score for the pre- and post- assessment BBS was provided by the research team for the RfPB study.

5.11 Data Analysis

5.11.1 Reliability testing

For all measurements (apart from the BBS and SS180) (see Table 8) intra- and inter-rater reliability was assessed using the intraclass correlation co-efficient. At completion of the initial extraction by the researcher, thirty points of data extraction (5%) for each measure were randomly selected and extracted by the experimental officer to allow analysis of the inter-rater reliability. There was a three month time period from the start of extraction to the selection of the random sample as this was the time frame required to extract all the data and therefore make all available for re-sampling at random. The randomly selected data points were also re-extracted by the researcher to enable intra-rater reliability analysis. Thirty data points (5%) was considered sufficient in order to complete an agreement analysis using intra- class correlation coefficients and enable intra-rater and inter-rater reliability testing respectively (agreed through discussion with previous researchers with experience in 3-dimensional movement analysis - Dr Verheyden).

5.11.2 Conversion of data from left and right.

All raw data were extracted using the turn directions of left or right. Using an SPSS Syntax code written for this data by the researcher, data were organised and re-selected based on participant's preferred turn direction to give the four types of turn as predicted/preferred (PPr), predicted/un-preferred (PUPr), un-predicted/preferred (UPPr), un-predicted/un-preferred (UPUPr).

Conversion of foot data was also achieved using formula code written for this data in Excel (with assistance from the experimental officer), to provide first and second foot data rather than left and right.

5.11.3 Variables extracted for analysis

After completion of the data extraction, the following variables were available for analysis:

Demographic measures	Age Disease severity (H&Y score) Foot and hand dominance Preferred turn direction.
Kinematic measures	Body segment latency Change in body segment angle Total weight transfer M/L weight transference A/P weight transfer Stance Total turn time Weight bearing position
Clinical measures	Turn time Step number Step quality Turn Type Total BBS Score

Table 9 – Variables extracted.

5.11.4 Methods of analysis

The impact of dance on the measures of turning in PwP was analysed, with an explorative purpose as it is not known which variables are influenced by dance in PwP at this stage.

5.11.4.1 Descriptive statistics:

For all variables obtained by 3-dimensional movement analysis, each type of turn (PPr, PUPr, UPPr, UPUPr) was completed three times by each participant. Using a SPSS syntax code written for this data, the mean of the three turns for each type of turn was calculated for each participant and this mean was used to calculate the group means, median, standard deviation (SD) and standard error (SE). Weight bearing position was extracted as nominal data (either anterior or posterior) and calculated as a percentage of the group with their weight in an anterior or posterior position at the FFM.

Analysis of SS180 data were completed as detailed by Stack and Ashburn (2005), providing a mean, median, SE and SD of the two turns; direction specified and direction un-specified and both turns collectively, for the variables providing ratio data (number of steps, time to turn and quality). Where data were nominal (type of turn), the frequency of each category was calculated.

Results from the BBS were provided by the RfPB study, giving a total pre-assessment and post-assessment score for each participant.

5.11.4.2 Statistical analysis on group differences.

Following detailed discussions with a medical statistician, Dr Sean Ewings, the following statistical analysis was completed.

- Independent T-test statistical analyses were used to show differences between demographic variables at pre-assessment where appropriate.
- A four-way Analysis of Variance (ANOVA) using time (pre/post), turn prediction (predicted/un-predicted) and turn preference (preferred/ un-preferred) as within participant factors, and group (dance/control) as the between participant factor was completed for each of the dependent variables providing ratio data (body segment latency, change in body segment angle, total turn time and force).
- A three-way ANOVA using time and the direction of turn (specified, unspecified and mean) as within participant factors and group as the between participant factor was completed for each the variables; number of steps, total turn time and quality from the SS180.
- A two- way ANOVA using time as a within participant factor and group as between participant factor was completed for the BBS.
- Descriptive statistics of mean, SD and SE were used to comment on the results from the ANOVA analysis.

Statistical package for the Social Science (SPSS) (Version 20) was used for all statistical analyses. The p-value for significance was set as equal as or less than 0.05, with trends of less than 0.1 also being reported.

5.11.5 Ethical approval

Ethical approval was granted from the National Research Ethics Service Committee South Central – Southampton A (2nd October 2012, Ethics ID: 12/SC/0355).

Chapter 6: Results

Results are presented with reference to the research question:

> Are the kinematic measures of body segment latency, body segment rotation and force variables during turning, and the clinical measures of the Standing start 180 degree turn test (S180) and Berg balance scale (BBS) altered after a dance intervention in PwP?

Demographic data is initially presented to describe the sample in each group (dancers and controls) at baseline. Measures of reliability across all kinematic variables are presented for discussion. Changes in the latency of each segment (eye, head, shoulder, thorax, pelvis and first and second foot) over time (pre-post assessment) are compared between the two groups using both descriptive and statistical analysis, with consideration of the type of turn (predicted/preferred, predicted/un-preferred, un-predicted/preferred and un-predicted/un-preferred). The relationship between the segments with regards to latency is also presented for discussion. The change in rotation of each segment (head, shoulders, thorax and pelvis) from the initiation of movement to the first foot movement (FFM) is presented using descriptive and statistical analysis, again with consideration of the type of turn. The changes in force variables are presented collectively across all turn types with both descriptive and statistical analysis, followed by results from the clinical measures of the SS180 and BBS.

6.1 Sample

A total of 48 of the 51 participants recruited to the RfPB study consented to taking part in the current study. The reason given by the three that did not give consent was the additional time required for the pre- and post-assessments, in addition to the time commitment of the RfPB study should they be allocated to the dance intervention (although at this point the participant had not been randomised).

After, randomisation, 27 participants were selectively recruited, with 25 completing the current study. Of the two that did not complete the study, one completed the pre-assessment, but later dropped out of the dance intervention due to medical circumstances and was therefore unavailable for post-assessment. One was excluded from this study after difficulty in completing the pre-assessment due to her cognitive ability making it difficult to follow the turning commands. The data from one participant was also excluded after review, as severe dyskinesia significantly altered their turning behaviour, causing them to adopt a unique pattern of movement that was not representative of the typical population. In total, 12 of the 36 participants who were randomly selected to receive the dance intervention from the RfPB study and 12 of the 15 allocated to the control group were selected for analysis in this study.

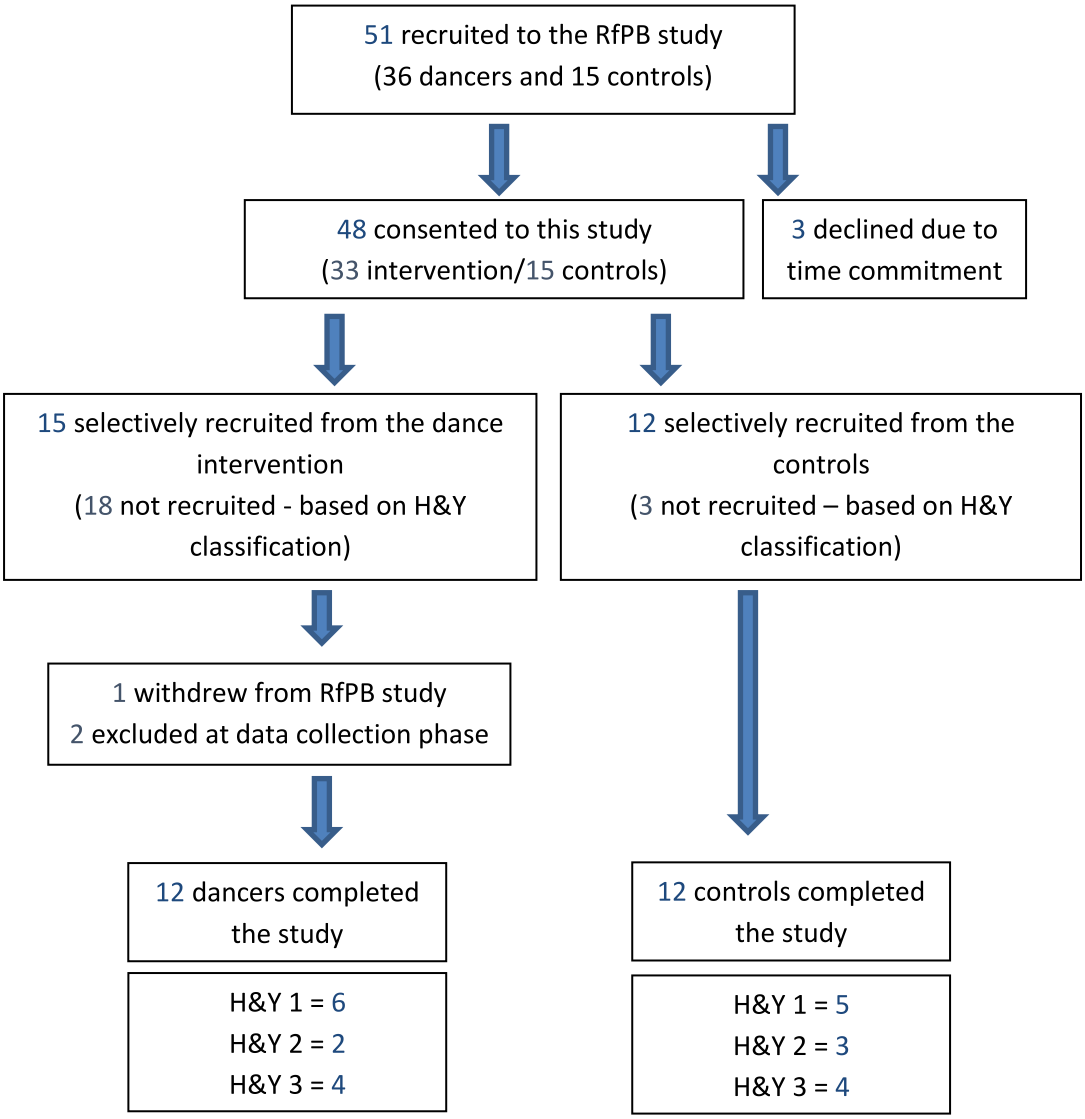


Figure 21 – Recruitment of participants.

6.2 Demographic data and pre-assessment measures

Demographic data is displayed in Table 10.

	Controls (SD)	Dancers (SD)	Statistical difference
Age	71.7 (±5.1)	73.4 (±4.9)	p = 0.283 (t = -1.102)
Years since Diagnosis	6.1 (±4.2)	5.3 (±3.9)	p = 0.662 (t = 0.444)
H&Y	1.8 (±0.9)	1.9 (±0.9)	N/A
Turn Preference	8 Right 4 Left	8 Right 4 Left	N/A
Hand dominance	11 Right 1 Left	11 Right 1 Left	N/A
Foot dominance	12 Right	11 Right 1 Left	N/A
Gender	5 Males	7 Males	N/A

H&Y = Hoehn and Yahr classification   Significant difference = p= ≤0.05

Table 10 – Mean, standard deviation (SD) and statistical difference of demographic data for controls and dancers.

The 12 participants in the control group had a mean age of 71.7 years (SD = 5.1), five were males. All were dominant in their right foot and 11 were right hand dominant and one left. Eight had a preference to turn to the right and four to the left. The mean number of years since diagnosis was 6.1 (SD = 4.2) and the mean H&Y classification was 1.8 (Range H&Y 1 = 6, 2 = 2, 3 = 4).

The 12 participants in the dance group had a mean age of 73.4 years (SD = 4.9), seven were males. Eleven were right foot and hand dominant and one left. Eight had a preference to turn to the right and four to the left. The mean number of years since diagnosis was 5.3 (SD = 3.9) and the mean H&Y classification was 1.9 (Range H&Y 1 = 5, 2 = 3, 3 = 4).

There was no significant difference found between the groups for age and duration of disease in pre-assessment demographics. Variables of disease severity (H&Y), hand, foot and turn preference and gender showed little or no substantial difference when comparing groups.

6.3 Measures of data extraction reliability

Reliability analysis showed high inter-rater (ICC 1,1) and intra-rater (ICC 3,1) reliability across all 3-dimensional variables extracted (Table 11). The variables of eye latency (VNG time) and pelvis latency (pelvis time) were the least comparable across inter- and intra-rater analysis. The starting angle of the pelvis was least comparable in intra-rater analysis.

Variable	Inter-rater reliability (ICC 1,1)		Intra-rater reliability (ICC 3,1)	
	ICC	95% CI	ICC	95% CI
VNG Sync 1	0.99	0.98-1	0.99	0.98-1
VNG Sync 2	1	1-1	0.96	0.91-0.98
VNG Time (Eye)	0.85	0.68-0.91	0.92	0.84-0.96
Coda Sync 1	1	1-1	1	1-1
Coda Sync 2	1	1-1	1	1-1
Light Cue	1	1-1	1	1-1
Head Time	1	1-1	1	1-1
Head start angle	1	1-1	1	1-1
Head FF angle	1	1-1	1	1-1
Shoulder Time	1	1-1	1	1-1
Shoulder start angle	1	1-1	1	1-1
Shoulder FF angle	1	1-1	1	1-1
Thorax Time	1	1-1	1	1-1
Thorax start angle	1	1-1	1	1-1
Thorax FF angle	1	1-1	1	1-1
Pelvis Time	1	0.99-1	0.93	0.86-0.96
Pelvis start angle	1	1-1	0.87	0.76-0.93
Pelvis FF angle	1	1-1	1	1-1
Left foot time	1	1-1	1	0.99-1

Left foot start angle	1	1-1	1	1-1
Left foot FF angle	1	1-1	1	1-1
Right foot time	1	1-1	1	1-1
Right foot start angle	1	1-1	1	1-1
Right foot FF angle	1	1-1	1	1-1
Time	1	1-1	0.98	0.98-0.99
Weight transfer M/L	1	1-1	1	1-1
Weight transfer A/P	1	1-1	1	1-1
Stance	1	1-1	1	1-1
Total weight transfer	1	1-1	1	1-1
A/P position	1	1-1	1	1-1

Table 11 - The inter- and intra-rater reliability of all variables extracted by 3-dimensional movement analysis.

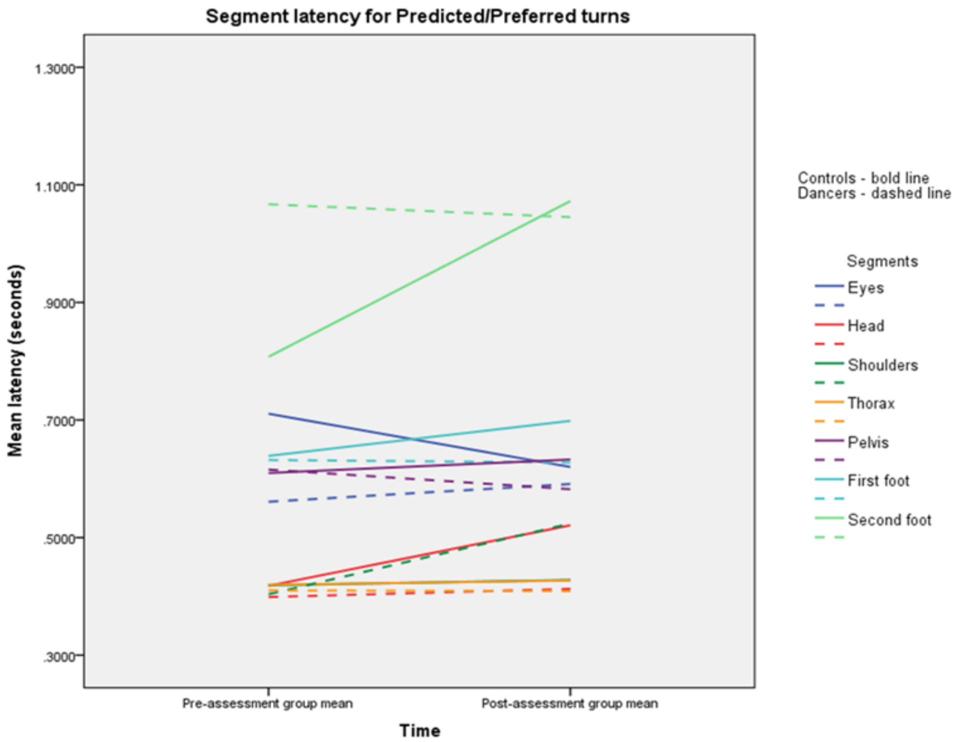
6.4 Data distribution

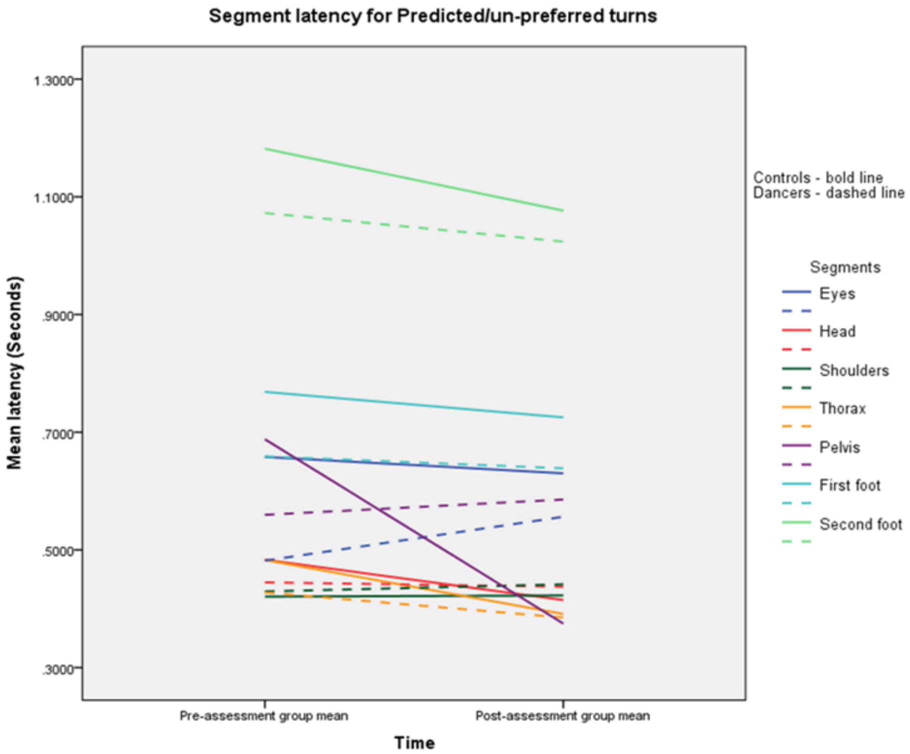
In discussion with a statistician (Dr Sean Ewings), the distributions of the outcomes were assessed visually for any gross departures from normality and none were found; therefore normality was assumed to be reasonable. In addition to this ANOVA is generally robust to departures from non-normality (Schmider et al. 2010). However there was evidence of non-normality in un-predicted/un-preferred segment rotation data across all segments and so results from this data set are treated with caution. All other assumptions of statistical tests used were met for all other data sets.

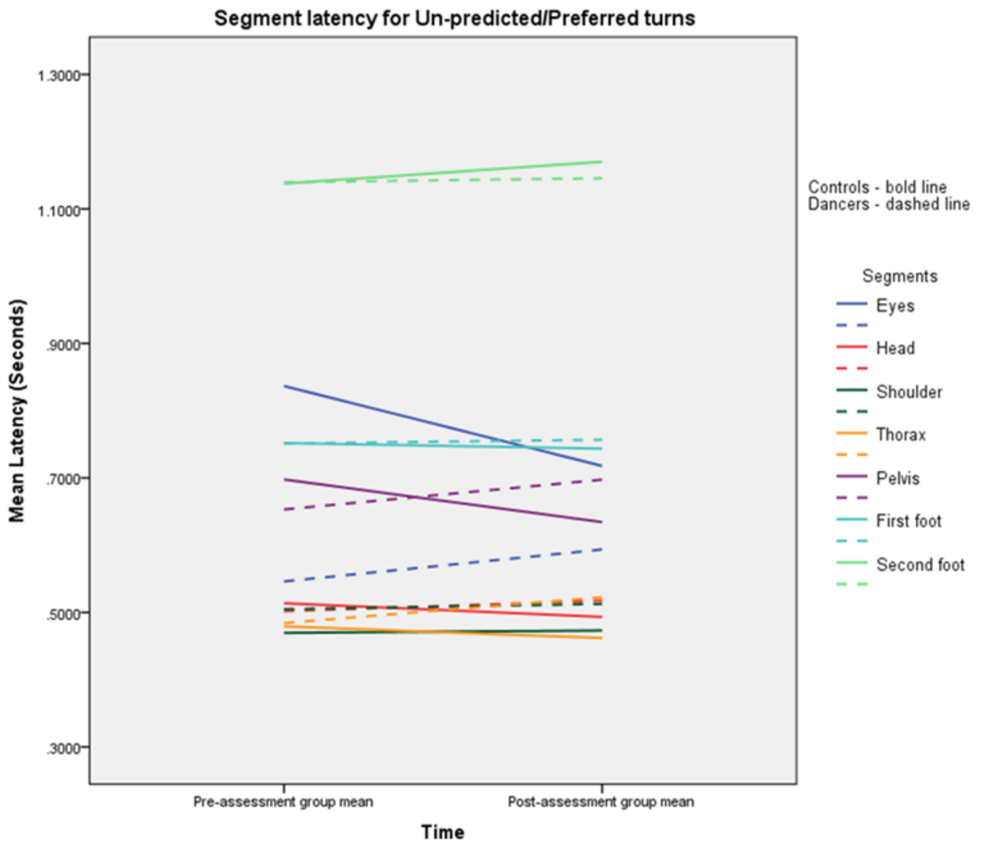
6.5 Segment latency

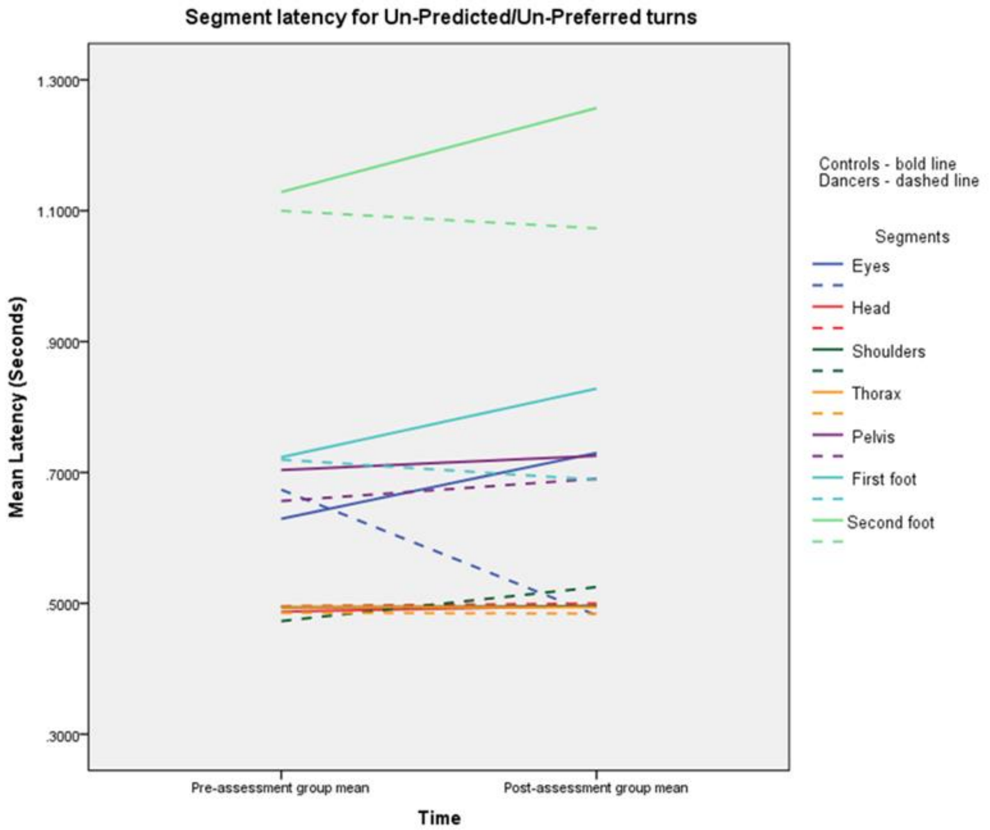
Descriptive statistics for latency (time delay from light cue to initiation of movement) of the eyes, head, shoulders, thorax, pelvis, first and second foot were calculated for controls and dancers in each type of turn (predicted/preferred, predicted/un-preferred, un-predicted/preferred, un-predicted/un-preferred). Data for mean latency of all segments comparing controls and dancers at pre-assessment and post-assessment in all turn types are displayed in Appendix 15 and visualised in Figure 22.

Figure 22 - Graphs to show the mean latency of all segments comparing controls and dancers at pre- assessment and post-assessment in all turn types.






Segment latency for Un-predicted/Preferred turns
1.3000
1.1000
.9000
.7000
.5000
.3000
Mean Latency (Seconds)
Pre-assessment group mean
Post-assessment group mean
Time
Controls - bold line
Dancers - dashed line
Segments
Eyes
Head
Shoulder
Thorax
Pelvis
First foot
Second foot


Segment latency for Un-Predicted/Un-Preferred turns
1.3000
1.1000
.9000
.7000
.5000
.3000
Mean Latency (Seconds)
Pre-assessment group mean
Post-assessment group mean
Time
Controls - bold line
Dancers - dashed line
Segments
Eyes
Head
Shoulders
Thorax
Pelvis
First foot
Second foot

Latency data were analysed using a four-way Analysis of variance (ANOVA) for each segment with the within participant factors of time (pre/post), preference (preferred/un-preferred) and prediction (predicted/un-predicted), and a between participant factor of group (controls/dancers). A significant four-way interaction was found for head latency ($F(1,22) = 8.372$, $p = 0.008$).

Review of the descriptive statistics across the four turn types suggests the four-way ANOVA interaction in head latency is greatest in control participants, in the predicted/preferred and predicted/un-preferred direction, with a 24.6% slower latency and 13% faster latency respectively between pre- and post-assessment scores. The direction of effect on the mean difference in both turn directions remains after consideration of the limits of the SE (mean difference ± (1.96 x SE)), indicating a true change in the mean that is representative of the population sampled (Table 12).

Changes in the dance participants and other turn directions were un-remarkable.

A four-way ANOVA interaction was also found for pelvis latency, although this did not reach significance ($F(1,22) = 3.452$, $p = 0.077$). Descriptive statistics suggest this interaction is greatest in control participants in the predicted/un-preferred direction with a 45.5% faster latency between pre-assessment and post-assessment scores. Changes in the dance participants and other turn directions were un-remarkable (Table 13).

Four-way ANOVA interactions for the first foot ($F(1,22) = 3.827$, $p = 0.063$) and second foot ($F(1,22) = 3.346$, $p = 0.081$) latency were also found, although again these did not reach significance. Descriptive statistics suggest the greatest effect to be in un-predicted/un-preferred direction, in control participants, for both feet with a 14.5% slower latency between pre-and post-assessment scores for the first-foot movement and 11.4% slower latency in the second foot. Changes in the dance participants and other turn directions were un-remarkable (Table 14 and 15).

No significant ANOVA interactions were found for the eyes ($F(1,22) = 1.846$, $p= 0.188$), shoulder ($F(1,22) = 2.829$, $p=0.107$) or thorax ($F(1,22) = 2.022$, $p= 0.169$).

Table 12 – Mean head latency (in seconds) in controls and dancers across all types of turn.

Head Latency (seconds)	Controls					Dancers				
	Mean (SE)Pre	Mean (SE) Post	Difference	% change	SE	Mean Pre (SE)	Mean (SE) Post	Difference	% change	SE
Pred/Pref	0.418 (0.03)	0.521 (0.06)	0.103	24.6	0.052	0.399 (0.03)	0.413 (0.02)	0.014	3.5	0.033
Pred/Un-pref	0.483 (0.05)	0.415 (0.03)	-0.069	-13	0.034	0.445 (0.04)	0.437 (0.04)	-0.007	-1.6	0.039
Un-pred/Pref	0.514 (0.04)	0.493 (0.06)	-0.020	-3.9	0.037	0.502 (0.03)	0.518 (0.05)	0.016	3.2	0.048
Un-pred/Un-pref	0.487 (0.03)	0.496 (0.04)	0.009	1.8	0.032	0.496 (0.04)	0.500 (0.06)	0.004	0.8	0.055

Significant four-way interaction (Time* preference* prediction* group) p = 0.008.

Red text indicates slower latency, green text indicates faster latency. Highlighted are results of interest. SE = standard error of the difference between the pre and post assessment scores, highlighted SE results suggest the mean change is greater than that expected by random sampling (mean difference ± 1.96 * SE), the standard error of the means is shown in brackets.

Pred/Pref = predicted/preferred turn

Pred/Un-pref = predicted/un-preferred turn

Un-pred/Pref = un-predicted/preferred turn

Un-pred/Un-pref = un-predicted/un-preferred

Table 13 – Mean pelvis latency (in seconds) in controls and dancers across all types of turn.

Pelvis Latency (seconds)	Controls					Dancers				
	Mean (SE) Pre	**Mean(SE) Post**	**Difference**	**% change**	**SE**	**Mean(SE) Pre**	**Mean (SE) Post**	**Difference**	**% change**	**SE**
Pred/Pref	0.610 (0.04)	0.633 (0.04)	0.023	3.8	0.036	0.616 (0.05)	0.582 (0.03)	-0.033	-5.4	0.041
Pred/Un-pref	0.688 (0.09)	0.375 (0.24)	-0.313	-45.5	0.260	0.560 (0.04)	0.586 (0.06)	0.026	4.64	0.541
Un-pred/Pref	0.698 (0.10)	0.634 (0.04)	-0.063	-9	0.074	0.653 (0.04)	0.697 (0.06)	0.044	6.7	0.051
Un-pred/Un-pref	0.704 (0.06)	0.725 (0.05)	0.022	3.1	0.060	0.656 (0.05)	0.690 (0.06)	0.034	5.2	0.049

Trend for four-way interaction (Time* preference* prediction* group) p = 0.077.

Red text indicates slower latency, green text indicates faster latency. Highlighted are results of interest. SE = standard error of the difference between the pre and post assessment scores, the standard error of the means is shown in brackets.

Pred/Pref = predicted/preferred turn

Pred/Un-pref = predicted/un-preferred turn

Un-pred/Pref = un-predicted/preferred turn

Un-pred/Un-pref = un-predicted/un-preferred

Table 14 – Mean first foot latency (in seconds) in controls and dancers across all types of turn.

First foot latency (seconds)	Controls					Dancers				
	Mean(SE) Pre	Mean(SE) Post	Difference	% change	SE	Mean(SE) Pre	Mean (SE) Post	Difference	% change	SE
Pred/Pref	0.639 (0.02)	0.699 (0.06)	0.06	9.4	0.055	0.632 (0.04)	0.628 (0.05)	-0.004	-0.6	0.045
Pred/Un-pref	0.768 (0.12)	0.725 (0.12)	-0.043	-5.6	0.038	0.659 (0.04)	0.639 (0.06)	-0.020	3	0.058
Un-pred/Pref	0.752 (0.08)	0.743 (0.07)	-0.009	-1.2	0.027	0.751 (0.06)	0.757 (0.06)	0.006	0.8	0.04
Un-pred/Un-pref	0.723 (0.06)	0.828 (0.11)	0.105	14.5	0.081	0.720 (0.05)	0.689 (0.06)	-0.031	4.3	0.047

Trend for four-way interaction (Time* preference* prediction* group) p = 0.063.

Red text indicates slower latency, green text indicates faster latency. Highlighted are results of interest. SE = standard error of the difference between the pre and post assessment scores, the standard error of the means is shown in brackets.

Pred/Pref = predicted/preferred turn

Pred/Un-pref = predicted/un-preferred turn

Un-pred/Pref = un-predicted/preferred turn

Un-pred/Un-pref = un-predicted/un-preferred

Table 15 – Mean second foot latency (in seconds) in controls and dancers across all types of turn.

Second foot latency (seconds)	Controls					Dancers				
	Mean(SE) Pre	**Mean (SE) Post**	**Difference**	**% change**	**SE**	**Mean(SE) Pre**	**Mean(SE) Post**	**Difference**	**% change**	**SE**
Pred/Pref	1.041 (0.05)	1.072 (0.06)	0.031	3	0.056	1.067 (0.06)	1.045 (0.08)	-0.022	-2.1	0.060
Pred/Un-pref	1.182 (0.12)	1.077 (0.10)	-0.105	-8.9	0.411	1.073 (0.05)	1.024 (0.09)	-0.049	-4.6	0.073
Un-pred/Pref	1.138 (0.10)	1.170 (0.10)	0.033	2.9	0.043	1.140 (0.08)	1.146 (0.09)	0.006	0.5	0.064
Un-pred/Un-pref	1.128 (0.08)	1.257 (0.13)	0.129	11.4	0.104	1.100 (0.07)	1.073 (0.07)	-0.027	-2.5	0.064

Trend for four-way interaction (Time* preference* prediction* group) $p = 0.081$.

Red text indicates slower latency, green text indicates faster latency. Highlighted are results of interest. SE = standard error of the difference between the pre and post assessment scores, the standard error of the means is shown in brackets.

Pred/Pref = predicted/preferred turn

Pred/Un-pref = predicted/un-preferred turn

Un-pred/Pref = un-predicted/preferred turn

Un-pred/Un-pref = un-predicted/un-preferred

6.5.1 Sequencing of segments

The latency response of each segment also enables the sequence of the segments to be determined. Results across all turns are shown in Table 16 for pre- and post-assessment sequences for both groups. Considered across all segments, results show an even separation of time between each segment following dance compared to a varied separation in time of each segment in the controls. When comparing the post-assessment scores, the controls show a short delay between the thorax to shoulder (13ms) and shoulders to head (25 ms), followed by a long delay before initiation of the pelvis (111ms), pelvis to eyes (93ms) and finally the first foot (59ms). In comparison, the dancers show on average shorter but even separation between the thorax to head (17ms), head to shoulders (33ms), shoulders to eyes (55ms), eyes to pelvis (84ms) and pelvis to first foot movement (45ms). This demonstrates an absence in the dancers of the varied delays between segments seen in the controls and can be considered a measure of body segment co-ordination.

The sequences of each segment were different across groups; therefore a comparison between groups was not feasible. However, comparison of the differences between pre- and post-assessment shows the influence of the intervention on each group individually and is shown in Figure 23 below.

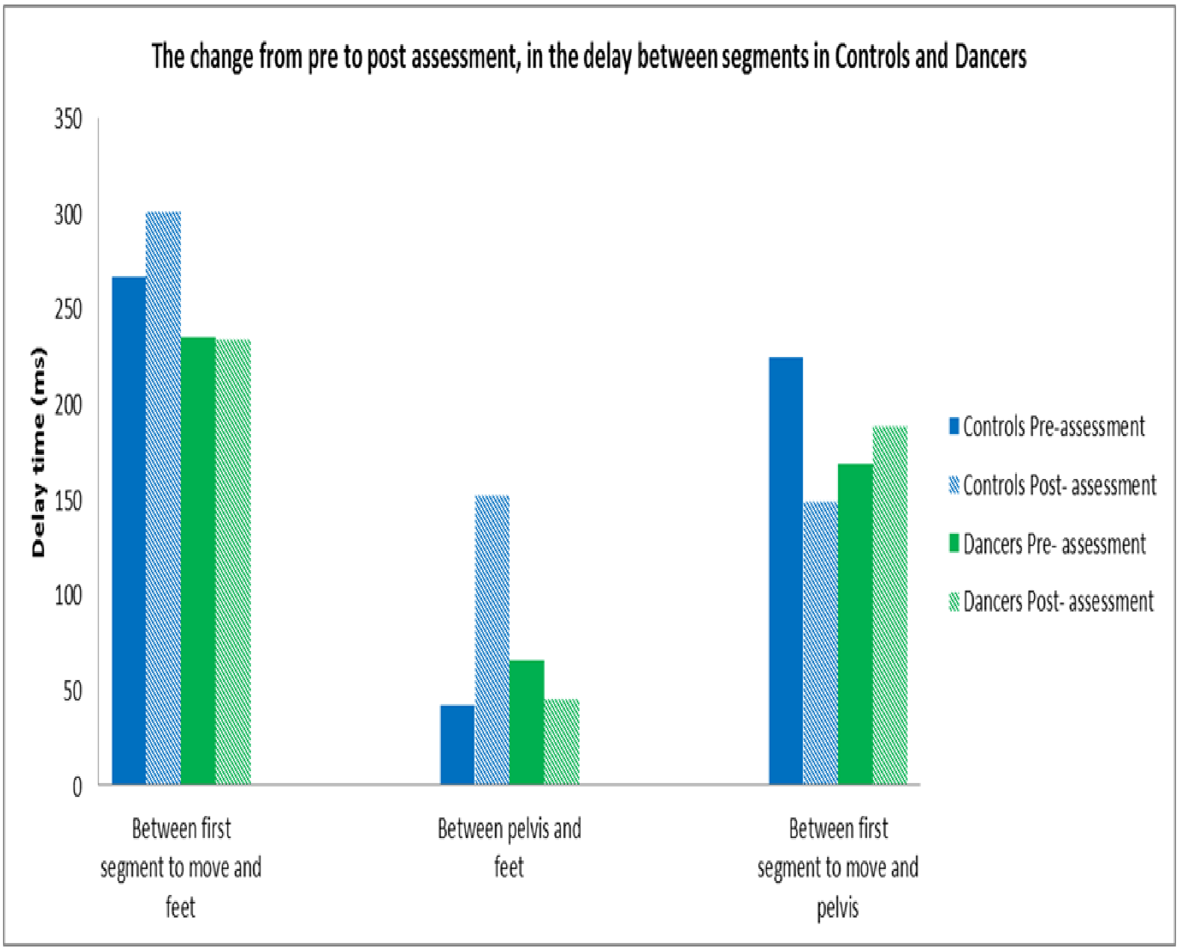


Figure 23 – The change in segment delay for controls and dancers from pre- to post-assessment.

Results shown in Figure 23 demonstrate that: 1) the change in delay between the first segment to move and the feet was less in dancers compared to controls; 2) the change in delay between the movement of the pelvis and the feet was less in dancers (a negative value meaning the delay between the movement of the pelvis and feet became less than before dance) compared to controls; 3) the change in delay between the first segment to movement and the pelvis was less in dancers compared to controls.

Controls	**Pre mean(s)**	**Shoulder** 0.451	**Thorax** 0.470	**Head** 0.477	**Pelvis** 0.676	**Eyes** 0.705	**First foot** 0.718	**Second foot** 1.118
	Delay (ms)		19	7	199	288	13	400
	Post mean(s)	**Thorax** 0.442	**Shoulder** 0.455	**Head** 0.480	**Pelvis** 0.591	**Eyes** 0.684	**First foot** 0.743	**Second foot** 1.140
	Delay (ms)		13	25	111	93	59	397
Dancers	**Pre mean(s)**	**Thorax** 0.452	**Shoulders** 0.453	**Head** 0.461	**Eyes** 0.570	**Pelvis** 0.621	**First foot** 0.687	**Second foot** 1.090
	Delay (ms)		1	8	109	51	66	403
	Post mean(s)	**Thorax** 0.450	**Head** 0.467	**Shoulders** 0.500	**Eyes** 0.555	**Pelvis** 0.639	**First foot** 0.684	**Second foot** 1.088
	Delay (ms)		17	33	55	84	45	404

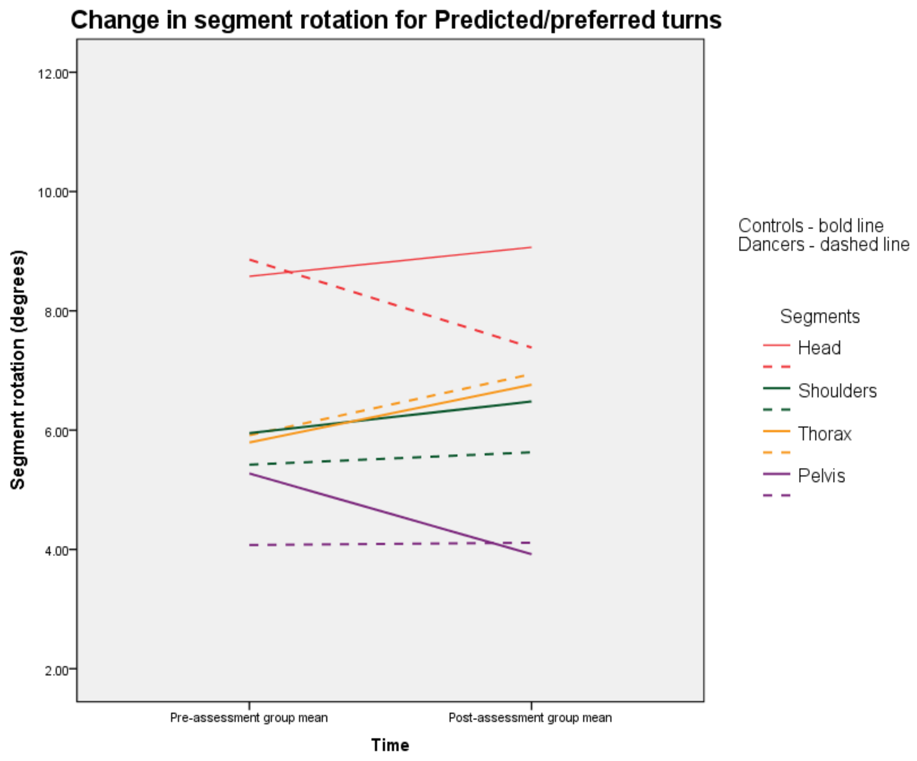
(s) = seconds (ms) = milli-seconds

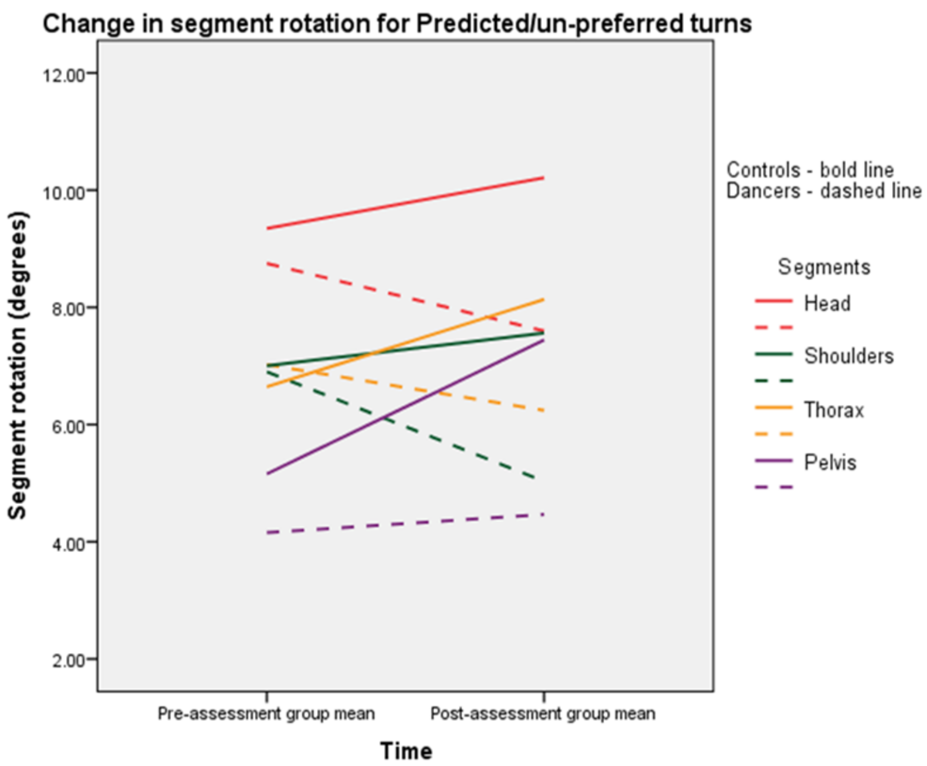
Table 16 – The order of segments in controls and dancers when all turns are considered together.

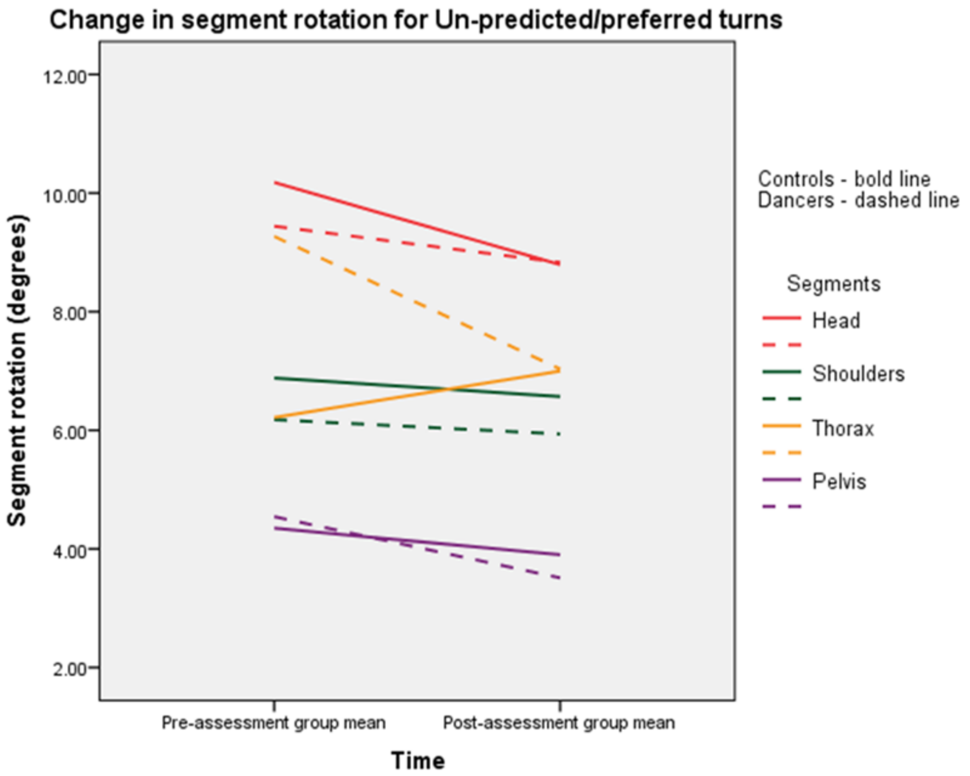
6.6 Segment rotation

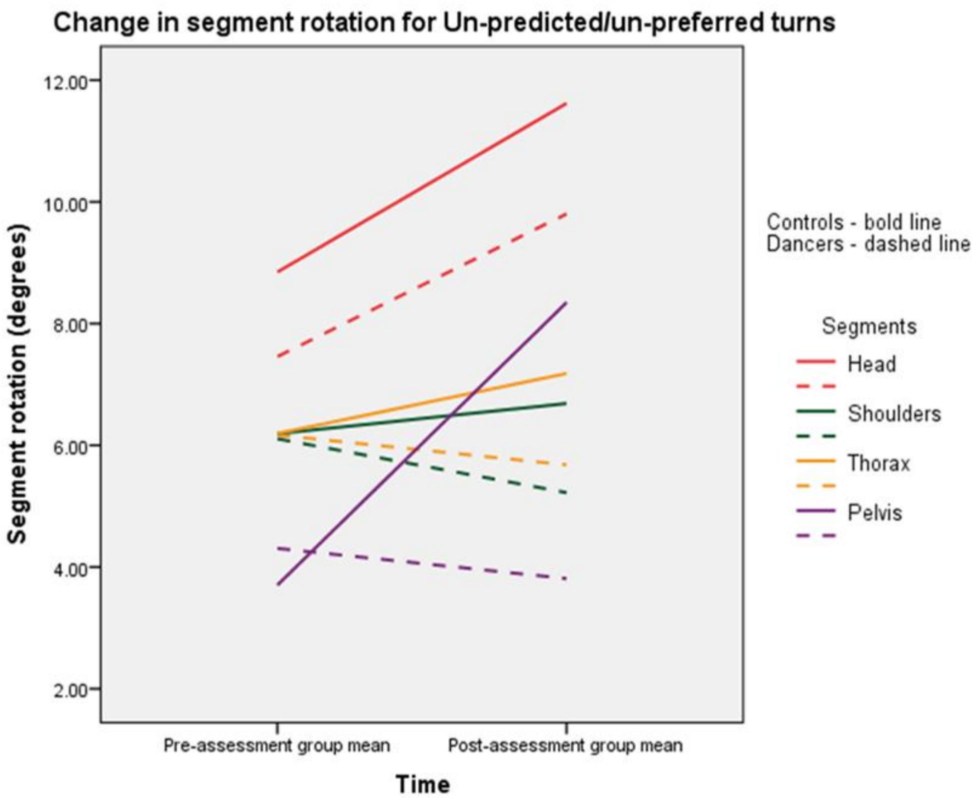
Descriptive statistics for segment rotation (change in segment angle from initiation (cue) to point of FFM) of the head, shoulders, thorax and pelvis were calculated for controls and dancers in each type of turn (predicted/preferred, predicted/un-preferred, un-predicted/preferred, un-predicted/un-preferred). These are displayed in Appendix 15 and visualised in Figure 24.

Figure 24 – Graphs to show the change in rotation comparing controls and dancers at pre- assessment and post-assessment in all turn types.






Change in segment rotation for Un-predicted/preferred turns
12.00
10.00
8.00
6.00
4.00
2.00
Segment rotation (degrees)
Pre-assessment group mean
Post-assessment group mean
Time
Controls - bold line
Dancers - dashed line
Segments
Head
Shoulders
Thorax
Pelvis


Change in segment rotation for Un-predicted/un-preferred turns
12.00
10.00
8.00
6.00
4.00
2.00
Segment rotation (degrees)
Pre-assessment group mean
Post-assessment group mean
Time
Controls - bold line
Dancers - dashed line
Segments
Head
Shoulders
Thorax
Pelvis

Segment rotation was analysed using the same four-way ANOVA model as that used in analysis of latency data. Significant two-way interaction for ('time*group') (F(1,22) = 5.015, p = 0.036) and a non-significant 3-way interaction ('time*preference *group') (F(1,22) = 3.424, p = 0.078) for pelvis rotation were found.

Review of the descriptive statistics across the four turn types suggest the greatest effect to be in the control group, with a 25.65% and 10.3% reduction in rotation in predicted/preferred and un-predicted/preferred turns respectively. An increased rotation of 44.32% and 125.41% in predicted/un-preferred and un-predicted/un-preferred turns respectively from pre- to post-assessment was seen. The dancers showed a 22.7% and 11.61% reduction in rotation in un-predicted/preferred and un-predicted/un-preferred turns respectively in the same period. The direction of effect on the mean difference in un-predicted/un-preferred turns in controls remains after consideration of the limits of the SE, indicating a true change in the mean that is representative of the population sampled (mean difference 0.603, 8.687) (Table 17).

There was no significant difference detected for the change in rotation of head (F(1,22) = 0.002, p = 0.969), shoulders (F(1,22) = 0.058, p = 0.812) or thorax (F(1,22) = 1.027, p= 0.322).

Descriptive statistics of the change in mean scores from pre- to post-assessment of dancers and controls shows an overall trend for an increase in rotation of all segments in the controls and a reduction for dancers, with the greatest effect being in the thorax and the pelvis (Table 18). The increase across all turn types in pelvis rotation in the controls remains after consideration of the SE, indicating a true change in the mean that is representative of the population sampled (mean difference 0.125, 2.441).

Table 17 – Mean pelvis rotation (in degrees) in controls and dancers across all types of turn.

Pelvis rotation (degrees)	Controls					Dancers				
	Mean (SE) Pre	Mean (SE) Post	Diff	% change	SE	Mean(SE) Pre	Mean (SE) Post	Diff	% change	SE
Pred/Pref	5.273 (0.57)	3.920 (0.83)	-1.353	-25.65	1.044	4.074 (0.55)	4.111 (0.62)	0.037	0.91	0.770
Pred/Un-pref	5.157 (1.12)	7.443 (2.37)	2.286	44.32	1.911	4.156 (0.73)	4.467 (1.06)	0.311	7.48	1.159
Un-pred/Pref	4.349 (0.94)	3.901 (0.56)	-0.448	-10.30	0.693	4.542 (1.12)	3.511 (0.82)	-1.031	-22.70	1.179
Un-pred/Un-pref	3.704 (0.48)	8.349 (1.94)	4.645	125.41	2.062	4.307 (0.84)	3.810 (1.05)	-0.500	-11.61	0.764

Significant interaction two-way (group*time) p= 0.036 and trend for three-way (time* preference* group) p = 0.078.

Red text indicates greater rotation, green text indicates less rotation. Highlighted are results of interest. SE = standard error of the difference between the pre and post assessment scores, highlighted SE results suggest the mean change is greater than that expected by random sampling (mean difference ± 1.96 * SE), the standard error of the means is shown in brackets.

Pred/Pref = predicted/preferred turn

Pred/Un-pref = predicted/un-preferred turn

Un-pred/Pref = un-predicted/preferred turn

Un-pred/Un-pref = un-predicted/un-preferred

Table 18 – Mean rotation of all segments (in degrees) in controls and dancers when averaged across all types of turn.

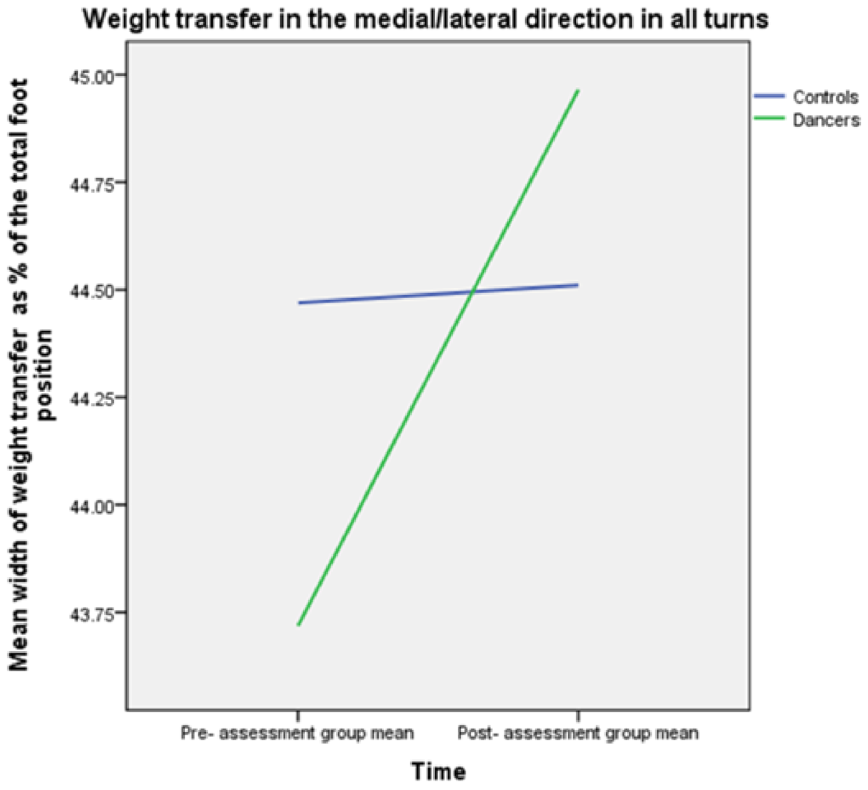
Segment Rotation (degrees)	**Controls**					**Dancers**				
	Mean (SE) Pre	**Mean (SE) Post**	**Diff**	**% change**	**SE**	**Mean(SE) Pre**	**Mean(SE) Post**	**Diff**	**% change**	**SE**
Head	9.238 (0.03)	9.922 (0.04)	0.684	7.40	0.723	8.627 (0.03)	8.404 (0.04)	−0.223	−2.7	1.119
Thorax	6.507 (0.04)	6.824 (0.03)	1.057	16.24	0.838	6.152 (0.03)	5.455 (0.03)	−0.620	−10.08	1.148
Shoulder	6.212 (0.02)	7.269 (0.03)	0.318	5.12	0.560	7.093 (0.03)	6.473 (0.06)	−0.697	−9.83	0.502
Pelvis	4.621 (0.07)	5.903 (0.06)	1.283	27.77	0.591	4.270 (0.04)	3.975 (0.05)	−0.295	−6.91	0.383

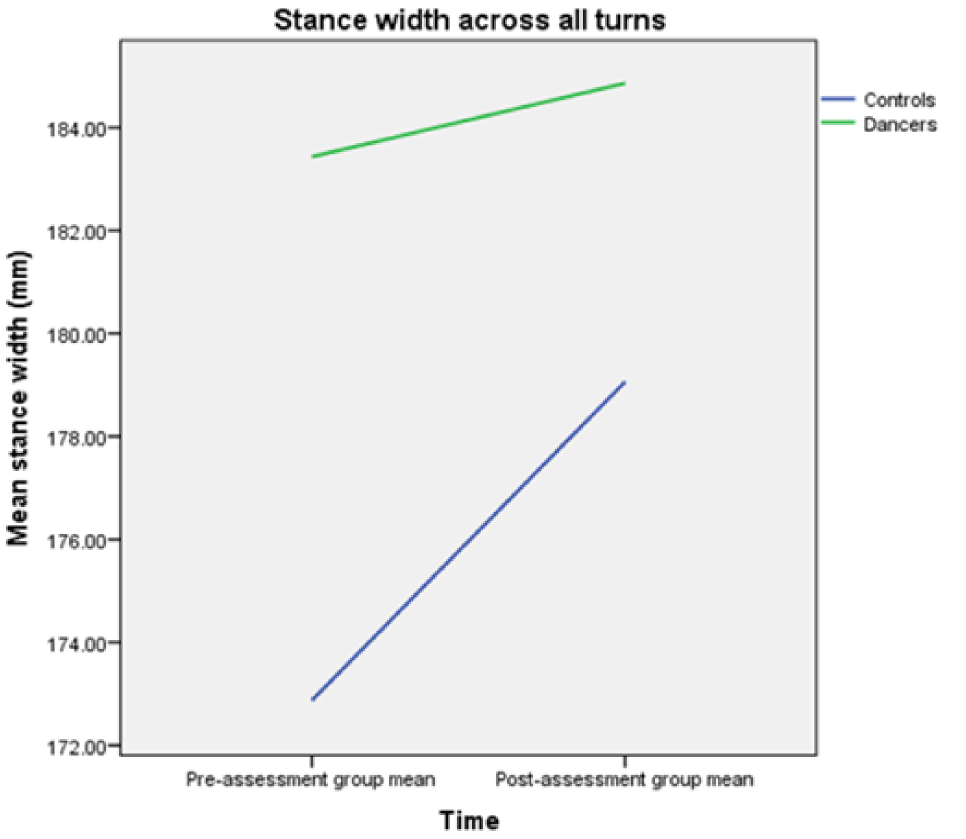
Red text indicates greater rotation, green text indicates less rotation. Highlighted are results of interest. SE = standard error of the difference between the pre and post assessment scores, highlighted SE results suggest the mean change is greater than that expected by random sampling (mean difference ± 1.96 * SE), the standard error of the means is shown in brackets.

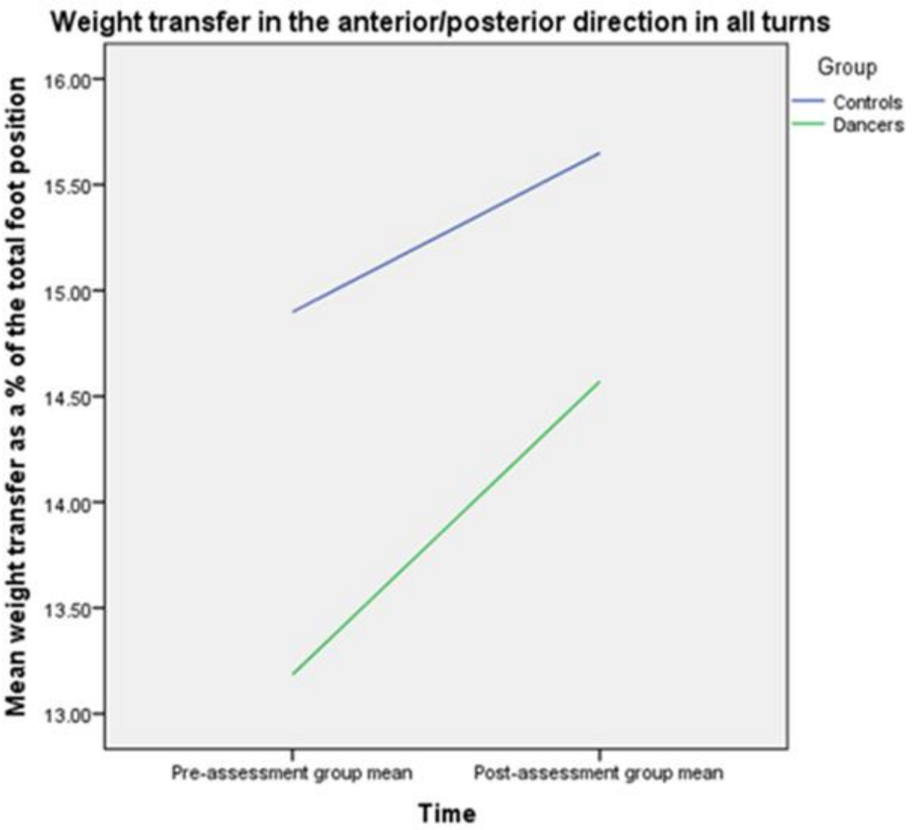
6.7 Force

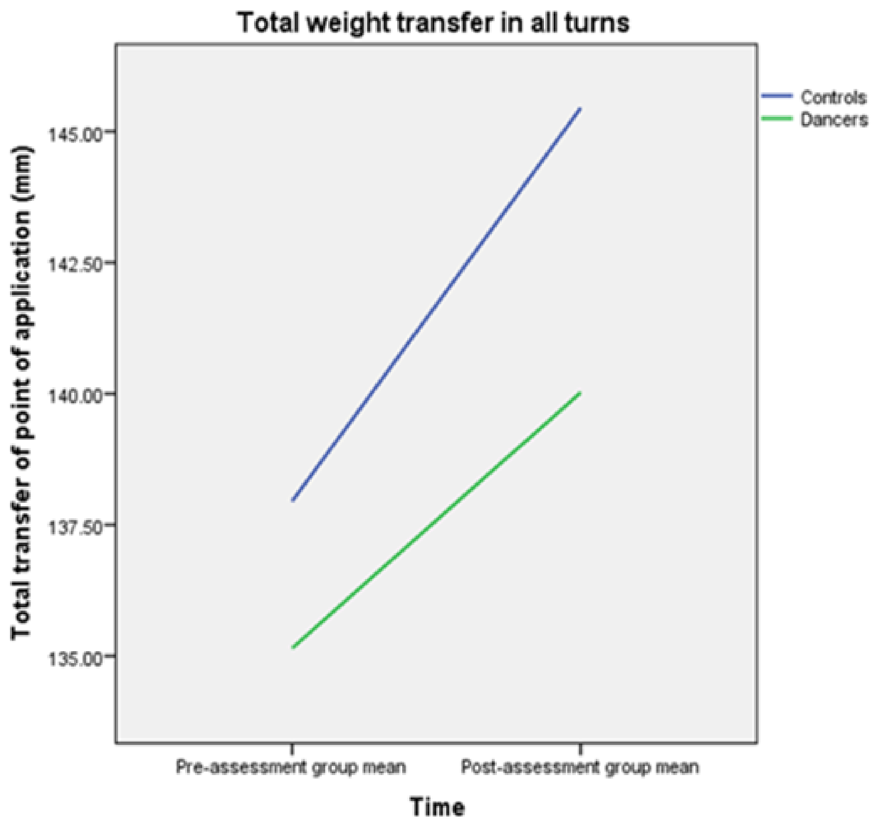
Descriptive statistics for the force variables; change in M/L and A/P weight transference in relation to position of the feet; total weight transference; stance width; and A/P weight bearing position, from initiation to the point of FFM were calculated for controls and dancers in each type of turn (predicted/preferred, predicted/un-preferred, un-predicted/preferred, un-predicted/un-preferred). These are displayed in Appendix 15 and visualised in Figure 25.

Figure 25 – Measures of force production in controls and dancers averaged across all types of turn.




Stance width across all turns
Controls
Dancers
Mean stance width (mm)
184.00
182.00
180.00
178.00
176.00
174.00
172.00
Pre-assessment group mean
Post-assessment group mean
Time


Weight transfer in the anterior/posterior direction in all turns
Group
Controls
Dancers
Mean weight transfer as a % of the total foot position
16.00
15.50
15.00
14.50
14.00
13.50
13.00
Pre-assessment group mean
Post-assessment group mean
Time



Results from the same four-way ANOVA model used in latency and segment rotation found no significant interactions for change in M/L weight transference ($F(1,22) = 2.281$, $p = 0.145$) ; A/P weight transference ($F(1,22) = 1.152$, $p = 0.295$); total weight transference ($F(1,22) = 1.679$, $p = 0.209$); and stance width ($F(1,22) = 0.001$, $p = 0.981$).

The number of participants with their weight in an anterior or posterior position, at the point of FFM, in relation to the central point of their foot position, across each type of turn was calculated for controls and dancers, with the percentage change in the anterior direction reported (posterior being the reverse of this) (Table 19). Results showed a greater number of dancers changed their weight-bearing position to anterior than controls.

Table 19 – Weight bearing position in relation to the central point of the position of the feet in controls and dancers across each type of turn.

Weight bearing position	Controls					Dancers				
	Pre (n)		Post (n)		% change Anterior	Pre (n)		Post (n)		% change Anterior
	Ant	Post	Ant	Post		Ant	Post	Ant	Post	
Pred/Pref	8	4	6	6	25% less	5	7	8	4	60% more
Pred/Un-pref	7	5	6	6	14% less	5	7	7	5	40% more
Un-pred/Pref	9	3	10	2	11% more	4	6	7	5	75% more
Un-pred/Un-pref	7	5	4	8	43% less	6	7	7	5	17% more

Red text indicates a reduction and green text an increase in the percentage of participants in an anterior weight bearing position at FFM at the post-assessment.

Ant = Anterior

Post = Posterior

Pred/Pref = predicted/preferred turn

Pred/Un-pref = predicted/un-preferred turn

Un-pred/Pref = un-predicted/preferred turn

Un-pred/Un-pref = un-predicted/un-preferred

6.8 Clinical measures

6.8.1 SS180 – Steps

The inclusion of the SS180 was primarily to provide a value of number of steps. The number of steps showed no significant difference in a two-way ANOVA with time (pre/post) as the within participant factor and group (controls/dancers) as the between participant factor ($F(1,22) = 0.820$, $p = 0.375$). Whether the direction of the turn was specified or not also showed no significant difference in a three-way ANOVA (time*group*turn direction) ($F(1,22) = 1.098$, $p = 0.306$).

Descriptive statistics show an increase in the number of steps taken to complete the 180 degree turn in dancers in all turn conditions (direction specified 10.07%, direction un-specified 16.42%, and mean of both turns 13.08%), none of which are reflected in the control group (Table 20).

Table 20 – The number of steps taken to complete the SS180 in controls and dancers in the pre- and post-assessment.

Number of Steps	Controls					Dancers				
	Pre (SE) mean	Post (SE) mean	Diff	% change	SE	Pre (SE) mean	Post (SE) mean	Diff	% change	SE
Direction un-specified	4.58 (0.66)	4.42 (0.58)	-0.17	-3.7	0.59	4.08 (0.26)	4.75 (0.49)	0.67	16.42	0.40
Direction specified	4.25 (0.71)	4.42 (0.67)	0.17	4	0.46	4.17 (0.46)	4.58 (0.71)	0.42	10.07	0.40
Mean direction	4.42 (0.67)	4.42 (0.61)	0.00	0	0.50	4.13 (0.30)	4.67 (0.56)	0.54	13.08	0.33

Red text indicates less steps, green text indicates more steps. Highlighted are results of interest. SE = standard error of the difference between the pre- and post-assessment scores, the standard error of the means is shown in brackets.

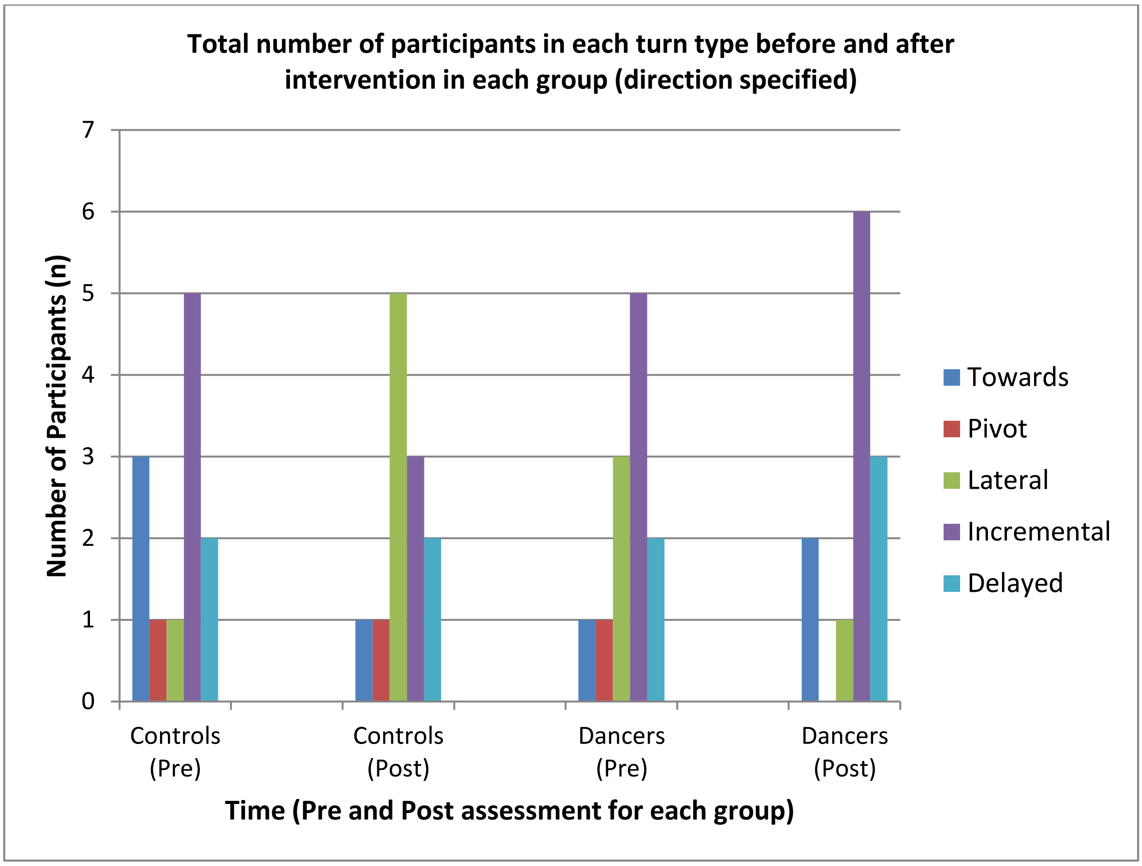
6.8.2 SS180 – Quality

The quality of the turn is also provided by the SS180, with no significant difference found in the mean quality ($F(1,22) = 0.972$, $p = 0.335$) between groups, over time.

6.8.3 SS180 – Type of turn

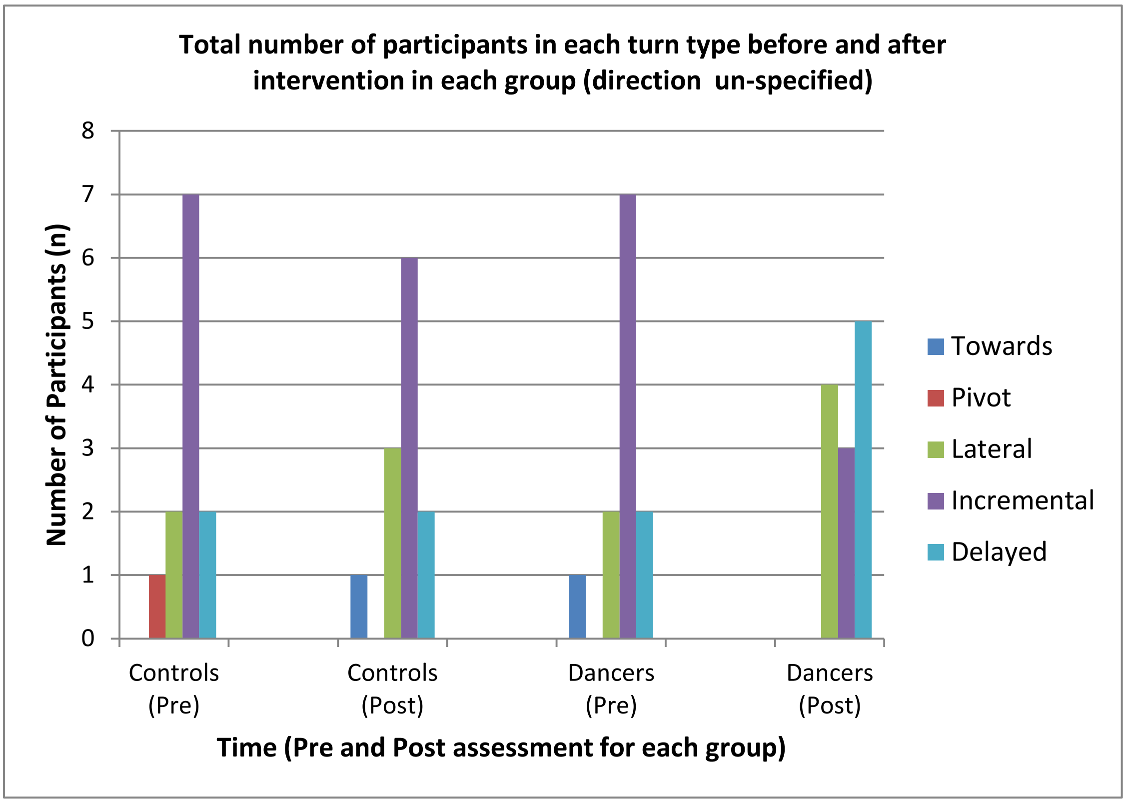
During specified turn directions in the SS180, six people in the control group and three in the dance group changed the type of turn they used over time (with dancers showing an increase in incremental turns and decrease in lateral turns, and the opposite occurring in the controls), shown in Figure 26.

Figure 26 – The changes in the type of turn completed in the SS180 by controls and dancers at the pre- and post-assessment when the direction of turn was specified.



During un-specified turn directions two people in the control group and five in the dance group changed the type of turns they used over time (with both controls and dancers showing an increase in lateral turns, and the dancers showing an increase in delayed turns, shown in Figure 27.

Figure 27 - The changes in the type of turn completed in the SS180 by controls and dancers at the pre- and post-assessment when the direction of turn was un-specified.



6.8.4 Time (SS180 and 3-dimensional movement analysis)

The total time taken to complete the turn was measured using 3-dimensional movement analysis and the SS180. This provided a turn time for each type of turn and a clinical comparison.

No significant difference was found from a four-way ANOVA for the pre- to post-assessment data from the 3-dimensional movement analysis for each type of turn between the two groups ($F(1,22) = 0.275$, $p = 0.605$), or a two-way ANOVA (time*group) for the pre and post assessment data from the SS180 between the two groups (F(1,22) = 0.012, p = 0.914). Descriptive statistics did not indicate any difference between the groups (see Table 21 and Appendix 15).

Table 21 – Mean time to turn (s) as measured by 3-dimensional movement analysis and SS180.

Time	**Type of turn**	**Controls**		**Dancers**	
		Pre (SD)	**Post (SD)**	**Pre (SD)**	**Post (SD)**
Coda (s)	**Pred/Pref**	3.908 (1.3)	3.957 (1.081)	3.71 (0.801)	3.6 (0.89)
	Pred/Un-pref	4.066 (1.415)	3.742 (1.209)	3.907 (0.886)	3.837 (1.209)
	Un-pred/Pref	4.066 (1.496)	4.048 (1.235)	3.811 (0.827)	3.642 (0.725)
	Un-pred/Un-pref	3.992 (1.068)	3.985 (1.25)	3.911 (0.785)	4.02 (3.73)
	Mean	4.013 (1.32)	3.93 (1.154)	3.835 (0.749)	3.77 (0.871)
SS180 (s)	**Un-specified**	2.31 (1.23)	2.23 (0.96)	2.3 (0.99)	2.24 (0.42)
	Specified	2.13 (1.2)	2.04 (1.02)	2.3 (0.79)	2.24 (0.94)
	Mean	2.218 (1.202)	2.132 (0.966)	2.295 (0.865)	2.237 (0.578)

(s) = seconds, (SD) = standard deviation

Pred/Pref = predicted/preferred turn, Pred/Un-pref = predicted/un-preferred turn, Un-pred/Pref = un-predicted/preferred turn, Un-pred/Un-pref = un-predicted/un-preferred

6.8.5 Berg balance scores

No significant difference was found in a two-way ANOVA (group*time) for the pre- to post-assessment data between the two groups (F(1,22) = 0.959, p = 0.338) for the BBS (see Table 22 and Appendix 15).

Table 22 – Mean pre- and post-assessment Berg balance scores.

BBS	Controls		Dancers	
	Pre score (/56) (SD)	**Post score (/56) (SD)**	**Pre score (/56) (SD)**	**Post score (/56) (SD)**
	51.92 (6.4)	50.42 (2.17)	50.5 (1.45)	50.3 (1.78)

(/56)= Berg balance scores are out of a total of 56

(SD) = standard deviation

6.9 Summary of results

Results have been presented in line with the research question posed:

> Are the kinematic measures of body segment latency, body segment rotation and force variables during turning, and the clinical measures of the Standing start 180 degree turn test (SS180) and Berg balance scale (BBS) altered after a dance intervention in PwP?

In summary, all measures of 3-dimensional movement analysis were found to have good inter- and intra-class correlation (Range 0.85-1), with the weakest correlation found in measurement of eye latency and identification of the starting position of the pelvis.

6.9.1 Body segment latency

The latency of the head was found to be significantly different between dancers and controls, over time, due to changes observed in the control group. In particular the head latency in the controls increased (longer delay) in the predicted/preferred turn direction in comparison to a decreased latency (shorter delay) in the predicted/un-preferred turn direction. Changes in pelvis latency were also noted in the controls (although non-significant), specifically demonstrating a decreased latency (shorter delay) in the predicted/un-preferred turn direction. Finally, both the first and second foot demonstrated a non-significant increase (longer delay) in latency over time in the control group in the un-predicted/un-preferred turn direction. In comparison, changes following dance were un-remarkable across all segments for latency.

When considering the interaction of segments during the initiation of the turn across all turn directions, controls demonstrated an increase in delay (longer delay) between the first segment to move and the feet (segments more separated), and between the movement of the pelvis and the feet (segments more separated). They demonstrated a decrease in the delay (shorter delay) between the first segment to move and the pelvis (segments closer related). In comparison, the dancers demonstrated less of a change in 'segment to segment delay' over the time frame, with a small reduction in the delay (shorter delay) between the pelvis and the feet (segments closer related) and an increase in the delay (longer delay) between the first segment to move and the pelvis (segments more separated).

6.9.2 Body segment rotation

When considering the amount of rotation each segment underwent from the point of initiation to the FFM, a significant difference was found between the controls and dancers over time in the pelvis. Controls showed a large increase in the amount of rotation of the pelvis in both predicted/un-preferred and un-predicted/un-preferred turns, with dancers in comparison showing a reduction in pelvis rotation during un-predicted/un-preferred turns and un-predicted/preferred turns. Although not significant, the trend for increased rotation in the controls and a decreased rotation in the dancers was replicated throughout all body segments.

6.9.3 Force

Results from the analysis of all force variables did not show significant differences between the groups over time, although a small increase in the medial/lateral weight transfer and a greater percentage with weight in an anterior position was noted in the dancers over time. No changes were noted in the controls.

6.9.4 Clinical measures

Finally, no significant difference was shown in the clinical measures of turning (SS180) and balance (BBS) between the groups over time. However, a trend indicating a greater number of steps to turn and a greater proportion of dancers turning with an ‘incremental’ (when the turn direction was specified) and ‘delayed’ (when direction was un-specified) style of turning over time was shown.

Having presented the results of the quantitative component of this thesis the implications with reference to the research question posed, will now be discussed in Chapter 7.

Chapter 7: Discussion

The aim of this study was to investigate the effects of ballroom and Latin American dancing on whole body coordination during turning in PwP. Due to the lack of previous knowledge of the effects of dance on turning or indeed any intervention this was an explorative design. In addition, previous research on turning in PwP has studied the behaviour of body segments during turning in isolation to each other, with little acknowledgment of the relationship and the co-ordination between segments and clinical measures of turning performance. Therefore the research question posed uniquely enabled, firstly, an exploration of the effects of dance on turning performance including measures of body segment latency, body segment rotation and force alongside clinical measures of turning and balance; and secondly a discussion of the effects of whole body co-ordination through interpretation of these results collaboratively.

The research question was:

Are the kinematic measures of body segment latency, body segment rotation and force variables during turning, and the clinical measures of the Standing start 180 degree turn test (S180) and Berg balance scale (BBS) altered after a dance intervention in PwP?

The impact of dance for PwP has not previously been investigated using 3-dimensional movement analysis; this is therefore the first known study to combine analysis across these variables and consider the relationship between them to turning performance and adds novel understanding to the impact of dance on PwP.

The results presented suggest body segment latency, body segment rotation and balance (a combination of force variables) in PwP whilst turning all appear to be affected by a 10-week, twice a week ballroom and Latin American dance intervention. In particular, body segments appear more coordinated in time and sequence following dance in PwP, suggesting a more ‘en bloc’ turning pattern with greater inter-segmental coordination.

Specifically, changes in the controls over time show a slower head, faster pelvis and slower foot initiation, resulting in a closer coupling of the axial segments (head and pelvis) with a delay in the initiation of the perpendicular segments (first and second foot). This is linked with overall greater rotation in all segments but specifically the pelvis, with weight distribution remaining more often in the posterior portion of the base of support. When compared to the minimal changes shown in body segment latency and M/L weight transference, with an overall reduction in body rotation (in particularly the pelvis), slight increase in the number of steps, and a greater proportion of participants with their weight in the anterior portion of their base of support in those that danced, these results suggest a multi-system effect of dance on turning ability, with changes in all variables having an influencing effect on each other.

This chapter discusses the results and the limitations of the quantitative component of this thesis, discussing the effects of dance on both the individual variables assessed and the relationship between them.

In order to comment on the outcome of results and discuss the implications, it is essential to consider the demographics of the sample selected and the analysis design.

7.1 Research design

7.1.1 Sample and analysis design

Baseline analysis (Section 6.2, Table 10) showed no significant difference in the demographic profile between the dancers and controls for the variables of age, gender, hand and foot dominance, turn direction preference, years since diagnosis and disease severity (measured by the H&Y classification). Therefore the changes discussed over time can be considered a result of the intervention that each group received.

However, results from the feasibility study (Appendix 3) showed variables of 3-dimensional movement analysis were susceptible to individual variation, due to personal movement styles, preferences and significant fluctuation in performance owing to variability of the presentation of symptoms in PwP.

Whilst the sample size was increased from the feasibility study in order to accommodate for these factors, the expected variation both between and within participants over pre- and post-assessments, suggests it is more appropriate to discuss the change in turning performance over time in each group. This allows comparisons of change in performance as a result of an intervention, rather than a direct comparison between groups, with an explorative research question and statistical analysis models to reflect this.

7.1.2 Research question and basis of discussion

The explorative design of the research question posed enabled a broad discussion of multiple outcomes and influencing factors. It was hypothesised that a 10-week, twice a week dance intervention would affect the way PwP turn around considering both kinematic and clinical outcome measures; however the exact mechanisms of effect were not predicted. The research question posed was:

> Are the kinematic measures of body segment latency, body segment rotation and force variables during turning, and the clinical measures of the Standing start 180 degree turn test (S180) and Berg balance scale (BBS) altered after a dance intervention in PwP?

In order to provide explanation of the results over the time frame of this study, it is was thought necessary not only to discuss the changes in individual variables assessed, but also the relationship of body segment latency, body segment rotation, force production and clinical measures of turning performance, before and after a dance intervention. This provides discussion of the changes observed alongside the possible relationships with other variables of turning performance, as purely hypothesising on effects of individual segments in isolation fails to consider the likely causes of the effect and the impact on the turn performance as a whole. With an appreciation of the suggestion that any ‘Parkinsonian’ symptom is a sum of the primary impairments plus the adaptive compensatory strategies (Bloem et al. 2001), results are grouped by clinical outcome (rather than specific segments), allowing the impact of dance on segment latency, segment rotation and balance (a combination of force variables) to be discussed alongside changes in clinical measures of turning performance.

7.2 Body segment latency

Body segment latency results (shown in Section 6.5) provide an indication of the speed that each segment responds to a cue to move (initiation), the order that the segments respond and the relationship of each segment to one another. Previous research has shown:

- A delay in initiation across all segments in PwP compared to controls (Vaugoyeau et al. 2006; Visser et al. 2007; Willems et al. 2007; Mak et al. 2008; Hong et al. 2009; Anastasopoulos et al. 2011; Akram et al. 2013a; Akram et al. 2013b)
- Alterations in segment coordination and order (Ferrarin et al. 2006; Vaugoyeau et al. 2006; Crenna et al. 2007; Earhart et al. 2007; Huxham et al. 2008b; Song et al. 2012; Akram et al. 2013a; Ashburn et al. 2014a)
- An 'en bloc' relationship between segments with a loss of inter-segmental control (Crenna et al. 2007; Huxham et al. 2008b; Mak et al. 2008; Akram et al. 2013b).

Results from this study indicated a significant difference between the groups over time, with an appreciation for turn type (predicted/preferred, predicted/un-preferred, un-predicted/preferred, un-predicted/un-preferred) in head latency, with controls showing a greater change in head latency than dancers (Figure 22 and Table 12).

From the descriptive statistics (Table 12), it appears the type of turn had an impact on the direction of this difference, with longer latency of head movement (slower) in predicted/preferred turns and shorter latency (faster) in predicted/un-preferred turns, over time in controls. The importance of prediction of turn direction has previously been demonstrated by Akram et al. (2013a), who found greater linking of body segments during on-the-spot turns in PwP when the turn was to a predicted direction and therefore a reduction in the degrees of freedom, which would possibly allow for expression of the influence of turn preference seen in this study. In contrast, the influence of preference was found to be non-significant across all segments during on the spot turns by Ashburn et al. (2014), with all turns being predictable. However, when considering only results for head latency, they also found a faster latency during un-preferred compared to preferred turns in PwP, which was not discussed independently from other segments. The influence of preference has also been demonstrated by Stack and Ashburn (2008), with 75% of PwP showing an increased step number and an adoption of an incremental turn style (multiple steps) (Stack et al. 2002a) when participants were instructed to turn to their un-preferred direction compared to their preferred. Whilst this is not specific to head latency, it does suggest the influence of preference when turn direction is predicted.

The results from this study, alongside previous research, therefore suggest that increasingly over time, when turn direction is predicted, the influence of directional preference is greater than when turns are un-predicted. This suggests that for head latency, the most important variable in turn performance as the condition progresses may be whether the turn direction is previously known and therefore pre-planned, or reactive to an un-predictable direction, as when this variable is stable, as is the case in both predictable conditions, the influence of preference was shown. The influence of prediction and preference over time becomes important when considering the lack of change observed in the dancers across all turn types over the same period. This suggests dance may influence the ability to accommodate for changes in turn type and provide a mechanism to stabilise changes in head latency with more or less challenging turn types (more challenging turn types considered to be in un-predicted and un-preferred directions), which increasingly become evident as the condition progresses in control participants.

It is important to note that the greatest change found in head latency was a slower latency in controls for predicted/preferred turn directions (Table 12). Slower latency across all segments has consistently been shown in movement analysis studies of PwP turning compared to healthy age-matched controls (Ferrain et al. 2006; Vaugoyeau et al. 2006; Crenna et al. 2007; Huxham et al. 2008b). It therefore appears that the influence of dance may have reduced the possible progression of this delay over time as a similar delay was not shown in dancers. A recent study however (Ashburn et al. 2014a), showed that the significant delay found in all segment latencies in PwP compared to controls is removed when results are accounted for by head velocity, demonstrating the influence of head latency on the latency of all other segments, thus making the difference seen in this study between dancers and controls even more important. The fact that the greatest change in delay in head latency was shown in the predicted/preferred direction is also interesting, as this is the turn most likely to be performed in activities of daily living by choice and therefore likely to have the greatest functional effect. It is also the turn most likely to have been performed or practiced by all participants over the duration of the study and thus the difference between the dancers and controls shows an effect of dance, over and above that expected from standard practice, as may be the case in less commonly used turns.

The appreciation of the standard error (SE) (Table 12) suggests the changes shown are in addition to that expected by random sampling and thus suggest a true change in the mean of this sample over the time frame of this study. In this respect, dancing may have resulted in an ability to maintain head latency at pre-dancing scores, in comparison to the changes observed in those who did not dance.

A similar pattern to that seen in the head was also found in pelvis latency (Table 13), although non-significant, with greater changes in latency seen in controls across all turn types, over time, than in dancers. The greatest change was found in the predicted/un-preferred direction with decreased (faster) pelvic latency in controls over time, which was not seen in dancers. Although the changes in pelvis latency did not reach significance (Table 13), they should be considered here alongside the significant changes seen in head latency. When considering the increased speed of head latency found in the same turn direction in controls, a link between the behaviour of the head and pelvis can be made, with both showing an increased speed. It is unsurprising that a similar pattern of change is observed in the head and pelvis considering the presence of the linked ‘en bloc’ turn found in previous literature in PwP (Crenna et al. 2007; Franzen et al. 2009; Visser et al. 2007; Hong et al. 2009;

Ferrarin et al. 2006; Visser et al. 2007; Willems et al. 2007; Schenkman et al. 2001; Vaugoyeau et al. 2006). However, what is surprising is the direction of effect, with previous literature reporting a specific delay in pelvis latency in PwP compared to controls (Vaugoyeau et al. 2006; Ashburn et al. 2014a) and therefore one would not expect pelvis (or head) latency to speed up over time, with no intervention. In order to hypothesise about this increase in latency of the axial segments (being the head and pelvis in this case), it is necessary to consider the behaviours of the perpendicular segments (being the feet).

The link between the two body sections has been discussed in detail in Chapter 4, with the suggestion of axial deficits driving perpendicular changes in PwP (Hulbert et al. 2014). However, this does not initially appear to be the case here, with an increase in axial segment latency speed in the controls, being more in line with the behaviour of healthy controls over time. However, when considered alongside the delay in the latency of the first and second foot movement in controls over time, which was not observed in the dancers, the potential mechanisms of effect become apparent. Whilst it is fundamental to consider all segments together in order to assess turning performance, these results must be treated with caution owing to the failure to reach the required significance value in the pelvis and first and second foot latency, possible reasons for which are discussed in Section 7.6.

The observed changes in latency in controls show a greater time delay between the pelvis and the feet and a closer coupling of the first segment to move (being the thorax in the controls) and the pelvis (Figure 23), suggesting a greater delay between the axial and perpendicular segments in the controls compared to the dancers over time. Interestingly, these findings have also been shown by Akram et al. (2013b), demonstrating a longer time delay between the pelvis and the feet when comparing turning in PwP to healthy age-matched controls, which is also found to correspond with a delay in the onset of body mass orientation and resultant delay in turning momentum (Mak et al. 2008). Specifically, the hip: trunk ratio has been shown to be higher in PwP compared to age-matched controls, representing greater rigidity between the trunk and hips (Wright et al. 2007). Clinically, those PwP who freeze during turning also showed closer coupling between the head and pelvis (Spildooren et al. 2013), even when controlling for disease severity and the speed of the turn.

The mechanisms of motor control believed to coordinate a turn at a high hierarchical level from the basal ganglia and associated structures (Crenna et al. 2007), suggest a top-down organisation of body segments controlled by the position of the head in space and the resultant reference frame for the shoulder and trunk, and bottom-up control of the feet and pelvis as a result of equilibrium maintenance (Vaugoyeau et al. 2006). Therefore the increased delay between the feet and pelvis is likely to result in reduced coordination between the top-down and bottom-up systems, often observed as bradykinesia of movement or freezing during the turn in PwP (Morris 2000). It has also been suggested that the control of axial and perpendicular movements have different origins, with the axial structures being controlled by the descending monaminergic pathways of the reticulospinal and vestibulospinal motor pathways particularly, compared to the corticospinal tracts which are more responsible for distal and voluntary movement of the perpendicular body segments (foot control) (Lawrence & Kuypers 1968). Thus, without adequate control of the trunk rotating, it is not possible to gain efficient voluntary movement of the distal components. This may result in a split or delay between the movement of the axial and perpendicular segments as seen in the controls in this study, supporting the notion of axial deficits driving a perpendicular change (Hulbert et al. 2014).

Results indicate that following dance, no such split occurs, with minimal change in the delay between the first segment to move and the feet, and a closer linking of the feet and pelvis (Figure 23). This has the effect of all segments becoming more closely linked in their initiation time as an ‘en bloc’ pattern, but following a reciprocal pattern of one segment triggering the movement of the next in relatively equal transition delays (Table 16). Although these results are descriptive observations of data, the pattern of segment behaviour has also been demonstrated by Huxham et al. (2008b), showing PwP constrained the thorax and pelvis closely together during a walking turn about a pole, compared to a matched control group who maintained a pattern of reciprocal oscillation throughout the segments. Therefore, the lack of change in the time delay across all body segments (Figure 22) and the shift in pelvis latency towards the feet (Figure 23) suggests dance may enable the two motor control systems to remain coordinated, with the pelvis linking the two. Thus, despite a faster latency in the axial segments in the controls initially appearing to suggest improvements in turning performance compared to dancers, when considered collectively this presents with an 'en bloc' presentation of the axial segments and a delay in the perpendicular segments of the feet, with a likely loss of coordination between them. This suggests that controls in this study actually appear more 'parkinsonian' over the time frame of the study than dancers with respect to combined segment latency.

Furthermore, the possible preservation of coordination between the two motor control systems may also reduce the degrees of freedom required to make the turn and thus the complexity of the motor control required. Studies of multi-segment movements such as turning, show a reduction in the number of degrees of freedom as a way of simplifying the control of complex movements (Courtine & Schieppati 2004). The coordination of the two systems with closer coupling ('en bloc' turn), between body segments, has indeed been found in the healthy elderly when turning under both challenging (challenging the vestibular, visual and proprioceptive systems by eyes closed and on a moving platform) (Akram et al. 2010a; Earhart et al. 2007) and non-challenging (eyes open on a stable surface) (Anastasopoulos et al. 2011; Akram et al. 2013a) conditions. This represents the possible mechanisms of adapting the degrees of freedom to either maintain tighter control of the turn in complex turning scenarios, or reduction of the 'cognitive cost' (attention required to complete the task successfully) and thus perceived difficulty in turns that are less challenging, an ability preserved in healthy elderly controls and as suggested by these results, potentially after dance in PwP.

It is unclear how dance may specifically maintain the coordination between the sections, however the principles of motor re-learning indicate that cortico-motor neuron pools are organised relative to specific tasks rather than specific muscles, with increasing evidence of neuro-plastic changes associated with the training of functional tasks rather than specific impairments (Hubbard et al. 2009). This suggests the best way to relearn a given task is to train specifically for that task. Indeed, task specificity states that in order to improve in a task, one must practice that task (Hubbard et al. 2009) with task-specific training shown to drive greater functional improvement than non-specific training (Kwakkel et al. 2007). Dance predominantly encourages body segment rotation about either a fixed environmental, or an internal body part axis. This may create unique spatial patterning in the brain (Brown et al. 2006) and allow PwP to access alternative neural motor pathways to the affected basal ganglia (Mink 1996), thus improving functional turning performance. The training of axial rotation in dance may also be linked to the argument for potential motor training to elicit neuro-plastic changes (Nudo 2013) and re-organisation in the pathological brain (Farley et al. 2008), as greater effect on improving balance and reducing freezing of gait have been shown through meta-analysis of results in dance than exercise alone (Sharp & Hewitt 2014), possibly due to the rotational aspects of the dance, with traditional exercise therapy rarely including specific rotational components (Keus et al. 2007). Thus the repetitive practice of turning and rotation in dance is likely to drive neuro-plastic adaptations such as synaptogenesis, axonal sprouting, re-organisation of ‘motor control maps’ in the homunculus and up- or down-regulation of neuro transmitters to improve motor output (Nudo et al. 1996). This would have the resultant effect of improved turning performance, as the functional organisation of the motor cortex is constantly reshaped by behavioural demands for the learning of motor skills (Nudo 2013).

Therefore, it is likely that the specific training of the movement of the feet and the rotation of the body together during turning steps in all directions through dance in this study enabled a dual-training effect, coordinating the top-down/bottom-up control system and thus reduced the degrees of freedom and complexity of the turning task.

Considering the specific mechanisms that this alteration in motor control may come from, research suggests there are five key principles of activity that enhance neuroplasticity in relation to PwP, the presence of which may slow progression of the condition; 1) intensive activity that maximises synaptic plasticity; 2) complex activities that promote greater structural adaptation; 3) rewarding activities that increase dopamine levels and promote learning/re-learning; 4) stimulation of dopaminergic neurons that are highly responsive to exercise and 5) introduction of activity early in the disease process (Fox et al. 2008). The dance intervention undertaken in this study was indeed intensive (1) and repetitive in its practice of the specific task of turning, which was practiced through inclusion in dance steps making it complex (2), but functional. The act of dance and thus turning practice was also enjoyable and rewarding (3), as evidenced by the qualitative interviews from the RfPB study, all of which would have brought about stimulation of dopaminergic neurons (4), driving greater neuro-plastic adaptation, than functional practice alone (as in the controls).

The lack of a potential ‘training effect’ in the controls may allow the development of disassociation between the axial and perpendicular segments, owing to disease progression and resultant loss of coordinated motor control. Whilst there are no previous studies investigating the deterioration of the specific symptoms of turning in PwP, longitudinal studies of general deterioration provide evidence for a variable course of progression for each of the different symptoms associated, with deterioration rates increasing with those diagnosed at an older age (Jankovic & Kapadia 2001). The complexity of symptom presentation makes it difficult to suggest if the observed changes in the controls in this study are representational of the population, however evidence suggests axial and postural symptoms evolve more rapidly than other motor features and appear to be the best indicators of disease progression (Evans et al. 2011). In addition, significant deterioration of measures of gait and over-all disease severity has been shown in PwP over the same time period (Hackney & Earhart 2009a). Therefore, the observed disassociation of axial and perpendicular segments in the control group in this study appears plausible. The possible deterioration presents the expression of a two-fold impairment; one being the deficiency of the basal ganglia to drive body orientation in space (Vaugoyeau et al. 2006) and thus segment initiation, with a resultant deterioration of top-down control and; two, the reduced capacity of the body to generate ground reaction forces owing to the impaired extensor muscle activity and ankle strategy (Vaugoyeau et al. 2006), impairing the bottom-up control. The importance of coordination of body segments during turning has previously been demonstrated by Peterson et al. (2012), showing coordination in complex tasks to be associated with severity of freezing scores and more freezing episodes during turning. In a turn, an increase in freezing has also been associated with increased perceived difficulty and a higher incidence of falls (Stack et al. 2006), highlighting the clinical and functional importance of segment coordination.

The performance of two separate motor commands would also require the need to dual task; an activity known to be challenging for PwP (Morris 2000) and thus a likely reason for the bradykinesia and increased delay between the pelvis and feet seen in the controls in this study. Developing the two systems through task-specific practice of turning the body and feet together during dance steps such as the ‘New York’ in the cha cha cha (stepping the feet across each other and turning the body) (see Appendix 10), may enable coordination to remain between the two motor control systems and an ability to dual task, even if improvements over natural deterioration are not shown.

The influence of the type of turn also appeared to change the observed direction of difference over time in controls, with the latency of the head, pelvis and feet being slower in predicted/preferred turns and faster in predicted/un-preferred turns as discussed (Figure 22). Whilst this consistent pattern of change across all segments, in any turn type (Figure 22), suggests the preservation of the ‘en bloc’ patterning and coordination of axial and perpendicular sections in the controls, the changes in the head and pelvis were greater than those in the feet and thus the two sections became split (Figure 23). As dancers showed minimal change over time compared to controls (Figure 22 and 23), the pattern of change does not appear to exist throughout the segments. This again supports the notion that dance may enable accommodation for the differing turn types and maintain pre-assessment performance irrespective of how challenging (un-preferred or un-predicted) the turn direction may be.

In addition to the possible internal adaptations in motor control through task-specific practice in the dancers, the external influence of cueing is also likely to have had an effect. The positive influence of cueing in PwP has been well reported in the literature (Nieuwboer et al. 2007) and supported by its recommended use in the recent European physiotherapy guidelines for Parkinson’s disease (Keus et al. 2014). Cueing may be beneficial to PwP by utilising the intact pre-motor cortex of the brain rather than the deficient, supplementary motor cortex and basal ganglia (Morris 2000), with auditory cues showing the greatest effect in improving turning performance in PwP (Nieuwboer et al. 2009). Therefore, those who received the dance intervention in this study would have practiced turning in time to the musical cue, thus providing an auditory cue to perform the turning step. Whilst the use of auditory cueing has been shown to be beneficial in improving turning performance in PwP (Nieuwboer et al. 2009), the effects reduce dramatically after removal of the cue (Spildooren et al. 2012). This suggests the training effect of musical cues during dance sessions may improve turning performance during dancing, but it is the repetitive, task specific practice of that improved turning that may drive a neuro-plastic adaptation of motor control over time, as music was not played during the post-assessment sessions. Thus the improvement in the coordination of initiation of segments in response to the light cue (but absence of the auditory cue) during the post-assessment was seen.

In addition to the auditory cue from the music, the visual and tactile cue from a partner by either turning themselves in time to the music, or facilitating a turn in PwP by hand and body guidance, would have also initiated turning and thus enabled practice of challenging turning types for PwP in a safe and controlled environment. This is particularly important when considering the integration of motor and interpersonal performance skills in partnered dance, which involves tightly coordinated interpersonal movement, with stronger functional mobility and balance outcomes than non-partnered dance due to the presence of dual task training (Batson et al. 2010; Hackney & Earhart 2010c). When considering that dual task activity performance (particularly related to balance), is also responsive to training in which both cognitive and motor performance skills are integrated within the activity (Morris 2010), the role of the partner may be multi-dimensional, including physical support, dual tasking, and cueing. Those in the control group would not have practiced coordinated segment turning with the aid of such cues and thus the observed separation in axial and perpendicular segments developed.

Despite a pattern of change being shown in the head, pelvis and feet of the controls, there was no change detected in the latency of the shoulders or thorax in either groups over time despite both being either the first or second segment to move following the cue (Table 16). The majority of papers discussed do not report shoulder and thorax segment latency separately, instead grouping them with the pelvis as 'trunk' rotation in total, thus making it difficult to compare with these results. However, an increased coupling between pelvis and shoulder rotation (Vaugoyeau et al. 2006), and thorax and pelvis (Huxham et al. 2008b), specifically in PwP compared to controls has been shown, which is reflected in the similar patterns of change shown in the descriptive statistics between the pelvis, shoulder, thorax and head in controls over time in this study. The lack of significant difference between the time frames for either groups in the shoulders and thorax, but significant change in the head and trend in the pelvis (Figure 22, Table 12 and 13), may reflect the importance of the pelvis and head in driving a turn. The head acts as the influencing segment in 'top-down' control owing to the vestibular mechanisms of maintaining a neutral head position in space (Mergner et al. 2003), with the position of the pelvis being the influencing segment of the bottom-up control owing to the location of the centre of gravity within it (Vaugoyeau et al. 2003). However after training of both systems through dance, movement control may be dispersed throughout the segments, providing a possible reason for the lack of difference observed in all segments over time in the dance group.

The lack of significant difference in eye latency (Figure 22) is also surprising given the larger importance of the eyes in turning performance in PwP compared to healthy controls, demonstrated by Anastasopoulos et al. (2011) using principal component analysis. One would expect that the changes in the head, pelvis and feet shown over time in the control group would also be reflected in the latency of the eyes, owing to the use of the same neural circuitry (Cameron et al. 2013). However no change was shown in either group over the time frame of this study. When measuring eye performance specifically following dance intervention in PwP, Cameron et al. (2013) found no change in anti-saccade performance (wilful eye movements away from a visual stimuli), but a detrimental effect on pro-saccade eye performance (highly automatic eye movements looking towards a visual target). When considering the method of measuring eye latency in this study as a visual cue (illuminated left/right arrow) to initiate a turn away from the light, it can be considered that latency in this study was a measure of anti-saccade movement and thus findings are in agreement with those of Cameron et al. (2013). These findings fit with the theoretical framework proposed by Mink & Thach (1991), suggesting one of the roles of the basal ganglia is to ‘switch off’ postural mechanisms that would otherwise interfere with voluntary movement. This can be used to describe the necessary switching of axial musculature from postural to kinetic control required during turning, a movement control pattern affected in PwP resulting in bradykinesia. Thus, it is conceivable that eye movements that do not compete with postural or voluntary movement would not be regulated in such a way by the basal ganglia, and thus shows no modification through dance.

However, it is also possible that the use of a light to initiate the turn may have provided an external visual cue to respond to, which is known to be beneficial in turning performance for PwP (Nieuwboer et al. 2007). This may have negated the changes brought about by dance by standardising the behaviour of the eyes across both assessment period and group. In addition, eye latency data were manually extracted from a visual trace of horizontal eye movement, which may have resulted in greater human error than the standardised pre-programmed system used to extract the latency of all other body segments. This is reflected in a reduced intra-class correlation coefficient of eye latency data. Due to these limitations, whilst in agreement with previous literature, the results of eye latency performance following dance in this study should be treated with caution, and further research is required.

The possibility of an overall greater coordination between the segments in dancers compared to controls as discussed is summarised by the average sequence and timing of initiation across all turns (Table 16). After dance, the head moves from third in sequence to second, with a more evenly spaced delay between segments than prior to dance. However, in the controls the head remains third in the sequence and the delay between each segment is varied. This demonstrates that whilst dancing does not appear to affect the latency of the individual segments over disease progression as discussed, it does affect the sequence and coordination of segments as a whole. It is important to note that this is a descriptive analysis of the mean latency of segments averaged across all turn types and therefore caution must be taken in extrapolating these results outside of this sample. It does however, demonstrate the changes between the two groups over the time frame of this study.

In summary, body segment latency did appear to be affected by a dance intervention when comparing the changes observed over time in control participants to those in the dance group. The greatest change appeared to be in the head, with trends shown in the pelvis and both feet. Most importantly, the changes shown in the control group suggest a split in the timing and coordination of the axial and perpendicular segments in their initiation to turn to a cue, which is not observed in the dancers. The main effect of dance may therefore be to maintain or potentially increase the 'en bloc' coordination across all segments, in both the axial and perpendicular sections of the body. This has the resultant effect of reducing the degrees of freedom of movement thus the complexity of the task and coordinates the 'top-down/bottom-up control' of segments during the turn, all of which are lost in the two-phase impairment expressed by the controls. The influence of turning to the preferred or un-preferred direction over time appears only to be expressed when the influence of prediction is stable and only in the control group. The lack of influence of prediction or preference over time in the dance group suggests dance may also provide a strategy to accommodate for changes in the difficulty of the turn. These results are, however to be treated with caution owing to the lack of significance in the results for latency of the feet and pelvis and the surprising lack of difference shown in the shoulders, thorax and eyes.

7.3 Body segment rotation

The key findings of a change in sequencing and coordination of the segment timing during turning in PwP after dance intervention has been discussed, demonstrating the behaviour of segments at the initiation of a turn. However, once initiation has occurred and the sequence is established, it is the subsequent amount of rotation that each segment undergoes that will indicate the relationship of the segments during the turn.

The measure of body segment rotation taken in this study demonstrated the amount of rotation each segment underwent from the point of initiation to the first foot movement and is shown in Section 6.4. This was designed to provide a measure of 'rotational wind-up' of the axial segments (head, shoulders, thorax and pelvis) prior to a 'release' by movement of the perpendicular segments (feet).

A significant difference was found in the amount of pelvis rotation, between groups, over time, with analysis of descriptive statistics demonstrating greater rotation in the control group compared to the dancers (Table 17). As in segment latency, the type of turn again made a difference to the direction of effect, with an increase in pelvis rotation in both conditions where turns were to the un-preferred direction and a decrease in rotation in preferred conditions. In contrast to segment latency, this suggests preference to be the more dominant variable to segment rotation in controls than prediction. The presence of an increased rotation in both un-preferred conditions (Table 17) suggests that an increase in rotation may be a compensatory strategy necessary to achieve turns to more challenging conditions, as previous research has reported turning difficulties are greater to the un-preferred direction compared to preferred (Stack & Ashburn, 2008). In addition, it has been shown that turns to the un-predicted direction are also more challenging for PwP (Ahmad 2012), thus the large increase in pelvis rotation in the controls in un-predicted/un-preferred turns (Table 17) supports the theory of greater pelvis rotation being a necessary consequence of achieving a more challenging turn. As with segment latency, the influence of prediction and preference over time in the controls becomes important when compared to the smaller differences and reduced rotation shown in the dancers over time. In comparison to the large increase observed in un-predicted/un-preferred turns in the controls, the dancers showed a small decrease in their pelvis rotation over the same time period (Table 17), suggesting the dancers found typically challenging turns in the un-predicted/un-preferred direction less challenging than the controls when compared over time.

Previous literature predominantly reports a reduction in body segment rotation in PwP compared to healthy controls (Akram et al. 2013a; Crenna et al. 2007;

Hong et al. 2009), owing to a specific deterioration in the maintenance of amplitude due to basal ganglia dysfunction (Farley et al. 2008). As discussed in Chapter 4 of this thesis, this potential reduction in axial segment rotation is also likely to contribute to perpendicular deficits, such as multiple stepping and changes in turn strategies (Hulbert et al. 2014). It is surprising therefore; that the controls in this study increased their pelvis rotation over the time frame despite not receiving intervention and the dancers maintained or reduced theirs. One would have expected the task specific practice of trunk rotation, through specific components of dance such as maintaining hold whilst in promenade in the Ballroom tango (see Appendix 10), to improve trunk rotation, particularly in the pelvis and thus make turning performance in PwP closer to that of healthy controls.

However, as with segment latency, it is again necessary to consider these results in relation to the behaviour of the other body segments, as purely reporting on one segment in isolation is not representative of the whole body turning performance. Although not significant, results across all turns combined indicated that all segments in the control group in fact increased their rotation in comparison to all segments in the dance group reducing their rotation, up to the point of first foot movement (Table 18). When considering the reported findings of an increase in pelvic latency (although not significant) (Table 13) and dissociation of the pelvis from the first and second foot movement (Figure 23), the increase in pelvis rotation (Table 17) (and all body rotation (Table 18)) becomes less surprising. The earlier initiation of the pelvis and closer coupling with the head in the controls compared to the dancers would allow a greater time for rotation prior to the first foot movement. In comparison, the closer linking of the feet and pelvis in the dancers would provide less time for the pelvis to rotate prior to the first foot movement. These results, therefore, again support the theory of a split in the top-down/bottom-up control system in the controls (main finding from latency data), compared to a coordinated combined turn with reduction in the degrees of freedom and thus complexity of the task in the dancers.

The closer coupling of the pelvis with the head and shoulders, and thus earlier initiation and greater time period available for rotation is one plausible reason for the increased rotation observed in the controls over time. However, it can also be suggested that the increased rotation may in fact be causing an early initiation of the pelvis and coupling with the head, as a direct result of changes in the motor control of the segments. Whilst the majority of literature reports a reduction in pelvis rotation in PwP (Akram et al. 2013a; Crenna et al. 2007; Hong et al. 2009), Huxham et al. (2008), also surprising reported an increase in pelvis rotation when taken relative to the corner of the room rather than over each footstep as in other studies. The authors suggested a possible reason for this apparent increase in absolute rotation was the presence of a separate motor command controlling rotation over all other aspects of directional change. This is indeed plausible considering the deficits found in head and trunk rotation in turning in PwP, with the absence of gait and balance abnormalities (Crenna et al. 2007). Caution must be taken however when relating the results from Huxham et al. (2008) with those of this study, as they are concerning walking turns, rather than the standing turns used in this study. Indeed, Akram et al. (2013a), using the same method of assessing rotation as in this study, also found a reduction in the early magnitude of rotation in PwP compared to healthy controls, suggesting a reduction in rotation to be a less favourable condition.

It therefore appears that the increased rotation in the pelvis seen in the controls over time in this study (Table 17) may be a result of both changes in segment coordination as demonstrated by altered segment latency over time and a resultant change in motor control of the rotational aspects of the turn. This may result in a reduced efficiency of the rotational force within the trunk, forcing the pelvis to rotate to a greater extent over each footstep to drive rotation of the other body segments above and below. The maintenance of the ‘en bloc’ coordinated control of the dancers, allows the rotation to be dispersed throughout the segments in an efficient top-down sequence and thus excessive rotation of the pelvis is not required to drive the turn. The observed reduction in pelvis rotation in the dancers (Table 17) may therefore also be due to both a reduction in the available time to rotate, owing to the closer coupling of the pelvis to the feet (Figure 23) and the preservation of an ‘en bloc’ motor command to reduce the complexity of the task.

The mechanisms by which dance affects rotation are likely to be similar to those bringing about a change in latency, with a task specific, repetitive and salient practice of turns to all directions driving neuro-plastic adaptation against the continued progression of the condition. Specifically, the use of the ballroom hold (see Appendix 10) results in the upper body and pelvis being held in a reasonably fixed position by both partners remaining opposite each other and the feet moving below. This is particularly the case in beginners where the contact between the bodies of the dancers and drive from the hips is not developed, owing to the focus being on the feet and the steps needing to be performed. In order for turns to be achieved, therefore, the feet must drive the turning momentum and thus remain tightly connected with the body. In this respect the pelvis is not driving the turn, as is potentially the case in the controls, but the feet are, and thus the observed relative increased speed (owing to greater number of steps in same time frame) of the feet and less or minimal rotation of the pelvis develops.

In order to discuss the hypothesis of a 'wind-up release' presentation between the axial and perpendicular segments being affected by dance, it is necessary to link the changes in body segment latency and rotation discussed to the number of footsteps in the turn.

Results from this study did not find a significant difference in the number of steps to complete the turn between the dancers and controls over time, however descriptive analysis highlighted a small increase in the mean number of steps taken after dance (Table 20). The increase in steps correlates with the hypothesis of a more 'en bloc' pattern of segment control and closer coupling of the perpendicular and axial segments as suggested by the main findings of segment latency and rotation. It would appear that the necessary increase in the number of steps for the dancers is therefore a negative effect of dance, as literature has consistently demonstrated a greater number of steps in PwP compared to healthy controls in both clinical measures (Ashburn et al. 2001; Stack & Ashburn 2005; Stack et al. 2006; Stack & Ashburn 2008) and using 3-dimensional movement analysis (Crenna et al. 2007; Earhart et al. 2007; Huxham et al. 2008b; Hong et al. 2009; Spildooren et al. 2009; El-Gohary et al. 2013). However, again when the increased number of steps (Table 20) is considered alongside the closer coupling shown from segment latency (Figure 23), relative minimal change in segment rotation (Table 18) suggesting a link between the axial and perpendicular segments, and the absence of change in the total time to complete the turn over the same time period (Table 21), the apparent negative effects can be argued. It appears that the greater ‘en bloc’ presentation of the axial segments following dance is linked to the quicker release of the feet, therefore enabling a greater number of steps in the same amount of time. What is unclear is whether the quicker release of the feet is causing the reduced segment rotation in the dancers, owing to a reduced amount of time between the initiation of movement of each segment and the first foot movement, or the closer coupling of segments and linking of the axial and perpendicular segments is causing the feet to release quicker? Whilst both suggestions are plausible, the findings of the literature review in Chapter 4 depict the presence of axial deficits driving perpendicular adaptation (Hulbert et al. 2014). This suggests the changes in axial segment latency, rotation and control as a result of dance, are enabling a coordinated quicker release of the feet, supported by the trend of an increased latency in both feet and an increased number of steps. Thus, whilst many steps to turn is considered a deficit of turning in PwP, in this instance many, faster steps may not seem as inefficient as previously thought, particularly if this allows greater coordination of the body as a whole, and therefore improvements in bradykinesia and the potential to freeze following dancing.

In addition, but again descriptive in nature, the greater adoption of ‘incremental’ and ‘delayed’ turn styles from the SS180 in the dancers over time, compared to the controls (Figure 26 and 27), also supports the main finding of a tighter coordination and coupling of the axial and perpendicular segments. Both turn types are described as turning on the spot and having a greater number of turning steps compared to ‘pivotal’, ‘lateral’ or ‘towards’ turn styles (Stack & Ashburn, 2005). The tighter coupling of the axial and perpendicular segments would result in a greater number of steps to turn and turning on the spot, however, neither of which resulted in an increase in the amount of time taken to turn (as one would expect). This again supports the idea of dance allowing a quicker release of the feet and closer linking of the axial and perpendicular segments.

In summary, it appears that body segment rotation did appear to be affected by a dance intervention when comparing the changes observed in the control participants to those in the dance group over time. As with segment latency, the greatest change over time was observed in the control group, specifically showing a large increase in the amount of rotation of the pelvis in comparison to a reduction in the dancers. This pattern was replicated across all segments when all turns were considered together. The influence of prediction and preference also again appear to make a difference to the direction of effect, with an increase in rotation of the pelvis in the controls over time in un-preferred conditions. This suggests, in contrast to latency, preference is the more important variable to rotation of body segments in turning compared to prediction, with dance again appearing to stabilise this difference, making all turn directions comparable. Again the changes observed support the theory of a top-down/bottom-up split in the axial and perpendicular segments in the controls, with the pelvis driving the turn in an attempt to link the two segments in comparison to the maintenance or indeed purposeful adoption of an 'en bloc' coordinated control in the dancers. Despite the collaboration of results in segment rotation with the main findings of greater co-ordination in segment latency, the high variability of pelvis rotation and the reduced inter- and intra-class correlation suggest these results should be treated with caution and extrapolation beyond the sample may not be justified. However, the importance of multivariable analysis has been demonstrated and thus warrants the need for further research as suggested in Chapter 8.

7.4 Balance

All measures of balance were designed and tested through the feasibility study (see Appendix 3) in order to indicate the effect of a potential change in the ground reaction forces brought about by potential changes in the axial and perpendicular segments following dancing in PwP. It is only by commenting on all three aspect of turning kinetics (latency, rotation and force) that we are able to truly identify the impact that dance may have on turning ability in PwP. Results from the variables of balance are shown in Section 6.5 or the results.

It is well known that PwP demonstrate postural instability whilst turning (Stack et al. 2004) and find it difficult to transfer their weight within their base of support (Morris 2000; Bonnet et al. 2014). Despite differences being identified between PwP and healthy controls during the feasibility study, no significant differences were found in this study between the dancers and controls, over the time frame or across the different turn types, for any of the direct measures of ground reaction force (weight transfer in the medial/lateral (M/L) and anterior/posterior (A/P) direction, stance width and total weight transfer). Despite this, descriptive statistics suggest a small increase in weight transfer in the M/L direction following dance (Figure 25). Although not significant, this finding is interesting, considering the specific deficit in the M/L axis found in PwP compared to healthy elders following voluntary weight shifts (Bonnet et al. 2014) and suggests an improved ability to shift weight between the feet in the M/L movement plane following dance. In addition, the greater delay between the onset of movement of the body centre of mass and foot movement found in PwP compared to controls (Mak et al. 2008), suggests the delay between the axial and perpendicular segments demonstrated in the controls in this study may also represent a loss of coordination of the centre of mass with the rotating body segments. This may therefore result in a greater likelihood of a loss of stability, as the centre of mass moves away from the base of support.

It has also been suggested that the reduced transfer of weight between the feet may be responsible for the increased number of steps when turning in PwP compared to controls (Stack & Ashburn 2008), owing to a decreased ability to load each foot in order to take a sufficiently large step with the other to rotate the body. However, when considered alongside the small increase in the number of steps (Table 20), no increase in the time taken to turn (Table 21), and the shift to ‘incremental’ and ‘delayed’ turn styles in the SS180 (Figure 26 and 27) following dance, the small increase in M/L weight shift in this study (Figure 25) does not appear to agree with the literature. It may be that the reduced weight transfer demonstrated in PwP compared to healthy controls (Bonnet et al. 2014) is a result of the disorganised rotation of body segments, making effective weight transfer challenging when segments are not turning in synchronisation, as is the case in the controls in this study. Indeed, Bonnet et al. (2014) demonstrated a reduced velocity and amplitude of the head, neck and lower back in PwP compared to healthy elders, which did indeed limit the performance of a voluntary weight shift task in the M/L direction. Following dance, the 'en bloc' presentation, whilst resulting in a reduction in amplitude over the first step, maintained the velocity and sequence of each segment. This is demonstrated by the lack of change in total time to turn (Table 21) and closer coupling of the pelvis and feet (Figure 23) (as discussed in Section 7.2), allowing greater coordination of the axial and perpendicular segments and thus a more efficient transfer of weight between the feet. This in turn enabled quicker release of the moving foot, as demonstrated by the results of more steps (Table 20), seen in the same turn time (Table 21) in the dancers in this study. As suggested in Chapter 4, the strategy of increased turning steps (and shift to 'incremental' and 'delayed' turning style) may indeed be a compensatory mechanism for postural instability, in order to maintain the rotating centre of mass (head and trunk) within the base of support (stance). This therefore may be a learnt adaptation by exposure to turning through dance and may in fact be a useful rehabilitation tool, rather than the negative effect reported by previous literature when looking at step number alone.

The evidence of disturbed electro-myographical activity of the lower leg muscles and loss of organisation of muscle activation causing complex changes in muscle firing patterns in PwP during gait (Dietz et al. 1995), supports the suggestion that a greater coordination of this system may enable a more efficient weight transfer and thus foot release in the dancers. This again, supports the idea of axial deficits driving a perpendicular change, with possible improvements in the coordination of the axial segments following dance, reflected in trends towards improved weight transference and resultant foot step patterning. Whilst the literature presented appears to support the effect of dance in driving a more efficient M/L weight transfer and thus foot release, caution must be taken when extrapolating this literature to the results of this study due to the differences between the automaticity and neural control of gait compared to a turning task.

The possibility of an increase in efficiency of weight transference can also be justified by absence of change in stance width (Figure 25). An increased stance width in PwP is a compensatory strategy to maintain the centre of gravity within the base of support (Huxham et al. 2008a) and has been shown to be a secondary compensation for a lack of lateral stability (Horak et al. 2005). The absence of change in stance width, despite an increase in M/L weight transference, suggests that the dancers became better able to tolerate the limits of stability in the M/L direction, without the need for compensation by stance width. The fact that the measure of M/L weight shift was recorded as a percentage of stance width also supports this, as the measurement is proportional to stance width.

Finally, it is not only the adaptation of neural control that may result in greater weight shift, but as with segment latency and rotation, the repetitive practice of shifting weight between the feet during dance practice. This is particularly the case in Latin American dances where side stepping is widely used (see Appendix 10), which would have brought about adaptation of performance owing to task-specific practice driving a neuro-plastic response to the training (discussed in Section 7.2).

It is important to note that whilst the relationship of axial segment behaviour, weight transfer and step number is interesting, changes in both step number and weight transfer following dance are non-significant and are minimal when considered clinically, however this may be due to limitations of the study (discussed in Section 7.6).

As well as the specific measures of ground reaction force, the global position of the centre of pressure at the point of first foot movement was also recorded to give an indication of the position of weight distribution (Table 19). Based on biomechanical principles, it is assumed that people are most unstable to backward body displacements since it is more difficult to exert dorsiflexion, than plantar flexion torque about the ankles (Winter et al. 1998). A study of the circumstances of falls in PwP found loss of balance following turning to most likely occur in the backward or sideways direction (Stack & Ashburn 2008), with specific reduction in the margins of stability found in both backward and lateral sway (Horak et al. 2005). The increased percentage of people with their weight in the anterior portion of their stance, at the point of first foot movement, following dance in this study (Table 19), suggests an anterior shift during turning occurs in more PwP following dance than not. This may enable greater stability in the posterior direction, as greater translation of the centre of pressure is available prior to over-reaching the limits of stability, resulting in a loss of balance in the posterior direction.

It is unclear how dance enables this shift, however, it may be the use of a partner being in front of the participant and thus encouraging them to transfer their weight forwards towards the safety of the partner's support. The repetitive practice of moving and turning with the support of the partner in front may have therefore had an impact on the perceived position of stability for PwP. Whilst turning was measured independently (without a partner) in the pre- and post-assessments, it is possible that this adaptation of a 'safe' body position may have continued outside of the dance environment.

When considered alongside the small increase in medial/lateral weight shift, both results suggest dance may improve stability, particularly in the directions that have been previously shown to be most deficient in PwP (Horak et al. 2005; Stack & Ashburn 2008), however further research is required due to the lack of significant results in this study.

Despite the suggested improvement in stability following dance in measures of force, changes in the clinical measure of balance were not identified, with no difference in measure of the BBS between the groups (Table 22). This is not surprising considering the specific nature of the measures of force behaviour for each individual, compared to the general measure of balance taken by the BBS, as both the kinetic adaptations reported following dance would have been difficult to identify in a clinical situation and were non-significant. In addition, the BBS has been shown to have a ceiling effect (Keus et al. 2014) and therefore less likely to identify changes in balance following dance in this sample owing to their mean H&Y score being less than 2 (bilateral or midline involvement, no impairment in balance). Whilst previous studies have identified an improvement in balance using the BBS following ballroom dance in PwP with a H&Y score of 1-3 (Hackney & Earhart 2009a; Hackney & Earhart 2009b; Hackney & Earhart 2009c), all studies used an assessor that was un-blinded to the randomisation of participants and thus results could have been influenced by bias and should be treated with caution. However, when considered alongside the results from this study, it does suggest the specific trends and possible multi-system effects reported may have a clinical impact on balance that failed to show in this study due to the limitations of the BBS.

In summary, specific measures of force did not show a difference between the groups, over the time frame or across different turn types, however descriptive statistics demonstrate a small increase in M/L weight shift in relation to stance width following dance. It is suggested that this may be due to the main finding of an increased coordination between the axial and perpendicular segments owing to adaptations in segment latency and rotation following dance, enabling a more efficient weight shift. This, in turn, allows a faster release of the moving foot and thus enabling a greater number of steps in the same turn time. It may also be that the increase in weight shift is a result of task-specific practice and neuro-plastic adaptation following intensive practice, owing to the large proportion of Latin American dances incorporating lateral weight shift and side stepping.

Results also indicated that a greater number of participants held their weight in the anterior position of their stance, possibly due to the presence of a partner. This may have the resultant effect of increasing stability in the posterior direction by increasing the distance available for the translation of the centre of pressure before reaching the limits of stability and thus loss of balance. Whilst both results are interesting, caution must be taken as significant differences were not found, limiting the analysis of these findings beyond the results of this study.

7.5 Summary

The results discussed demonstrate that body segment latency, body segment rotation and balance (as a combination of force variables), alongside clinical measures of turning (SS180), are affected following ballroom and Latin American dance in PwP. Through discussion, the interaction between these variables and the resultant impact on turning performance in PwP has been suggested, however many results did not reach the required significance level, making extrapolation beyond this study challenging.

Results suggest changes in the controls over time showed slower initiation of the head and feet and faster initiation of the pelvis. This suggests a closer linking of the axial segments of the body (head and pelvis) and a disassociation with the perpendicular segments (feet). Alongside this, greater rotation of all body segments, but specifically the pelvis was shown, with weight distribution more often in the posterior position of the base of support. The changes found in the control group are meaningful when compared to the minimal change in initiation of segments, overall reduction in the amount of rotation of segments and slight increase in the number of steps shown in the dancers, suggesting a closer linking of the axial and perpendicular segments together. Slight increases in the M/L weight transfer and weight distribution, more often in the anterior position within the base of support was also found in the dancers, suggesting dance to have a multi-segment effect.

Synthesis of results across all variables suggests the key finding of those who danced were better able to coordinate their axial and perpendicular segments, with a reduction in the complexity of the task and thus maintain efficiency. The exact mechanism by which this may have been achieved have been hypothesised, with suggestions of task specific, repetitive and salient practice of challenging turning conditions, using mechanisms such as cueing to drive neuro-plastic adaptation and thus prevent deterioration caused by the progressive nature of the condition. As a result, those PwP that danced surprisingly appeared to become more ‘en bloc’ in their turning behaviour. Whilst this was previously suggested to be a maladaptive result of the condition, results discussed suggest this may be a beneficial adaption to stability, stepping speed and coordination of body segments and thus efficiency of a turn for PwP.

7.6 Limitations

Despite consideration of the study’s research design through the inclusion of a feasibility study, it was not possible to control for some limitations. These are discussed in detail in this section with further consideration of the impact they may have had on the results and conclusions drawn.

7.6.1 Bias

Efforts were made to reduce the influence of researcher bias on the extraction process (the area with greatest potential for influence), with the researcher remaining blind to the group allocation of each participant in the extraction of data. However, during the data collection process at the post-intervention assessment, the researcher was aware of the group allocation (owing to her involvement in the RfPB study as a research assistant at the dance centre) and the participant was obviously aware of their group allocation and thus an opportunity to bias the process was available. This was over-come with strict protocol and written script for each participant ensuring all were treated the same, however the participant and researcher were more familiar with each other if the participant was from the dance group owing to a greater time spent together, and thus the participant may have 'wanted' to change their turning style to demonstrate the influence of dance and to please the researcher. Future studies should consider a blinded assessor for both the data collection and data extraction processes.

7.6.2 Variable multiplicity and design

Due to the lack of previous data on the effects of an intervention on turning ability in PwP, this study was explorative in nature. This meant that many variables were assessed to give a broad understanding of the effects of dance, with the resultant necessity for multiplicity testing. An appreciation of the effects of multiplicity was taken through statistical analysis by using four-way ANOVAs rather than multiple T-tests. However, this may have prevented subtle differences from being detected. Future work may wish to consider the inclusion of factor analysis such as principal component analyses (PCA) to reduce the variable numbers in turning performance and thus reduce the impact of multiplicity; unfortunately this was outside the scope of this thesis due to the sample size.

In addition to the analytical implications of multiplicity, the practical implication of data management and extraction also presented a limitation. When analysing multiple variables as in this study, consideration must be taken of the time and work load involved in extracting and processing large volumes of data, and as such a reduction of variables would also put less of a strain on resources.

7.6.3 Sample

It was not possible to complete a power calculation prior to the study as no previous studies had used a similar set of measures to assess the impact of an intervention in turning performance. Therefore the sample size was based on previous research comparing PwP and healthy controls. It is likely that the trends in results found in this study were a result of under-powered analysis (owing to an appreciation for multiplicity) and the possibility of a type two error cannot be ruled out. The use of methods such as PCA or factorial analysis to reduce the number of variables assessed, whilst maintaining an appreciation for the multi-model presentation of turning in PwP, would reduce the influence of multiplicity in future studies. However, it is likely that such methods will require substantial numbers themselves in order to run the level of analysis required, with suggestions of a minimum of 15 participants per variable or total numbers greater than 50 considered necessary for PCA analysis (Osborne & Costello 2004) (although sample size for such analysis is debated in the literature). With a reduction in variables, it would then be possible to identify the primary variables in turning performance with an appreciation for the impact of all variables for PwP, and thus a power calculation for future studies could be completed.

Despite the need for formal identification of a primary variable through methods of variable reduction as suggested, it is possible to justify the selection of some variables from the results of this study and therefore produce a suggested sample size for future studies. As the results of this study suggest, the impact of head, pelvis and foot latency alongside pelvis rotation can be used to describe some of the relationship between variables of turning performance in PwP and possible differences following a dance intervention. Effect sizes for each variable were calculated, demonstrating that a significant level of 5% at 80% power, required a total sample of 128 (64 in each group) to detect a standardised effect size of 0.5. Whilst this is a much larger sample than this study, alternative methods of data extraction (discussed in section 7.6.5), may allow a sample of this size to be feasible in future.

In addition, the sample size in this study did not permit sub-classification by disease severity (H&Y score), gender or disease duration, which makes the assumption that all disease severities are affected by dance in the same way. Subsequent analysis from the RfPB study identified significant positive effects of dance on the BBS and balance confidence following sub-classification in favour of those with longer disease severity and males, neither of which were present in full data analysis (Ashburn et al. 2014(unpublished data)). This demonstrates the influence of sub-classifications, which may have been missed in this study.

7.6.4 Data collection

Independent, static, 180 degree turns were selected for analysis in this study owing to their functional relevance, need to gain data from the force plate (more difficult in walking turns) and link with data collected from the SS180 clinical measure. This however, makes the assumption that standing turns will be affected by dance, which when considering the majority of dance steps practiced during the intervention period were partnered, walking turns, there is the possibility that the measure may not have been sensitive to the specific changes brought about through dance practice. In addition, dance intervention requires cognitive focus to remember the steps and physical function to perform the steps. The data collection procedure did not assess the impact of cognitive challenge on turning performance and thus the possibility of task specific improvement in dual tasks (known to be challenging for PwP) could not be demonstrated. Future studies should include static and walking turns, with and without a cognitive task to fully represent the training effect brought about by an intervention.

It would have also been useful to collect a self-reported measure of turning to link the perceived effects of the intervention with the physical outcomes. Many of the participants in this study, reported through conversation with the researcher, that they felt their turning was better after dancing (un-reported data), but this was not recorded or measured in a standardised way to enable a link to be drawn with the hypothesised physical improvements. Future studies may wish to collect this data through a questionnaire basis or interview.

7.6.5 Extraction process

The method of extracting data from Coda has been standardised by a pre-programmed system using Excel for the measurements of segment latency and angle. The programme identifies all points that meet the pre-selected criteria in a set of data, and the correct data point is then identified and recorded by the researcher. Whilst this method enabled the correct selection of data through human interaction rather than automatic selection, it was labour-intensive with the possibility of human error. It was for this reason that an inter-class correlation coefficient analysis was performed, which did identify variability in pelvis latency (ICC(3,1)= 0.93 (95% CI [0.86,0.96])) and start angle (ICC(3,1)= 0.87 (95% CI [0.76,0.93])). These differences were probably due to the large range and variability in the pelvis data across the sample, which is important to consider when discussing the significant difference in pelvis rotation and trend in pelvis latency found.

In addition, it was not possible to extract eye data through the same system, thus manual extraction of eye latency for each turn was necessary. Again, this was time intensive and had a large element of human influence and possible error as indicated by the inter-rater (ICC(1,1)= 0.85 (95% CI [0.68,0.91])) and intra-rater (ICC(3,1)= 0.92 (95% CI [0.84,0.96])) correlation coefficients, that are lower than those found for all other segment latency (ICC (1,1) = 0.87-1 (95% CI[0.76-1])).

The use of more sophisticated extraction processing using computer software such as 'Matlab' should be used in future. The researcher of this study was not aware of such methods at the start of this study and thus it was not used. However, subsequent trial with a small selection of the data from the feasibility study and initial development of the syntax commands required for automatic data extraction (with the assistance of Dr P. Worsley, University of Southampton) has demonstrated that this may be a feasible method in future. This will allow extraction of a greater volume of data and a more robust method of extraction (particularly for eye data). Cross-checking with a manual extraction method would also still be required as an automatic system may not always choose the correct data point.

Through review of the literature, assumptions were made that the initial phase of a turn would be an appropriate point to assess the concept of 'wind-up' with segments rotating around each other, followed by release via movement of the feet. Whilst this did provide a measure of 'wind-up' over the first step and was deemed feasible through initial testing, conclusions drawn are limited to this specific phase of the turn. Results from the feasibility study suggest that this is the part of the turn where segments are 'winding-up' with reference to each other, remaining in position for the rest of the turn, however extrapolation to discussion of turning performance as a whole should be treated with caution. Future studies, using more sophisticated, automated and time efficient data extraction methods may wish to assess 'wind-up' across different steps of the turn to address the relationship of segments throughout the whole turn, or the use of factor analysis to identify other points in the turn where segment interaction is important to turn performance.

7.6.6 Comparison analysis

There is no literature available at present that shows the changes in turning performance in PwP over time. Longitudinal studies of general deterioration provide evidence of a variable course of progression for each of the different symptoms associated with the condition (Jankovic and Kapadia, 2001). However, evidence suggests axial and postural symptoms evolve more rapidly than other motor features and appear to be the best indicators of disease progression (Evans et al. 2011). In order to show the changes brought about by a dance intervention in this study, changes in turning ability were compared with PwP who did not dance over the same time period. This makes the assumption that individual changes in turning performance are; 1) comparable between the groups (i.e. the effects of normal variation and progression are equal); and 2) that turning performance presents with a gradual decline (rather than a 'threshold effect' of movement control, which when reached presents with a sudden deterioration in performance), neither of which are known at present. In addition, whilst efforts were made to regulate the effect of medication by testing participants at the same time of day for their pre- and post-assessments, the variable nature and un-predictability of the condition could not be controlled for. Many participants reported they would have performed differently on a different day, if their symptoms were better or worse (un-reported results). Indeed, the large changes in the control participants in this study was surprising, and may suggest that changes in turning performance are not gradual, transient over time or stable within each participant.

The time frame in which the change occurred is also unclear from the literature with few studies comparing dance intervention to a control group, rather using a pre-post intervention design or comparing two intervention groups. A significant decline in PwP who did not dance, with respect to disease severity (UPDRS), and gait (time spent in single support during forward and backwards walking) has been shown over the same time period (Hackney & Earhart 2009a) used in this study. This suggests the decline demonstrated in the controls in this study is comparable. However, caution must be taken when extrapolating measures of gait to measures of turning specifically, as discussion has shown, the motor control and symptom progression of gait and turning may follow a different disease trajectory.

Future studies may wish to use a within participant comparison design, taking baseline data for the same time period prior to the intervention, possibly reducing the influence of individual variation. Assessment of change over time, rather than direct pre/post comparisons would still however be required owing to the nature of the condition being progressive. If more time effective methods of data extraction or variable reduction could also be designed, subsequent studies may benefit from assessing twice before and after intervention to allow calculation of a mean score. This may account for a proportion of the normal variation within each participant on a day to day basis and thus give a clearer indication of the effect of the intervention specifically.

In addition, it would have been interesting to assess the impact of the dance intervention on the healthy age-matched partners, as this would enable extension of the discussion on the specific effect of dance on PwP compared to healthy peers and thus help with clarification of the mechanisms of effect.

Future studies may wish to include healthy controls; however consideration of the time commitment to data collection and extraction should again be made.

7.6.7 Extrapolation of results

No previous study has linked body segment latency, rotation, ground reaction forces and clinical measures in the analysis of an intervention on turning performance. Therefore discussion of the relationship between the variables and their influence on each other is based on clinical reasoning and prior clinical experience, alongside synthesis of current literature, in order to suggest an overall influence on function. Whilst an interesting and valid discussion of the interaction between the variables has been made, with the use of literature to support ideas, caution must be taken owing to the lack of specific literature to support the claim. There is the possibility that future analysis of data using 'Matlab' software may allow quantification of this relationship.

Finally, the cognitive and physical demands of the task required participants to have a moderate-high cognitive ability, and moderate physical ability, being able to respond to instructions appropriately and turn independently, thus results cannot be extrapolated to those that have cognitive difficulties or reduced mobility.

7.7 Conclusion

In conclusion, segment latency, segment rotation and measures of balance (by ground reaction force) all show a difference over time in those that danced compared to those that did not. Results of each segments' behaviour taken in isolation do not appear to support the use of dance in improving turning performance; however, this has limited clinical relevance and importance when considering the performance of turning as a whole in the functional setting. Therefore, when considering the measures of latency, rotation and balance collectively, the main findings of this study does in fact appear to suggest the preservation of an efficient, 'en bloc' turn with coordination between the axial and perpendicular segments in PwP who danced; a pattern which may have been lost over time in controls owing to the progressive nature of the condition.

Chapter 8: Overview of research presented

8.1 Context of thesis

Both the quantitative and qualitative components of this thesis were undertaken alongside the larger RfPB feasibility study of the effects of dance in PwP (Ashburn et al. 2014b), and contribute to the growing literature on the effects of dance as an intervention for the treatment and management of Parkinson's.

Results from the RfPB study indicate it is feasible to conduct a larger clinical trial on the effects of ballroom and Latin American dance in PwP. Whilst the aim of the RfPB study was to address issues of feasibility, secondary results showed specific effects of improved balance and balance confidence in those who danced, but only in a sub-sample of men and those that had Parkinson's for longer. There was also a qualitative component to the RfPB study, demonstrating that those people who participated in dance found a multi-faceted sense of enjoyment, including a sense of physical achievement, and social interaction, (unpublished results).

Results from this thesis work alongside the findings from the RfPB study, but specifically contribute a qualitative exploration of the expectation and experiences of the dance teachers delivering dance classes for PwP, plus addressing the effects of dance on body segment coordination, rotation and balance in PwP, neither of which were discussed in the RfPB study.

8.2 Unique contributions to knowledge from this thesis

Due to the explorative nature of this thesis and the inclusion of both quantitative and qualitative components, there are a number of areas where unique contributions to knowledge have been made. It is anticipated that the specific contributions to knowledge will have implications for both the clinical treatment and management and future research of PwP. Both the contributions to knowledge and the implications will be discussed in this section in order to consider the impact of this thesis in the wider context of dance for PwP and are summarised in Table 23.

8.2.1 Clinical contributions and implications

8.2.1.1 Qualitative component - Expectations and experiences of dance teachers delivering dance classes for PwP.

The inclusion of a qualitative component of this thesis provided an exploration of the expectation and experiences of dance teachers delivering a ballroom and Latin American dance class for PwP for the first time. The insight into the experience of teachers delivering the class provided by this study is essential when considering the implementation of dance for PwP on a larger scale, both socially and through research. Used alongside previous studies of the experience of community dance teachers already delivering classes to PwP (Houston 2014) and the attitudes of allied health professionals to the perceived barriers of delivering a dance class for PwP (Demers et al. 2014), this research uniquely adds to the knowledge of the experience of delivering a dance class for PwP from the perspective of new teachers in the genre of ballroom and Latin American dance.

With a better understanding of teachers' experience, it is anticipated that teachers wishing to begin dance classes for PwP can be supported in a more relevant way, paying attention to the areas that may require highlighting. As suggested by the results of the qualitative study, these areas may include the importance of the 'role of adaptation', the 'main aims of the class and outcome', 'how achievement is measured' and the 'role of the teacher' with attention of these areas requiring specific preparation for class delivery. In addition, the sharing of insights from the experiences of the participants in this study will increase knowledge and awareness of the issues related to preparing to work with PwP, which may help dance teachers prepare to work with people experiencing a progressive condition. This knowledge will be used in the development of training programmes for new teachers wishing to start dance classes for PwP, through the researcher's involvement in the 'Dance for Parkinson's Network UK (Steering group member)' and mentoring of new dance teachers through the ‘Participation and outreach program’ at Pavilion Dance Southwest (the Southwest’s regional dance agency).

The findings that the teachers’ expectations and experiences suggest a multi-dimensional impact of dance for PwP support its context in the social paradigm, with importance placed on socialisation, increased confidence, level of achievement and participation over therapeutic gain. As discussed in Section 3.6, there is a need for skilled delivery of dance, alongside a clinical understanding of the condition, and thus delivery is likely to bridge both the rehabilitation and social settings. The knowledge gained from this study will therefore not only have implications for the delivery of individual classes through the preparation of teachers, but also on the setting and context of dance for PwP, a topic that has not previously been discussed in the literature. It is anticipated that the findings of a need for both dance and therapy skills will be presented at both clinical and arts based arenas, through invitation to speak at the ‘Dance for Parkinson’s network UK’ and the ‘Association for physiotherapists interested in neurology’, where discussion of the issue of delivery will be started. It may not mean that dance will be offered to a greater extent in the clinical or rehabilitation setting as it is not likely that staff will have the additional dance skills required, however recommendation of its inclusion in the management of PwP can be encouraged in clinical practice.

8.2.1.2 Quantitative component –Effects of ballroom and Latin American dance on turning ability in PwP.

After consideration of the broader implications of delivering dance classes for PwP from the perspective of the teachers, the quantitative component of this thesis uniquely addressed the specific issues of the impact of a ballroom and Latin American dance class on turning ability in PwP, with no previous research on this topic being published.

Despite a growing number of review studies that support the role of dance in the treatment and management of Parkinson’s (Earhart 2009; Mandelbaum & Lo 2014; Sharp & Hewitt 2014; Dhami et al. 2015; Shanahan et al. 2015), none have considered the effects on turning specifically, or indeed the specific mechanisms of the effect of dance in their reviews. Considering the significant difficulty in turning experienced by many PwP (Stack & Ashburn 2008), and the need to develop novel and effective rehabilitation of dysfunctional turning, findings from this study, for the first time suggest that turning in PwP is affected by a ballroom and Latin American dance intervention when compared to controls.

Uniquely, the analysis of results suggests the relationship between body segments is altered following dance, with the possibility of a closer coupling and thus tighter coordination between the axial and perpendicular segments compared to controls being the main finding. Used alongside previous studies demonstrating the clinical effect of Argentine tango (Hackney & Earhart 2009a; Hackney & Earhart 2009b; Hackney & Earhart 2009c; Hackney & Earhart 2010a; Hackney & Earhart 2010b; Hackney & Earhart 2010c; Hackney et al. 2007a; Hackney et al. 2007b; Hackney et al. 2007c), contemporary dance (Marchant et al. 2010; Westheimer 2008; Heiberger et al. 2011), Irish dance (Volpe et al. 2013), Ballet (Houston & McGill 2013) and Tai classical dance (Khongprasert et al. 2011) in PwP, these results provide a detailed insight of the possible mechanism of effect of a dance intervention specifically for PwP, which has not previously been considered. It is anticipated that this will stimulate discussion of the pathophysiological effects of dance at the 'World confederation of physical therapy', 2015, where the results of this component of the thesis will be presented.

From the perspective of the practicing clinician, the growing body of evidence for the use of dance for PwP has enabled collaboration of results through systematic review and meta-analysis (Shanahan et al. 2014; Hewitt et al. 2014), both of which are likely to have a greater impact on changing practice than the isolated trials previously published. However, as no previous trial has published a detailed analysis of the physiological and biomechanical implication of dance in general, or specifically related to turning, this study will provide unique knowledge to the field. This can be used to aid the clinical justification of dance as a form of rehabilitation, as well as a form of social involvement and increase participation in physical activity, all considered essential for the management of Parkinson's. By providing an understanding of the possible clinical effects, clinicians will be better able to consider dance as an adjunct to the treatment and management of PwP. This is likely to raise the profile of dance in the clinical setting, as clinicians can justify and clinically reason its use, supported by evidence from this thesis. Dissemination of these results through presentation at the 'World confederation of physical therapists', 2015, 'Association of physiotherapist interested in neurology', 2015, and future article publication will facilitate access to the findings for clinicians in the field and encourage promotion in the clinical setting.

8.2.1.3 Quantitative component – Analysis and treatment of turning in PwP

Whilst the primary aim of this thesis was to explore the effects of ballroom and Latin American dance on turning ability in PwP, the subsequent exploration and analysis of turning specifically also has implications for clinical practice.

By discussing the impact of dance on turning from a 'multi-system' perspective, considering all body segment latency, body segment rotation and force alongside clinical measures of turning and balance, results from this study highlight the importance of considering all influencing factors on turning performance together. This further suggests that addressing each 'system' or segment/variable in isolation fails to represent the true clinical situation and thus may have little benefit from a functional or practical perspective. This has not previously been discussed in the literature and provides valuable insight into the mechanisms of turning performance in PwP and the potential effect of an intervention.

As suggested in the paper published from literature reviewed in Chapter 4 of this thesis (Hulbert et al. 2014), the role of the axial segments of the body in driving turning performance should be considered to a greater extent in clinical practice than they currently are. There is a wealth of literature detailing the deficits of the axial segments of the body during turning in PwP, with previous studies investigating turning ability using 3-dimensional movement analysis (Vaugoyeau et al. 2006; Hong et al. 2009; Huxham et al. 2008a; Huxham et al. 2008b; Akram et al. 2013a; Akram et al. 2013b; Crenna et al. 2007; Spildooren et al. 2013; Ashburn et al. 2014a; Visser et al. 2007), including measures of force production (Song et al. 2012; Horak at al. 2005;

Mak et al. 2008; Ferrarin et al. 2006; Bonnet et al. 2014), eye tracking (Lohnes & Earhart 2011; Anastasopoulos et al. 2011) and clinical measures (Stack & Ashburn 2008; Stack et al. 2004), however none have combined these measures or linked them to the effects on perpendicular deficits as in this study.

As demonstrated in the recent publication of the European physiotherapy guidelines for Parkinson's disease (Keus et al. 2014), clinical focus still remains on gait parameters and the subsequent perpendicular deficits in stepping. With regard to turning specifically, the guidelines state a 'weak' recommendation (benefits probably outweigh the risks) for the use of 'conventional physiotherapy' to improve functional mobility for transfers. It predominantly focuses treatment outcomes on perpendicular gait parameters such as stride length, speed and turn time, with general recommendations on turning practice. However, from the research presented (Section 4.3 and 4.4), it is evident that a focus on improving axial movement ability, specifically in conjunction with perpendicular strategies to improve turning, may result in better functional outcomes than limb and compensatory strategies alone.

Whilst it is important to remember that rehabilitation should be goal directed and functional from the patient's perspective, the WHO (2002) guidelines do suggest attention should be paid to all components of the condition, including the specific impairments that bring about the functional decline. Therefore, if greater attention was given to the impairments in axial segments during turning that may in fact be driving perpendicular deficits, improvements in the functional performance of turning may be found. It is therefore suggested that clinicians pay attention to the rehabilitation of axial impairments to the same extent as perpendicular deficits through their provision of therapy and exercise prescription, be this in the group or individual setting, through the medical model of rehabilitation, or the social model of dance and fitness.

In addition to highlighting the importance of axial deficits, the results from this thesis also suggest that the 'en bloc' turning strategy adopted in PwP may in fact enhance coordination of movement and stability, and therefore might be an effective adaption to maintain turning performance as the condition progresses. Previous literature suggests each deficit in isolation is a negative adaptation as a result of the condition compared to healthy controls. However, results from this study suggest, that when considered collectively across whole body performance, taking into account the relationship between each segment, the possibility that individual deficits may in fact contribute to the maintenance of functional performance has been made. Again, this suggests the previous focus from both a clinical and academic perspective on the individual deficits of turning in PwP may be inappropriate when considering performance as whole. It is anticipated that the knowledge gained from this thesis on the adaptive turning patterns used by PwP after an intervention, will focus rehabilitation aims on multi-system training and improved coordination rather than adapting the movement of the head or the feet in isolation, as is often the case in rehabilitation presently (clinical experience).

Finally, despite the large amount of literature discussing the deficits of turning in PwP, and the positive effects of rehabilitation on gait and balance, this is the first study to address the impact of a regular intervention on turning performance specifically in PwP. Previous studies have shown transient improvements in turning performance following auditory and proprioceptive cueing, however these effects were lost as soon as the cue was removed (Nieuwboer et al. 2007). This is therefore the first study to report on the sustained effects of an intervention on turning performance over time. Results suggest a regular intervention that incorporates multi-system training of turning can influence turning performance in the short term, and provides evidence of the possibility for improvement through rehabilitation.

8.2.2 Research contributions and implications

As well as the unique contributions to knowledge and implications to clinical practice and delivery, the knowledge gained from this thesis will also contribute to the design of future clinical trials of dance and turning performance in PwP.

8.2.2.1 The selection of variables to assess turning performance in PwP

The implication of the importance of body latency, body segment rotation and force to 'multi-system' analysis suggested in this study presents the significant problem of multiplicity and the associated complexity of analysis. Previous studies have isolated one or two variables to investigate turning performance in PwP, however as these results suggest, this is likely to neglect the complex interplay of all variables on turning performance and thus present an incomplete analysis. These results therefore imply future research of turning performance in PwP may benefit from the use of more advanced methods of data analysis such as principal component analysis (PCA). The use of PCA enables an accurate reduction of variables based on their impact on turning performance as a whole. This enables identification of primary outcome measures and power calculations, improving the strength of future research. From a negative perspective, PCA requires a large sample initially if multiple variables are compared (as discussed) and detailed statistical support.

In the absence of methods of variable reduction, future studies will again rely on clinical reasoning to determine the most important variable to collect when analysing turning performance. Therefore the results from this study (and the feasibility study associated) suggest that body segment latency and body segment rotation are both feasible measures of turning performance. Analysis of intra- and inter-class correlation also suggests them to be reliable. They were sensitive and able to identify change over time and between groups, although further work is required to determine if the change detected reached the 'minimally important change' (MIC) for functional relevance. MIC can be defined as the smallest difference in a measurement of impairment or limitation which a patient perceives as beneficial (Jaeschke et al. 1989). As suggested in Section 7.6, future research with these measures should include a patient reported measure such as questionnaires or interviews to determine the extent of change in turning performance required to make a difference in function.

The measures of force used in this study failed to identify the changes in balance performance over time or between groups, which is surprising considering the changes found in latency and rotation suggest a whole body effect. Whilst inclusion is essential when considering the 'multi-system' model of turning performance, future studies may which to investigate alternative methods of measuring balance and force variables. For example, 'measures of the margin of stability' as described by Horak et al. (2005), using a translating platform or 'dynamic postural control' as described by Song et al. (2012) in walking turns. Both measures are derived from centre of mass and centre of pressure displacement and have identified difference between PwP and healthy controls; however, neither have been used to assess the impact of an intervention, therefore a feasibility study would be required.

In summary, the implication of the 'multi-system effect' to turning performance reported by this study suggests future studies must consider all components in analysis, as purely considering isolated variables is not sufficient to demonstrate functional turning performance. Future research should consider initial investigation of multiple variables in turning performance and the possibility of reducing these through statistical analysis. These measures must also be related to clinical performance. Therefore, results from this study indicate the need for development of a new measure of turning, incorporating the sophisticated and detailed analysis of 3-dimensional movement analysis variables (body segment latency, rotation and force) via an associated reduction in variables, alongside measures more readily available such as step count and time to turn. It is only with such a measure, that analysis of whole body coordination can be related to the functional outcome of turning performance in PwP and truly reflect the biomechanical and physiological effects of an intervention.

8.2.2.2 Control comparisons in turning performance

This study demonstrated that the influence of an intervention on turning performance can be studied over time in PwP, which has not previously been investigated in the literature. However, as discussed in Section 7.6, the 'normal variability' of PwP and the inconsistency of symptom presentation must be considered. As previous research in 3-dimensional movement analysis tends to investigate PwP through a single assessment design compared to healthy controls, consideration of individual variation over time has not been required. To date, there is also no known longitudinal study of turning performance in PwP and thus the impact of each variable over time and across disease severity is not known. As found in this study, the use of controls allows the comparison of an intervention over a specific time frame, but it is not possible to determine if the behaviour of the controls in this study was ‘typical’ of the change in performance expected over time, owing to the nature of degeneration or simply normal variation in disease presentation. Thus, results from this study indicate the need for a longitudinal study of turning performance using 3-dimensional movement analysis from which to compare intervention and control behaviour. This would also enable the identification of changes in specific deficits over the course of the disease and thus better tailor intervention to the needs of the individual at different stages of the condition.

8.2.2.3 Dance intervention

The results from this study indicate that ballroom and Latin American dance does appear to have an impact on turning performance in PwP, however as discussed in the qualitative component of this thesis, many of the dance classes currently running for PwP are in the genre of modern and contemporary dance. Whilst all forms of dance incorporate turning and stepping, and thus the findings of this study may be extrapolated across all dance styles, caution must be taken owing the differences in dance content and movement practiced throughout the differing dance genres. It would therefore be interesting to compare the impact of more than one type of dance in future studies. This could bring clinical justification to the current practice of dance for PwP and thus bridge the gap between the ‘artistic delivery’ of dance classes and the need for evidence based practice in the medical rehabilitation setting.

In summary, the explorative nature of the studies included in this thesis has led to development of knowledge in the broad context, including the delivery of dance classes for PwP, the impact of dance on turning ability in PwP and the requirement of a multi-system approach to analysing and rehabilitating turning performance in the clinical setting. From a research perspective, knowledge developed by this thesis contributes to the appropriate selection and analysis of variables used to assess turning performance, the changes in turning performance over time and the importance of considering a variety of dance genres. The development of knowledge alongside the implication to future practice as a result of this thesis, in both the clinical and research setting, is summarised in Table 23.

Table 23 – Unique contributions to knowledge and the implications from this thesis.

Context	Topic	Previous knowledge	Contribution to knowledge from this thesis	Implication
Clinical	Delivering dance classes for PwP	Experiences of teachers with established dance classes for PwP. Perceived barriers and facilitators to delivering dance by allied health professionals.	The expectation and experience of teachers of a new dance classes for PwP (Chapter 3). Importance of the multidimensional impact of dance, socialisation, increased confidence, level of achievement and participation (Chapter 3).	Tailoring of 'Dance for PD network UK' training for new dance teachers. Initiate discussion of the context (social or medical) of class delivery.
	Effects of ballroom and Latin American dance on turning ability in PwP	No previous knowledge on turning specifically. Knowledge of the positive effects of dance on balance, gait, posture, quality of life and mood.	Dance does affect turning ability in PwP (Chapter 7). Body segments appear more coordinated in time and sequence, suggesting a more 'en bloc' presentation following dance (Chapter 7).	Evidence for the use of dance for turning deficits in PwP. Promotion and justification of dance for PwP with turning difficulties.
	Analysis and treatment of turning in PwP	Turning deficits of isolated variables in clinical and 3-dimensional movement analysis. No previous knowledge of the effects of a regular	Axial deficits in turning may drive a perpendicular change (Chapter 4). Turning in PwP has a multi-system presentation (Chapter 4). The adoption of an 'en bloc' turning strategy may improve turning performance and safety	Greater attention to both axial and perpendicular deficits of turning and the relationship between them. Adaptation of isolated deficits to reduce the 'en bloc' presentation of turning in PwP

		intervention on turning in PwP.	in PwP (Chapter 4). Turning can be affected by a sustained intervention over time (Chapter 7 & 8).	should be discouraged. Turning deficits should be specifically targeted through intervention.
Research	The selection of variables to assess turning performance in PwP.	Isolated deficits in segment latency, segment rotation, step number and length, turn strategy and time in PwP compared to controls.	Deficits of axial and perpendicular segments and the consideration of the relationship between them; requiring multi-system analyses (Chapter 8). Suggested improvements in the data extraction process of 3-dimensional movement analysis to optimise resources and decrease required sample size (Chapter 8).	Justification of the importance of multi-system analysis for future research. Need for a new measure of turning performance in PwP incorporating 3-dimensional movement analysis and clinical performance.
	Control comparisons in turning performance	No previous research on the longitudinal presentation of turning performance in PwP.	The changes in turning performance over three months in PwP (Chapter 6 & 7).	Need for a longitudinal study of turning performance.
	Dance intervention of different genres.	Impact of Argentine tango, contemporary, ballroom, Irish, Tai and modern dance on PwP.	Impact of ballroom and Latin American dance on turning in PwP (Chapter 6 & 7).	The need for future research to include different dance styles.

8.3 Developmental work from this thesis

The explorative design of this thesis enabled a large number of variables to be collected and considered in the wider context of the effects of dance on turning in PwP. This was necessary due to the lack of knowledge of the impact of an intervention on turning and thus identification of a primary outcome measure was not possible. Results from this thesis are the first to demonstrate that dance does affect the co-ordination of body segments in turning in PwP. In development, the interpretation of the results also suggests it is not viable to isolate one measure to quantify turning performance, as it is the relationship of many variables that constitute turning performance. This is unsurprising when considering the multi-dimensional effects of dancing being an activity that incorporates the whole body and mind through its 'training' of turning. In addition to this, previous research has compared turning performance of PwP to healthy aged matched control. This makes judgement of the status of turning performance against the normal movement patterns of those without Parkinson's. However, this research also suggests that adaptive and compensatory movement patterns such as the 'en bloc' turn with greater co-ordination may in fact be beneficial in PwP with regards to safety and efficiency of the turn despite its deviation from that seen in healthy controls. Considering these novel findings, future research on the effects of dance for PwP should be guided towards the measure of turning from a multi-dimensional perspective and consider the adaptive effects of dance against clinical measures of turning performance, including the perception of turning ability in functional practice by PwP. This engenders the future hypothesis of:

1. What effect does the change in co-ordination of body segments being more 'en bloc' following dance have on turning ability?

However, in order to answer such a question, preparatory research needs to:

1. Design a multi-dimensional measure of turning performance that can be used as a primary outcome measure of turning performance.

2. Relate this measure to the functional and perceived efficiency of turning from the perspective of PwP as well as the biomechanical efficiency of turning.

Possible method by which this may be achieved such as more advanced statistical methods of analysis of turning performance in PwP and mixed method research to address the impact of change on functional turning performance respectively have been discussed in section 7.6 of this thesis.

In addition to the larger development of the work from this thesis, there are areas that the researcher hopes to develop as part of a post-doctoral position in the Faculty of Health Sciences at the University of Southampton. These developmental areas were beyond the scope of this thesis, but are useful to discuss here in order to demonstrate the imminent progression of this research in the academic field.

8.3.1 Further analysis

Interpretation of results in this thesis suggests a greater co-ordination of body segments during a turn following dance in PwP. This was particularly shown when looking at the relationship between segments with regards to the delay between each and the coupling. However, these were descriptive explorations of data and were not analysed using statistical methods. In order to expand on these interpretations, subsequent comparison analysis of pre- and post-assessment scores with regards to segment to segment delay (Figure 23 – Section 6.5.1) would enable a clarification of the experimental significance of the differences found after dancing in PwP in this study. This may aid understanding of the depth and breadth of data collected in subsequent articles written for publication.

8.3.2 Data management

1) The extraction process used for this study was selected based on previous experience from the laboratory (Verheyden et al. 2012; Ashburn et al. 2014; Ashburn et al. 2010); however it is possible that preliminary investigation using alternative computer software such as

'Matlab' may be appropriate for further analysis. 'Matlab' would allow analysis of the whole turn with reduced extraction processes and time. This may then allow identification of the variation in turning from each variable from the data from the quantitative component of this thesis and compare it to previous data collected in the feasibility study from healthy age matched controls. From this, a profile of 'variable influence' on turning performance in PwP compared to healthy age matched controls could be established, and thus begin the process of identifying those most likely to be essential in analysing future turning performance. It is possible that a similar reduction of variables could also be achieved through PCA analysis, but this is not recommended in this instance owing to the small sample size in relation to the number of variables.

2) With consolidation of variables and advancement of the data extraction process using 'Matlab', it would also be possible to look at the influence of variables throughout the turn, as it is possible that different variables may be more or less influential at different points of the turn i.e. head latency is likely to be influential initially but may be less influential once the feet start to move. By identifying these influencing factors to turning performance, interventions can be better tailored to the specific deficits of turning in PwP and systematically analysed through the advanced processes of system modelling.

3) It is important to note, that the use of a more automated system of data extraction such as 'Matlab', however, may not be as reliable as the process of manual extraction and excel used in this PhD (as found in previous attempts by the experimental officer in this study). The verification of the correct value by human interaction is often required as pre-programmed extraction is not always capable of selecting the correct value from a selection over a close time frame of data. A reliability study between the two methods would indicate the suitability of automated methods of data extraction in future.

8.3.3 Control comparisons

Whilst results are reported for the changes in gait and disease severity over the same time period (12-14 weeks) (Hackney & Earhart 2009a), there is no evidence of the changes in turning ability over this time, and thus extrapolation of the decline in other symptoms and variables owing to disease progression should be treated with caution. Having identified a large change in the controls over the time period and used this to justify the effects of dance intervention in this study, it would be advisable to select another sample of controls and assess over the same time period. This would be a relatively cost-effective design to compare the changes found over time in this study in the controls and therefore validate the justification of the effect of a dance intervention, without the need to administer further costly dance classes. However, as discussed, this would only be possible with further refinement and reduction in the workload required for data extraction, and is not as favourable as a design with direct control/comparison intervention with greater sample size in future.

8.3.4 Qualitative follow-up and development

Due to many requests from the participants of this study, the dance school has decided to continue the classes on an independent basis. They are keen to develop the class and progress the content from their experience in the study. It would therefore be interesting to re-visit these teachers after a period of this continued class and investigate their continued experiences under a more realistic scenario of teaching.

8.4 Overall conclusion

Results from this thesis are the first to consider the expectation and experiences of dance teachers delivering a new ballroom and Latin American dance class for PwP and the effect of a dance intervention on turning ability in PwP.

If dance is to be encouraged through both the social and healthcare settings, better understanding of the practical application and delivery of dance classes is fundamental. Knowledge gained from the qualitative component of this thesis, suggested those teaching the class felt a multi-dimensional impact was achieved, with both physical and social affect being discussed. However, specific importance was given to socialisation, increased confidence and participation for PwP. The previous experience of the teacher, perceptions of achievement and role in the class, alongside the genre of dance taught, were also all suggested to influence the experience for those delivering the class and should be considered when designing both future research and clinical intervention.

Specifically, the quantitative component of this thesis is the first study to look at the specific effects of a dance intervention in PwP using 3-dimensional movement analysis, thus providing the first suggestion of the biomechanical and physiological effects of ballroom and Latin American dance for PwP. When considering the initial research question; measures of body segment latency, rotation and balance alongside measures of clinical performance, differences between those who danced and those who did not were found. The relationship between these variables surprisingly appeared to suggest the preservation of an ‘en bloc’ turn in those that danced. When discussed across the segments collectively, this suggests greater coordination between the axial and perpendicular segments in whole body turning performance. This highlights not only the fundamental importance of multi-system analysis in research, but in the designing and justification of rehabilitation interventions for PwP.

Finally, the results of these studies, alongside previous literature in the field suggests ballroom and Latin American dance may have an effective and positive impact on improving both the physical and social aspects of the lives of PwP. However, further research with ‘multi-system’ variables, larger samples and across the dance genres will enhance the understanding of the specific mechanisms of effect of dance in PwP and its future delivery across both social and rehabilitation settings.

Appendices

Appendix 1 – Dissemination

Published articles

<u>A narrative review of turning deficits in people with Parkinson's disease.</u>

Sophia Hulbert*, Ann Ashburn, Lisa Roberts and Geert Verheyden

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A narrative review of turning deficits in people with Parkinson's disease.

Sophia Hulbert*, Ann Ashburn, Lisa Roberts and Geert Verheyden

Abstract

Purpose: Clinically, people with Parkinson's disease (PD) demonstrate a loss of axial rotation of the spine often described as moving "enbloc", with little dissociation between the head, trunk and lower limbs whilst turning. The purpose of this narrative review is to explore the behaviour and relationship of the reported deficits during whole body turning in people with PD, compared to controls.

Better understanding of the relationship and impact of the deficits will permit the development of tailored and novel intervention strategies to improve functional performance in turning for people with PD.

Method: Four electronic databases with the search terms: Parkinson* and turn* were used.

Results: 87 papers were reviewed. Turning deficits in people with PD were identified as originating from two hypothetical body segments - perpendicular (i.e. legs) or axial (i.e. head, trunk and pelvis) segments and the relationship between them discussed.

Conclusion: Specific movement deficits in turning in people with PD can be categorised into axial and perpendicular deficits. Synthesis of the literature suggests the possibility of axial deficits driving secondary responses in the perpendicular segments. This should be explored when designing rehabilitation aimed at improving turning performance, as current therapy guidelines focus on exercises emphasizing perpendicular aspects.

Implications for Rehabilitation

- Turning performance is compromised in people with PD, which can lead to significant disability, falls and loss of function.
- Specific movement deficits can be categorised into perpendicular deficits (taking more steps and shorter steps and an altered turn strategy) and axial (segment rigidity, altered segment co-ordination and timing, reduced segment rotation and the effects of altered posture)
- Axial deficits may drive secondary responses in the perpendicular segments during turning in people with PD. Therefore specific focus should be made to the rehabilitation of the axial deficits alongside those of the perpendicular body segments in the design of multi-modal treatment strategies to improve turning performance.

Introduction

Parkinson's disease (PD) is estimated to affect 1 in 500 of the population in the United Kingdom, totalling an estimated 127,000 and, whilst prevalence increases with age, 1 in 20 presenting with the condition are under the age of 40 years [1].

People diagnosed with PD experience movement disorders that if not managed, can lead to "considerable disability" [2] including: bradykinesia (slowness of movement); rigidity (resistance to movement); resting tremors, (involuntary movement), and abnormalities of postural reflexes that occur with increasing disease severity. Such motor deficits commonly lead to poor performance in measures of balance and functional tasks, and have been associated with generalised deficits of attention and falls [3]. Difficulties with turning around the longitudinal axis are a common and early feature of PD, and can be present while lying recumbent [4], seated [5], standing [6-15] or walking [9-19].

Turning is a complex action, in which head and trunk rotation in the transverse plane are vital, to seek out and align with a new path [20]. Healthy young and older adults engage in cranio-caudal sequences of movement to turn while walking, with head rotation leading, then trunk and then pelvis rotation to re-orientate the body towards the new direction [9, 20] resulting in inter-segmental reciprocal movements [16]. This is not the case in people with PD, who demonstrate a loss of axial rotation of the spine [21], with little dissociation between the head, trunk and lower limbs [8], which results in a decreased inter-segmental coordination producing an 'enbloc' turn [8, 22] ie, a turn which has been described as 'nearly simultaneous rotation of head and trunk and decreased relative head excursion after the second turning step' [22]. Whilst some studies have also found the presence of an 'enbloc' turn in the healthy elderly [8], kinematic analysis of body segment movements during turning reveals clear abnormalities within the 'enbloc' turn in people with PD, including head-on-trunk turning [9, 23, 24], trunk-on-hip turning [5, 6], whole body turning [19, 25], stepping of the feet [9, 10, 12, 15, 16, 22, 25-29], turning step strategy [10, 16, 28, 30, 31] and timing of the turn [14, 17, 19, 25, 26, 32, 33]. Globally, the characteristic Parkinsonian turn from a standing start involves at least four steps over two seconds prior to forward gait, the quality is poor with reference to independence, continuity, ground clearance, stability and posture, and differences between turning directions are marked [34]. As well as being detrimental to everyday life, difficulty in turning is a sensitive predictor of the two key symptoms of PD locomotion; freezing - a sudden interruption of on-going movement [34] and falling [26], highlighting the importance of understanding turning impairments in people with PD.

Whilst current literature focuses on specific deficits in turning in people with PD in isolation to each other, the exact relationship and effects they have on each other with regards to functional performance (being the efficient and safe execution of a turn), are less well understood but may hold greater clinical relevance when considering turning performance as a whole. Therefore a narrative review was undertaken to 1) summarise the specific deficits of whole body turning in different positions for people with PD; and then 2) comment on the relationship and impact that these have on each other, with reference to whole body turning performance.

Method

A literature search was conducted using the bibliographic databases: Cumulated Index of Nursing and Allied Health Literature (CINAHL), Medline, Web of Science (Core collection), Cochrane and Physiotherapy Evidence Database (PEDro) between the period 2000 and August 2014.

The search terms 'Parkinson*' and 'Turn*' with truncations were searched and combined with the Boolean operator 'AND' for all databases apart from Cochrane which was searched for by Parkinson* only, due to limited material. Additional filter of 'English language' was also used.

After completing the electronic search, papers were reviewed through title and abstract by the lead author on two separate occasions. Due to the broad search specifications for this topic, all papers investigating physical parameters in people with PD were included initially, and then further refined to include only papers regarding turning specifically. The reference lists of included papers were also searched, for papers not identified in the electronic search. Selected papers were then critiqued and synthesised by the lead author based on the design of the study, methods used, sample size, analysis and limitations. The synthesis was discussed with all authors.

Results

The search results are shown in Table 1.

A total of 2231 papers were identified after excluding 998 duplicates. Initial review of the combined search results by title and abstract lead to 171 papers being selected for all physical parameters. Exclusion of papers at this stage was due to their focus on the pharmaceutical management and biochemistry of deficits in PD. The search was then refined to 57 papers with specific focus on turning and PD. Papers at this stage were excluded due to their focus being on gait rather than turning. Reviewing the reference list of key papers provided 20 additional papers of interest. A total of 77 papers were read in full by the lead author and were used in the development of this review.

As a variety of experimental methods were used in the articles selected, it was not appropriate to use a general literature review tool. Due to the explorative nature of this review, papers considered poor in quality (ie, small sample size, methodical difficulties and case reports) were not excluded and this is considered in the discussion.

From the synthesis of the literature, two hypothetical distinctions were identified, with all turning deficits in people with PD discussed being related to either the perpendicular or axial segments.

For the purposes of assigning the deficits to the hypothetical distinctions, perpendicular segment deficits were defined as 'non-optimal movement' occurring in any aspect of the perpendicular areas of the body (being the lower limbs in this case). Axial segment deficits meanwhile were defined as 'non-optimal movement' of the axial structures of the body (being the head, shoulders and pelvis in this case).

Using the distinction of “axial” and “perpendicular” segment deficits has enabled the influence and relationship of each on turning performance to be determined in people with PD.

The segment distinctions and related deficits are shown in Table 2.

Review

From the literature, perpendicular deficits include the abnormalities of increased step number [12, 15, 22, 25, 26, 29, 34-36]; shorter steps [10, 16, 25, 27, 37] and an altered turn strategy [10, 16, 28, 38]. The axial deficits include segment rigidity [4, 13, 24, 25, 39], altered trunk segment co-ordination [6, 8, 22, 27, 29, 38-40] and timing [6, 8, 9, 14, 19, 25, 26, 32, 33], reduced segment rotation [9, 14, 22, 27] and altered posture [2, 5, 7] (Table 2). Each deficit, alongside their interactions and clinical implications, will be discussed in this review.

<u>**Table 1**</u>

Literature search results

Database	Search results	Duplicates	Physical	Turning	Total used in review
CINAHL and MEDLINE	1477	998	171	57	77
Web of Science	1741				
Cochrane	6				
PEDro	5				
Reference list search	-	-	-	20	
Total selected	3229	2231	171	77	

Perpendicular deficits

For the purposes of this review, perpendicular deficits will be considered as ‘non-optimal movement’ occurring in any aspect of the perpendicular areas of the body, (i.e. lower limbs in this case).

i) Perpendicular deficit - Number of Steps

A greater number of steps to complete a turn has consistently been shown in people with PD compared to controls using both clinical measures such as the Standing Start 180° turn test (SS180) [26, 34-36], and laboratory based 3-dimensional movement analysis [12, 15, 22, 25, 27, 29]. This appears to be more pronounced when turning to the un-preferred direction [34] or in unfamiliar surroundings [26]. Interestingly, Stack and Ashburn [36] showed, a mean of 7 steps for people with PD compared to 5 in healthy age-matched controls, which is clinically important when considering the ‘5 step count’ believed to indicate a difficulty in turning in the elderly population[41].

The significant correlation between the Unified Parkinson’s Disease Rating Scale (UPDRS), Self-Assessed disability Scale (SAS) and increased number of steps during a turn, for people with PD compared to controls, [34] demonstrates the impact of disease severity on the number of steps during a turn, and furthermore, the degree of difficulty experienced.

Although an increase in step number is believed to indicate a difficulty in turning, being less-efficient and of lower quality [31], it is possible that a purposeful increase may in fact be useful in order to maintain function. The finding by Stack et al. [31] supports this, demonstrating that few people with PD who fall or have severe PD use this compensatory strategy.

Clinically therefore, although the results suggest a more advanced presentation of PD may exhibit a greater step number in turning, the reason for this is unclear. It may be that the strategy of increased turning steps might be a compensatory mechanism for the postural instability and limited axial rotation which is evident in advancing PD. Therefore, whilst an increased number of steps to turn is considered an indicator of reduced turning performance, as a rehabilitation tool it may be beneficial, particularly in those at risk of falls during turning, in order to maintain functional independence. However, the reduced efficiency, reduced quality and increased perceived difficulty must also be considered.

ii) Perpendicular deficit – Step length

It is important to note that reduced step length is an integral component of turning for all in order to achieve a turn around a point [42]. However, people with PD show an even greater reduction in step length (37%) compared to controls (22%) [16]. Furthermore, the step length of people with PD during normal linear walking has also been shown to be 26% shorter than that of controls [16], demonstrating a shorter baseline step length prior to turning.

Using 3-dimensional (3-D) movement analysis, Huxham et al.[16] showed stride length to be a major contributor to turning accuracy: In a study of 10 people with PD compared to 10 healthy controls, the healthy controls turned significantly more accurately using a '3 step cross-over' technique about a point to complete a walking turn, compared to the 'wide arc' technique used by people with PD. A reduction in step length and thus speed, and increased step number, have also been shown to be accompanied by hypokinesia in people with PD [16], often resulting in 'freezing' during the turn [10, 28], with one third of turns (19/56 – 34%) demonstrating the feet fail to clear the floor, or one foot clearing the other to place in front [34]. The tighter the turn the more these spatiotemporal characteristics are affected, with tighter turns electing a systematic decrease in step length and step time variability and velocity [10]. The reduced co-ordination of step length between feet (measured as an integration of accuracy and consistency of left -right stepping phases) has also been linked to increased difficulty and freezing during turning [37].

Clinically therefore, this suggests that whilst many small steps at a slower speed sacrifices efficiency and may result in freezing episodes, it may be an effort to preserve postural stability and maintain a wider base of support throughout the turn, maintaining the centre of gravity central to the base of support. Thus, the apparent decrease in step length and speed may be a purposive adaptation to maintain functional balance and safety whilst turning, and thus reducing this in isolation through rehabilitation, must be treated with caution.

iii) Perpendicular deficit – Turn Strategy

Leading on from step length, people with PD have been shown to predominantly use an incremental turn type (turning on-the-spot before walking) as opposed to a toward-type turn (direct advance to target whilst turning) or a pivotal-type (broad-base turn initiating advance to target) used by healthy controls [10, 28, 43]. This profile appears to change if the turn is not to the favoured direction, as both controls and people with PD perform a turn in the un-favoured direction as an 'incremental turn' [28]. The findings by Stack et al. [31], that two-thirds of people with PD (8/12, 67%) at the severe stages (H&Y 4 – severe disability, still able to walk and stand unassisted) [44] appeared unstable when completing a turn as assessed by the SS180 and those of Salmon at al.[43], showing those with greater motor symptoms (as measured by their UPDRS Score) and reduced balance confidence (Activities-specific balance confidence scale) adopt a multiple step pattern rather than a spin turn, supports the possibility of instability causing a change in turn style.

Using 3-dimensional movement analysis, Song et al. [38] also demonstrated adaption to turning style with people with PD tending to use a step-round style (when the change of direction was to the opposite side of the pivot foot) rather than a spin style (when the change of direction was on the same side of the pivot foot) used by healthy controls. In comparison to Stack et al. [31], the inclusion of study participants with an early diagnosis of less than a year, suggests that the presence of turning deficits occurs early in the disease progression. The study also reported the influence of turn style on the translation of centre of pressure (the equilibrium point of the distribution of the resultant ground reaction force applied to the base of support) and centre of mass (the position that represents the equilibrium point of the body's mass), showing the step-round strategy to result in greater postural stability. This is likely to occur as a slower step-round strategy allows a greater use of feedback mechanisms whilst turning [41].

These results suggest clinically, under more challenging turning conditions, a natural motor performance produces an incremental turn strategy, suggesting dysfunctional turning in people with PD may be a result of a lack of perceived stability requiring a secondary adaption to turning style. This again may be a compensatory strategy to gain control of the centre of mass within the base of support, secondary to the impaired postural control and inability to adjust to the functional task demands.

In summary, perpendicular deficits (reduced step length, increased step number and alteration of turn strategy), predispose those with PD to experience difficulty in turning. The reason for such changes are less well understood and it is not clear if these are direct responses to the physiological changes as a result of the condition, or secondary effects from a need to gain greater stability and function in turning. In order to discuss this relationship, it is necessary to comment on the axial deficits of people with PD during turning and the impact of these on the perpendicular deficits.

Axial deficits

For the purposes of this review, axial deficits are considered as 'non-optimal movement' of the axial structures of the body, i.e. the head, shoulders and pelvis. Whilst the role of the eyes is also evident in the literature, it is beyond the scope of this review.

Structurally, the axial musculature links all parts of the body, giving support and stability, to allow mobility and proximal limb movement. The axial musculature is anatomically and physiologically complex, controlled by cortical and subcortical structures via the descending monoaminergic pathways (particularly the reticulospinal and vestibulospinal motor pathways). It is also responsible for automatic postural reflexive movements and different from the corticospinal tracts controlling distal limb/perpendicular and voluntary movements [45].

Whilst a degree of tonic regulation (sustained postural control) of axial muscles is necessary to provide a stable base of support for movement of perpendicular body segments to be coordinated and controlled, excessive control as a result of axial motor impairments in people with PD, leads to axial segment rigidity, which has been identified during turning.

i) Axial deficit – Axial segment rigidity.

It appears that disorders of axial movement are dependent on the duration of the disease progression and associated increase in severity due to neurodegenerative properties, demonstrating a more prominent axial rigidity [4].

To demonstrate this, Steiger et al.[4] assessed the ability of 36 people with PD to turn in bed before and after dopaminergic stimulation. Whilst dated, this paper potentially provides a design to compare the same individual at stages of increased and decreased disease severity. Axial rotation was measured using the Kings College Hospital (KCH) rating scale, with the sub-score of axial rotation being a mean of the score rating for rising from a chair, postural stability, axial rigidity and whole body bradykinesia. In total, 19/36 participants demonstrated a difficulty in turning in bed when examined in the 'off' state following a levodopa drug withdrawal, with all but one improving with a levodopa challenge. There was a significant correlation between axial rotation and difficulty turning in bed suggesting an influence of axial rotation on turning performance. Interestingly, the authors also noted increased use of the upper limbs to help achieve the turn when off medication, suggesting the loss of automatic movement and sequencing of axial rotation may be responsible for the adoption of secondary compensatory strategies in the perpendicular body segments. Indeed, deficits in sequential motor organisation are a core component of Parkinson's disease, resulting in difficulty achieving automatic associated movements [2].

Whilst this paper does highlight the influence of axial rotation on turning performance, it is unlikely that this is a result of improvements in axial rigidity particularly, as Levodopa has since been shown to be ineffective at improving specific axial deficits during turning [13]. However, when considering the component of the KCH rating scale for axial rotation also includes measures of perpendicular performance, such as rising from a chair and whole body bradykinesia, this again suggests the influence of levodopa on secondary compensations only; highlighting the need to address axial rotation deficits specifically as the disease progresses and turning becomes more challenging.

In support of the idea of axial deficits driving perpendicular adaptions, Hong et al. [25] demonstrated a similar pattern of muscle activation in the lower limbs (perpendicular segments) of people with PD compared to controls, but greater variability and reduced rotation of the head, trunk, pelvis and foot, suggesting PD may affect the ability to organise and appropriately scale the amplitude of the axial movements of the turn, with muscle activation patterns of the perpendicular segments remaining intact or indeed adopting compensatory strategies in the foot. Unfortunately this research did not collect EMG readings from the axial musculature which would have been useful to distinguish the impact of each area.

Finally, Franzén et al. [24], uniquely demonstrated using a combination of clinical and functional tests alongside 3 dimensional movement analysis, people with PD to have a significantly (43%) higher axial torque compared to controls, which was correlated to their functional performance in turning tasks. Interestingly, again in contrast to Steiger et al. [4], the authors found no effect of levodopa on axial rigidity, but did show an improvement after levodopa administration in functional tasks (Figure of 8 walk test). This again suggests the presence of compensatory perpendicular adaptations when the patient finds the task more difficult (off medication), with an underlying axial rigidity remaining.

These combined results suggest axial rigidity, leading to deficits of axial rotation, to be a key contributor to the development of secondary perpendicular adaptations and turning difficulties experience by people with PD.

It is possible however; that the relationship between axial and perpendicular deficits and the dominance of each during turning may change with increasing disease severity due to the need for compensatory strategies to achieve a functional task. It appears from the literature that axial rigidity can be further divided into deficits in the co-ordination, timing and rotation of the body segments within the axial structure and the influence of postural change. Each will be discussed.

ii) Axial deficit – Segment coordination and timing

When turning, people with PD have consistently shown linked movement of the head, trunk and pelvis in a characteristic 'enbloc' appearance [6, 8, 17, 22, 27, 29, 46]. In comparison, healthy young controls demonstrate a reciprocal oscillating pattern of movement, with movement of one segment resulting in co-ordinated counterbalancing in the next [16, 20], also retained in healthy older adults during walking turns [17, 22].

It is likely that a lack of segment co-ordination will lead to a perception of instability and the possibility of a purposeful adoption of a 'rigid trunk' in order to achieve an adequate base of support from which to move the appendicular segments, as clinically without such control of the trunk, it is often difficult to achieve selective movement of the limbs. In addition the adoption of an 'enbloc' turning sequence may be an advantage by reducing the dimensionality of the interconnected chain of axial segments to one degree if freedom in order to simplify the co-ordination of movement required in the transverse plane [8]. This suggests simplifying the task may be a strategy to cope with the loss of inter-segmental co-ordination in people with PD. The tighter control of the 'enbloc' pattern of turning has also been replicated in healthy elderly when turning with their eyes closed [47] and whilst challenging the vestibular, visual and proprioceptive systems by eyes closed and on a moving platform [29], all of which suggests a purposeful adaptation to simplify the control of movement, by reducing the degrees of freedom in the axial segments when turning under more challenging conditions. However, recent studies have also found an 'enbloc' turning strategy in healthy older adults when the turn is simple, such as to a predictable direction, self- paced and on-the-spot [8, 32], suggesting an ability to also reduce the degrees of freedom in turning movement when the task is simple; a flexible adaption that may not be possible for people with PD, therefore making all turning environments challenging.

It is not only the co-ordination of the timing of body segments during the onset of turn that is affected in people with PD but also the velocity of the segments during the turn [8, 9, 19] and the total time to complete the turn [14, 19, 25, 26, 32, 33]. It can be suggested that the delay in these timing variables throughout the turn may be a result of the bradykinesia experienced by people with PD [2] however, the findings that those with relatively un-affected walking strategies still present with a delayed 'enbloc' turn, often similar to those with more advanced symptoms [17, 22], and walking velocity to be un-related to segment-co-ordination in the healthy elderly [48], suggests the perpendicular deficit of bradykinetic gait is unlikely to be the driver of timing and axial co-ordination deficits in people with PD.

In an effort to distinguish the key features of the deficits in an 'enbloc' turn, a delay in the onset of pelvic rotation has been found [6, 9]. Vaugoyeau et al. [6], suggests a possible reason may be due to the control systems of each segment, with top-down organisation using the head position in space as a reference frame to co-ordinate shoulder position and a bottom-up control, which when a person is standing, regulates the position of the centre of gravity in space as well as that of the pelvis. Bottom-up control, would be mainly related to equilibrium maintenance and thus more severely affect in people with PD, owing to the reduced capacity to generate ground reaction forces [49] as a result of an impaired extensor muscle activity and ankle strategy. This is reflected in the findings of Ashburn et al.[46] and Akram et al.[9] showing the greatest difference in the onset latency of segments to a turning cue between people with PD and healthy controls in the lower body segments (pelvis and feet). A resultant delayed co-ordination with top-down control may arise [6] which may also be influenced by the difficulty people with PD experience in achieving dual motor tasks simultaneously [2].

These results appear to suggest that adopting an 'enbloc' turning strategy with less degrees of freedom simplifies the turn and therefore is adopted by people with PD in response to a lack of segmental co-ordination, but also by healthy, age-matched controls under challenging conditions or conditions that do not require inline adaption such as on-the-spot turns.

It can also be suggested that the un-coordinated control of axial segment rotation in people with PD represents a twofold impairment in motor organisation of rotation. Firstly the general role of the basal ganglia in driving body orientation in space, when deficient, results in delayed segment initiation, and secondly, the deficit in coordinating the descending control of body segments with that of ascending control. This further suggests a relationship between the axial deficits and those of the limbs, with a complex interplay of differing control mechanisms being responsible for the dominant turning deficits at different stages of the disease process.

ii) Axial deficit – Amount of segment rotation

The ‘en-bloc’ un-coordinated turning presentation in people with PD may also result in variation in the amount of rotation each segment achieves about the vertical axis during each foot step of the turn.

Using 3-dimensional movement analysis of a walking turn about a pole, Huxham et al. [27] studied 10 people with PD and 10 age-matched controls. The results (surprisingly) demonstrated greater rotation in the thorax and pelvis of people with PD compared to controls when taken in relation to the corner of the turn (pole). When considered with relation to the axial deficit of reduced intersegment coordination producing an ‘enbloc’ presentation (closer linking of the segments at each footfall), and the perpendicular deficit of reduced segment rotation when considered over each footstep in people with PD compared to controls found by the authors, this again supports the suggestion of axial deficits driving perpendicular changes.

It can be hypothesised that if the trunk and pelvis are moving together as a unit as in people with PD, rather than rotating, as seen in controls, then only a limited amount of rotation is possible in the vertical axis before the feet must move, leading to the increased number of steps and decreased step length often observed. Therefore, if the ‘enbloc‘ trunk rotates as much as possible over each foot step to maintain orientation with the head, this may appear as if rotation is greater in relation to the corner of the turn (pole) compared to control subjects, who can disperse the rotation through the head, shoulders, trunk and pelvis. This hypothesis leads towards a multiple ‘wind-up-release, wind-up release’ turn performance in people with PD and suggests a possible reason for the multiple stepping pattern often seen.

Another possible hypothesis for the increased rotation as suggested by Huxham et al. [27], is the presence of a separate motor command for segment rotation compared to all other aspect of the turn. This may well be the case as supported by the findings of Crenna et al. [22], showing deficits in head and trunk rotation in the absence of gait and balance abnormalities in 14 people with PD with mild clinical impairment . However, considering the direction of this effect it is not likely that the increases in axial rotation seen by Huxham et al. [27] are compensating for footstep patterning, but quite the opposite, of axial deficits driving a perpendicular adaptation. Indeed this can be supported by the findings of two companion papers by Akram et al. [8, 9], showing similar magnitude of segment rotation at the onset of foot re-orientation in people with PD compared to healthy, age-matched controls during predictable, self-paced walking turns, but a reduction in magnitude during on-the-spot turns, with both studies showing a delay in segment turning velocity. This suggests the in-line control of the magnitude of segment rotation may be preserved during walking turns, possibly due to the stepping pattern accommodating for the axial deficit. However, when turning from a stationary position during on-the-spot turns, the delay in segment initiation and reduced turning velocity cannot be adjusted for, thus resulting in a reduction in the amount of rotation seen at each footstep. Unfortunately the authors did not comment of the total number of steps taken to complete either of the turn types, so the impact of a possible perpendicular step accommodation for axial deficits across the whole turn cannot be made.

Finally, the findings by Mak et al. [14] again using 3-dimensional movement analysis, show smaller turning angles of axial body segments, slower initiation of the foot step and a narrower step width to turn in people with PD compared to healthy, age-matched controls in walking turns. This again demonstrates the hypothesis of a reduced segment rotation magnitude leading to an adaption in step strategy, which in this case is step width. The authors also noted the narrow step width to be related to an inadequate force to accelerate the centre of mass towards the turn direction, with a resultant destabilisation effect and axial rigidity.

The presented results appear to suggest people with PD have a reduction in the amount of rotation each segment undergoes during a turn, however the variety in methods used to assess this aspect of turning with regards to the point at which the rotation is measured appears to distort the reported findings. Furthermore, it appears there may be an element of accommodation for this deficit during walking turns by changes in perpendicular factors such as stepping patterns; however the exact impact and mechanism of this adaption is unclear.

iii) Axial deficit – Postural impact

The role of musculoskeletal posture in the generation of static axial torque must also be considered, as it is likely that the characteristic forward stoop and increased flexion of the hips and knees will raise static torque in the hips and trunk and thus contribute to axial rigidity. Indeed, Wright et al. [7] demonstrated a statistically higher axial rigidity in relation to the hips and trunk considered separately in people with PD compared to age-matched controls, a measure that is predominantly combined in other studies. Interestingly, the authors suggest the reduced speed and amplitude of axial segment rotations may be a secondary protective mechanism to avoid such phasic reflex responses, which may in turn produce ‘freezing’ of movement.

As with perpendicular deficits, it could also be suggested that some of the postural changes demonstrated in people with PD are compensatory for the reduction in perceived stability when turning, in particular the flexed spine and bent knees typically associated with the condition and in situations of balance perturbation. It is likely however, that the primary contributor to postural deficits is the disturbance in neurotransmitters in the output projections from the internal globus pallidus to the midbrain and brain-stem region in people with PD, which have been shown to be involved in maintaining upright stance and extensor muscle activity [50].

Schenkman et al. [5] demonstrated that overall range of movement (both axial and perpendicular), but not spinal position is reduced in the early stages of the condition, compared to age-matched controls, which is consistent with the suggestion by Morris [2], of excessive kyphosis and limited lordosis to occur later in the disease process. This suggests that in addition to the neural drivers of postural change, the secondary non-neural musculoskeletal changes associated with immobility also have a significant effect on posture, leading to further instability of the centre of mass trajectory during a turn and thus contributing to the difficulty experienced by people with PD.

These results suggest the inter-relationship of both the neural and non-neural determinants of posture in people with PD requires further research; however their role in the generation of axial torque and therefore potentially axial rigidity, alongside the orientation and displacement of the centre of mass during a turn, must not be overlooked.

In summary, it is apparent that axial deficits make a significant contribution to the experienced difficulty in turning for people with PD. Axial segments appear to present with global rigidity and stiffness in a characteristic ‘enbloc’ movement pattern. Specific deficits have been shown in segment co-ordination, delay in all segments’ initiation time, reduction in all segments’ rotation and postural control. Most of these deficits have been shown, even in the early stages of the disease in the absence of perpendicular deficits.

The penultimate version (published for review) of the first European Physiotherapy Guidelines for Parkinson’s disease, due to be published Summer 2014, states a ‘weak’ recommendation (benefits probably outweigh the risks) for the use of conventional physiotherapy to improve functional mobility for transfers [51]. It predominantly focuses treatment outcomes on perpendicular gait parameters such as stride length, speed and turn time, with general recommendations on turning practice. However, from the research presented, it is evident that a focus on improving axial movement ability, specifically in conjunction with perpendicular strategies to improve gait, may result in better functional outcomes than limb and compensatory strategies alone, however further research is warranted to evaluate this at different stages of disease severity.

Limitations:

Every effort was made to search for and include all papers relevant to PD and turning in this narrative review and in doing so a broad search strategy was used, resulting in a large number of papers found. This meant that papers were initially selected by title in the first instance and then by abstract. There is a possibility therefore, that relevant papers may have been excluded as full text was not read for all in the initial stages of the process. In addition, as this was not a systematic review, the search process was completed solely by the lead author with final papers included being discussed by the team. Therefore the search method was not cross-checked by all authors. The findings do however, indicate the need for a systematic review of the deficits of turning linked to the available evidence based for treatment.

Conclusion:

The perpendicular deficits of an increased step number, decreased step length and alteration in turn strategy have been compared with the axial deficits of increased axial segment rigidity comprising of reduced segment co-ordination, timing and rotation and postural impact. The relationship of movement between the axial structures and the perpendicular structures is unclear, with the possibility of axial deficits driving a secondary response in the lower limb. Therefore the mechanism and pathophysiological location of these deficits is unknown, however suggestions of differing descending monoaminergic pathways (rectiulospinal and vestibulospinal pathways controlling axial musculature and predominantly corticospinal pathways controlling perpendicular), differing global motor control mechanisms (top-down/bottom-up) and direct secondary compensatory effect on each other have been made, but all require further investigation.

Disease severity appears to be a factor in determining the relationship between the perpendicular and axial deficits, with the possibility that axial deficits are present even in the absence of perpendicular deficits at the early stages of the disease and may potentially drive the perpendicular compensatory changes as the disease progresses.

This review suggests that functional limitation in turning stems from a combination of axial primary neural impairments such as the ability to organise and appropriately scale the amplitude of the movements, and secondary adaptation in the perpendicular segments including musculoskeletal loss of range of movement as a consequence, with the basic movement form remaining intact. Further research is required to assess the impact of multi-modal treatment strategies that include specific focus on axial rotation rehabilitation alongside those of the perpendicular body segments.

<u>**Table 2**</u>

Deficits of turning in People with Parkinson's disease (synthesised from the literature).

Perpendicular deficits		Axial deficits	
Definition: 'non-optimal movement' occurring in any aspect of the perpendicular areas of the body (limbs)		**Definition: 'non-optimal movement' occurring in any aspect of the axial areas of the body (head and trunk)**	
Step number	Increased number of steps to complete the turn.	**Segment rigidity**	Increased rigidity with disease progression.
	Step number increased to a greater extent when turning to the un-preferred direction.		Deficit in scaling the amplitude of segment rotation.
	Increased step number related to disease severity.		Higher axial torque related to reduced axial rotation in turning tasks.
ay be a useful compensatory strategy.		*Leads to adoption of secondary compensatory strategies.*	
Step length	Reduced step length.	Segment coordination and timing	Linked segments producing an 'enbloc' turn.
	Reduced step length reduces turning accuracy.		Simplifies the co-ordination of movement to

			one degree of freedom.
	Reduced step length is linked to hypokinesia and reduced foot clearance.		Delayed segment onset, velocity and total time of the turn.
	Tighter turns elicited a greater reduction in step length.		Delay in pelvis and foot co-ordination possibility due to differing control mechanisms.
May be an effort to preserve postural stability.		*Leads to un-coordinated movement of the axial and perpendicular structures.*	
Turn Strategy	Incremental turn strategy rather than spin or step round.	Segment rotation	Reduced individual segment rotation around each footstep in standing turns.
	Change may be due to perceived instability.		May be a component of delayed segment initiation and reduced velocity.
	Changes appear to be evident in the early stages of the disease.		
		Leads to secondary step compensatory strategies.	
May be an adaptive strategy to maintain greater postural stability.		Postural changes	Increased forward inclination and flexion in the trunk as primary disease response and secondary musculoskeletal adaptation.
			Increased axial rigidity.
			Instability of the centre of mass trajectory due to altered posture.
		May be a compensatory strategy to lack of stability.	

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Declaration of Interest

The authors report no declarations of interest.

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This work has not been previously published, and is not under consideration for publication or in press elsewhere.

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<u>A design to investigate the feasibility and effects of partnered ballroom dancing on people with Parkinson disease: randomised controlled trial protocol.</u>

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Protocol

A Design to Investigate the Feasibility and Effects of Partnered Ballroom Dancing on People With Parkinson Disease: Randomized Controlled Trial Protocol

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Abstract

Background: Self-help and physical leisure activities has become increasingly important in the maintenance of safe and functional mobility among an increasingly elderly population. Preventing the cycle of deterioration, falling, inactivity, dependency, and secondary complications in people with Parkinson disease (PD) is a priority. Research has shown that people with PD are interested in dance and although the few existing trials are small, initial proof of principle trials from the United States have demonstrated beneficial effects on balance control, gait, and activity levels. To our knowledge, there has been no research into long-term effects, cost effectiveness, the influence on spinal posture and turning, or the personal insights of dance participants.

Objective: The purpose of this study was to determine the methodological feasibility of conducting a definitive phase III trial to evaluate the benefits of dance in people with PD. We will build on the proof of principle trials by addressing gaps in knowledge, focusing on areas of greatest methodological uncertainty; the choice of dances and intensity of the program; for the main trial, the availability of partners, the suitability of the currently envisaged primary outcomes, balance and spinal posture; and the key costs of delivering and participating in a dance program to inform economic evaluation.

Methods: Fifty participants (mild-to-moderate condition) will be randomized to the control (usual care) or experimental (dance plus usual care) groups at a ratio of 15:35. Dance will be taught by professional teachers in a dance center in the South of England. Each participant in the experimental group will dance with his or her spouse, a friend, or a partner from a bank of volunteers. A blinded assessor will complete clinical measures and self-reported ability at baseline, and at 3 and 6 months after randomization. A qualitative study of a subgroup of participants and partners will examine user's views about the appropriateness and acceptability of the intervention, assessment protocol, and general trial procedures. Procedures for an economic evaluation of dance for health care will be developed for the main trial.

Results: Recruitment began in January 2013 and the last participant is expected to complete the trial follow-up in June 2014.

Conclusions: Findings from our study may provide novel insights into the way people with PD become involved in dance, their views and opinions, and the suitability of our primary and secondary outcomes.

Trial Registration: International Standard Randomized Controlled Trial Number (ISRCTN): 63088686; http://www.controlled-trials.com/ISRCTN63088686/63088686 (Archived by WebCite at http://www.webcitation.org/6QYyjehP7).

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KEYWORDS

Parkinson disease; ballroom dancing; balance; posture

Introduction

Parkinson disease (PD) is a common, progressive neurological condition estimated to affect 100-180/100,000 of the population [1]. People with this condition frequently experience deterioration of their spinal posture, mobility, and stability, leading to dependency and falls; therefore, preventing the cycle of inactivity and secondary complications is a priority. Despite disabling movement deficits, access to physiotherapy is limited [2]. Poor performance on measures of balance and functional tasks is common and has been associated with generalized deficits of attention and fall events, leading to decreased quality of life among sufferers [3]. The problem of unwanted secondary deterioration is of considerable concern.

People with PD experience slow movements (bradykinesia), rigidity, resting tremors, and abnormalities of postural reflexes. Gait characteristics include a shuffling pattern of walking with increased flexion of the hips and thoracic spine and reduced movement at the ankle with loss of heel strike. Restricted rotational movements of the head and trunk can contribute to the overall instability experienced by individuals. Key approaches to improving the function and activity of people with PD include balance and strengthening exercises [4] as well as strategies using rhythmical cueing to enable people to initiate movements [5]. Ballroom dancing comprises many of these facilitating components described; hence, the reason that dance was considered an appropriate activity for people with PD. The music provides the rhythmical cue for stimulating movement and the stepping and turning activities challenge balance control.

Self-help and physical leisure activities are increasingly important in the battle to maintain safe functional mobility among people with PD. Although there is growing evidence of the benefits of exercise for people with PD, research into the benefits of long-term exercises through leisure pursuits such as dance and self-help activities is limited. Research has shown that people with PD are interested in dance and early findings suggest a positive effect on balance and gait following Argentine tango classes, partnered or nonpartnered [6]. The effectiveness literature on dance in PD is growing, although the findings of the early studies have been limited by small sample sizes—the average study recruiting under 20 participants, and the largest recruited 52. These studies have shown proof of principle that dance, usually Argentine tango, for people with PD can be delivered [6-12] and can positively influence balance control and gait. Another study compared the tango with the waltz and the foxtrot and dance was superior to no dance but there was no distinction among dances. One-hour sessions, twice weekly for 10 weeks is beneficial. Only one recently completed study has evaluated dance delivered in the community. Earhart and Duncan [13] and Foster and Earhart [14] described a 12-month community-based tango program that demonstrated that dancing using community facilities was possible and they showed that those participants who danced increased their participation in activities of daily living. Positive effects were also shown when people were tested off medication.

Gaps in knowledge have been highlighted by a number of researchers. Two meta-analyses have identified the need for more well-designed randomized controlled trials and qualitative studies of the dance experience of people with PD [15,16]. Hackney and Earhart [6] highlighted a gap of knowledge concerning the long-term effects and cost effectiveness of dance. No existing studies have examined the influence of dance on spinal posture and turning (a task that inherently makes people unstable) or the personal insights of participants about their experiences with dance. We were aware that no-one had examined the feasibility of teaching a number of standard ballroom dances to people with PD through a local dance center in the UK or how a center would cope with finding dance partners for people with PD, and it is important to explore these feasibility issues before running a large multicenter trial.

Because this is a feasibility study, we will not be testing a hypothesis but will determine the methodological feasibility of evaluating the benefits of multiple dances taught through a dance center as a precursor to a definitive phase III trial. We need to understand how much dance people with PD and healthy partners will tolerate, which dances work best, how easy it is for dance teachers and dance centers to accommodate the needs of people with PD, and identify barriers and facilitators to participation in dance including the financial costs. We will build on the proof of principle studies [6-8] from the United States, address gaps in knowledge in planning a definitive trial of the impact of dance on balance and spinal posture, as well as turning, long-term follow up, economic evaluation, and user views. We will examine the appropriateness of primary and secondary outcomes currently envisaged for the future main trial and provide novel insight into user views on involvement in dance through a qualitative component, and develop procedures for economic evaluation for a future trial.

Specific questions of the feasibility study are:

1. What are the key routes to successful recruitment of healthy partners, people with PD, and dance centers to a randomized controlled trial of dance?

2. What are the most appropriate dances for people with PD?

3. How frequent, and how much dance is reasonable and likely to result in benefit for people with PD and healthy partners?

4. What specific adjustments do dance centers need to make regarding the delivery of dance to this group of people?

5. What level of dancing will be sustained to 3 and 6 months?

6. Will we obtain high quality data on spinal posture, balance, turning, and walking during home assessments?

7. Will we obtain high quality data on self-reported health status and balance confidence?

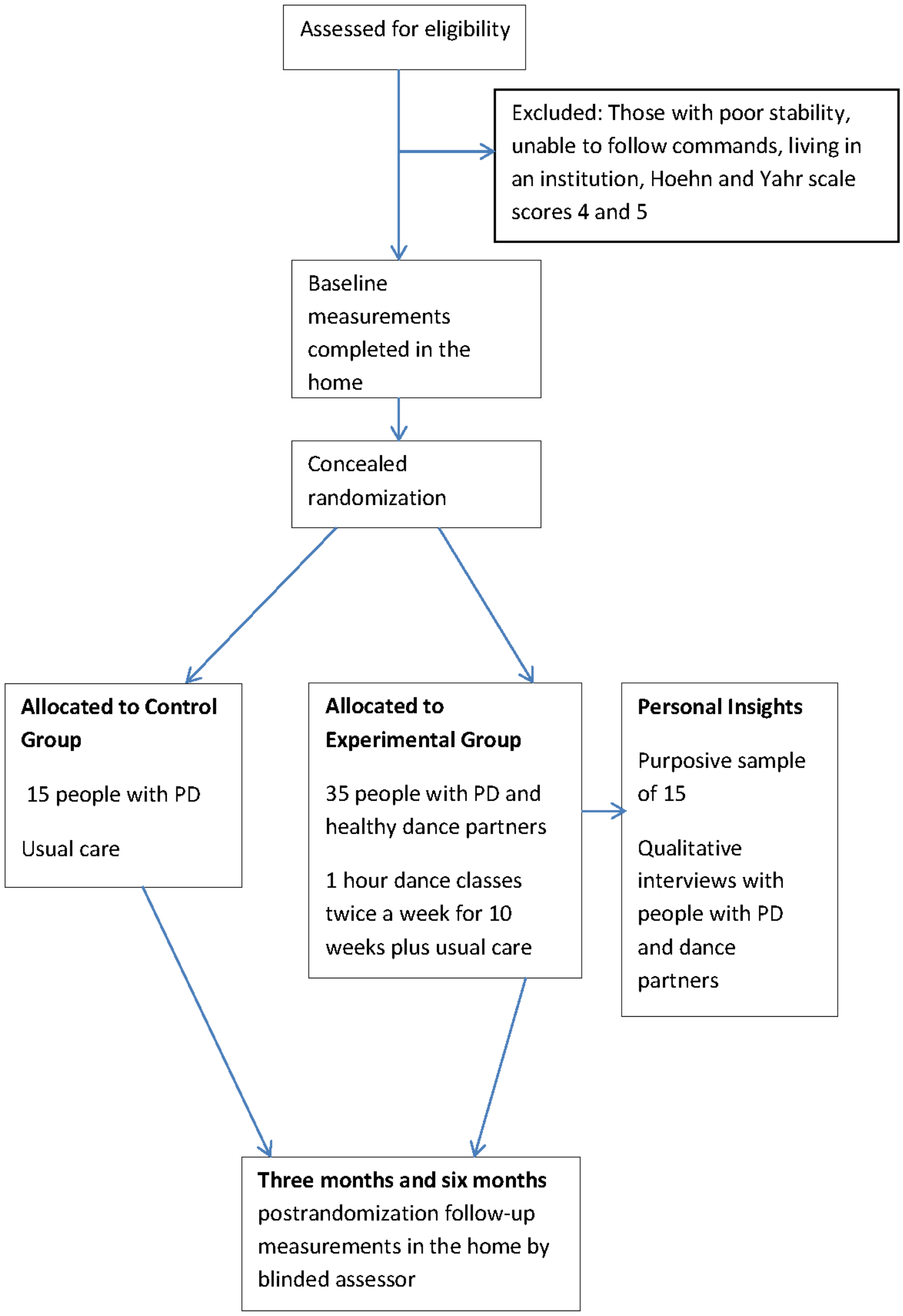
8. How appropriate and burdensome is the battery of assessments?

Methods

Overview

We followed the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) guidelines [17] for developing the protocol and Figure 1 presents a diagrammatic representation of the study based on the Consolidated Standards of Reporting Trials (CONSORT) [18] flowchart. Two research fellows, physiotherapists with experience in PD, will conduct the research trial in collaboration with the dance teachers in a dance center in the South of England. Research fellow A will recruit participants and conduct baseline and follow-up assessments and will be blind to group allocation. Once a participant has consented to the trial, their name will be passed on to the second research fellow B, who will carry out the random allocation procedures, be present throughout all the dance classes, help arrange transport to the dance classes according to need, and organize volunteers for dance partners.

Figure 1. Flowchart of trial design.



Participants With Parkinson Disease

Research fellow A will obtain informed consent and recruit 50 people with PD from outpatient services, local support groups (Parkinson's UK), and the DeNDRoN (Dementia and Neurodegenerative Disease Research Network, a clinical research network for dementia and neurodegenerative conditions). Eligible people with PD will have a confirmed diagnosis of PD, Hoehn and Yahr [19] scale of 1-3 indicating mild-to-moderate mobility and stability; will be able to stand, turn, and walk safely and unsupported but may experience freezing of gait [20]; will live at home; understand and follow commands, through a screen for cognitive impairment [21]; and be able to tolerate the dance intervention. People with PD lacking sufficient stability to dance with another person in the clinical opinion of research fellow A (eg, in danger of losing balance control each time they turn around) will be excluded. The decision as to whether a potential participant with limited mobility can safely undertake the dance intervention will be based primarily on their performance on the Berg balance scale (BBS) [22] and the motor component of the unified Parkinson's disease rating score (UPDRS) [23]. For example, someone scoring 0 on questions 7, 8, or 13 of the BBS, indicating inability to "stand unsupported with feet together," inability "to attempt to reach forward" in standing without losing balance or inability "to stand unsupported with one foot in front of the other" will be considered ineligible. The UPDRS motor component gait questions 29 and 30 will also be used as indicators: a severe disturbance of gait that requires constant assistance or lack of postural stability to such an extent that balance is spontaneously lost in standing, will also discount potential participants.

Healthy Dance Partners

Healthy people identified by participants in the dance group will act as dance partners. Some people with PD will be single; others may have a spouse unwilling to participate, so relatives, volunteers, or responders to an advert will also be considered. The feasibility of recruiting healthy dance partners will be examined in the study. Our inclusion criteria for the dance partners are similar in age to people with PD, able to understand and follow commands, willing to participate, and able to tolerate the dance intervention. Evidence of a neurological condition, vestibular impairment, or multiple falls would lead to exclusion, but experience of a single fall would be acceptable (risk of falling is linked to repeated falling, not a single fall event) [24]. Otherwise healthy individuals who are considered to be at risk of instability while dancing will be excluded.

Randomization

After the baseline assessment, eligible and consenting people with PD will be randomized to the dance or control group. Research fellow B obtained allocations by telephone from the trial medical statistician. Allocation will be randomized in 1 block of 11 participants (8 dance and 3 control), and 3 blocks of 13 (9 dance and 4 control), to yield participants entering each of 4 consecutive series of dance classes. The feasibility trial is too small to incorporate stratification. The dance-to-control ratio of 35:15 was chosen to maximize the number of people with PD experiencing the dance classes, while still including some control participants for feedback on the acceptability of randomization to control, retention, and fidelity in this group. The research fellow will contact participants to inform them of their allocation and of the times of their dance classes.

Interventions

Control Group

Participants in this group will continue with usual care. Usual care comprises medication, attendance at medical clinics, and review by PD nurses. Exercise therapy may be accessed but this is not routinely prescribed in the UK. As a way of encouraging adherence to follow-up at the end of the trial, participants in the control group will be offered vouchers to attend nontrial dance classes at the dance center.

Dance Group

In addition to usual care, participants will attend dance classes (with a healthy partner) at a local dance center, led by a professional dance teacher and supported by a second teacher and research fellow B (Figure 2). Classes will last 1 hour, twice a week for 10 weeks. The length and number of sessions was chosen following discussions with the dance teacher and based on results from published literature [6]. Care will be taken to ensure that the pace of teaching is appropriate and will reflect that recommended by Hackney and Earhart [6]. Class sizes will be small and supervision from both the dance teachers and research fellow B will minimize any risk of falling. Participants will learn 6 dances (3 ballroom and 3 Latin American dances). Each session will start with a warm-up, then new steps will be introduced and practiced, and a record of the session will be kept. Proposed dances included the social foxtrot, the waltz, the cha cha, ballroom tango, the rumba, and rock and roll. Emphasis will be placed on encouraging individuals to extend their postures, turn their heads and trunks, heel strikes, and toe push-offs because these movements are affected by PD and associated with changes in balance responses. The dance program will be tailored to individual capabilities in each class (the dance teachers will dance with couples who were struggling), and the research fellow will ensure the safety and well-being of participants and their partners. The research fellow will keep a record of each class, and some of the classes will be videotaped (with consent from participants).

Figure 2. Participants enjoying a dance class.

Assessments

Research fellow A will carry out baseline and follow-up assessments at 3 and 6 months and will be blinded to participant group allocation. Prior to each assessment, participants will be reminded not to reveal whether they have been dancing, and following each assessment the assessor will be asked to record awareness of group allocation. The assessments will be organized at similar times of the day, will last approximately 1 hour, and be completed in the person's home approximately mid-point in the medication cycle.

Data collected for the anticipated primary outcome measures for the main trial will be the BBS [22], a categorical scale of balance activities (a high score is good with a maximum of 56), and spinal posture, which will be measured using the spinal mouse [25]. The spinal mouse is a handheld device that can measure the position and mobility of the pelvis, and lumbar and thoracic spine by recording the segmental angles as it is rolled over the spine. This device has been used with people with PD [26] and the data will describe angles of the participants' spinal segments in the standing position and the overall degree of forward inclination in relation to upright. We used these tests in previous research studies [27].

At baseline, we will characterize our sample using the following measures: demographic data; measures of disease severity (Hoehn and Yahr Scale [19]; 1-5, high score is poor) and UPDRS motor section [23] (0-56, high score is poor); medication (using levodopa equivalent daily dose); freezing of gait questionnaire [20] (0-24, high score is poor); the Montreal cognitive assessment of cognitive function [21] (0-30, high score is good); and we will ask participants to retrospectively recall fall events during the previous 12 months using a standardized questionnaire [28].

Outcome measures will be recorded at baseline, and at 3 and 6 months and included the primary outcome measures, the Berg balance scale [22] and the spinal mouse [25]. The secondary outcomes include a measure of turning, the standing start 180° (SS180°) test in which the individual turns in both directions and the number of steps, time, and quality of turn are rated [29]; the timed up and go test, stand up from a chair and walk forward 3 meters and turn and return [30]; the PDQ39 (a self-completing questionnaire rating how hard it is to complete a range of everyday activities [31]; 0-100, low score indicates better health); the ABC, which is a questionnaire about balance confidence [32] (0-100, high score is good) ;the phone-FITT, a questionnaire delivered over the phone and designed to gather information about levels of the physical activity of older adults, such as how many times a week do you do housework activities such as tidying or dusting, walking, swimming [33], scoring is according to frequency of activities, duration, and intensity; and the Euroquol-5D, which is a simple quality-of-life measure [34] (1-5, high score is poor but a high visual analoge score is good).

At the final assessment, participants will be given a questionnaire about resource use that will be used in economic evaluation such as travel, refreshments, and buying shoes for the dance class and their views on the acceptability and benefits of the research project and to collate additional information needed for the economic evaluation. Participants will be asked to complete this questionnaire on their own time and to return it to the research team in the freepost envelope provided. We plan to ensure that the measurement battery is appropriate for use in a definitive multicenter phase III trial and not burdensome for the assessor or participants.

Statistical Analysis

Feasibility issues will be addressed by examining numbers and percentages successfully recruited and completing various components of the trial protocol. The choice of outcomes for the main trial will be addressed by examining the completeness of data collection, relevance to issues raised as important by users, and comparison to related studies in the literature. The statistical analysis plan for the primary efficacy outcome in the main trial is currently envisaged to contrast the dancing and control groups (presented with 95% CI), after controlling for the primary outcome measured at baseline and center, either performed separately at 3, 6, and 12 months in analysis of covariance, or in a mixed model including both follow-up points. Depending on the primary outcome chosen, the corresponding modelling approach in logistic or Poisson models may be appropriate. Comparisons of outcome will be done on an intention-to-treat basis, with sensitivity analyses restricted to those completing the allocated interventions. The analysis of outcome data from the pilot randomized controlled trial, along with information from the literature, will inform the power calculation for the main trial. The current trial is not powered to demonstrate efficacy. We will examine the predictive power of baseline characteristics such as the Hoehn and Yahr severity, freezing of gait, and phone-FITT scores, to assess the benefit of additionally including them as stratifiers in the randomization of the main trial.

Qualitative Substudy

Aim

The aim of the qualitative substudy will be to identify and explore the views of people with PD and their dance partners about the appropriateness and acceptability of the dance programs and the perceived impact on their mobility. Their views of the trial procedures will also be explored. An experienced qualitative researcher has been employed to complete this part of the study.

Methods

Fifteen of the 35 couples in the experimental group will be recruited to the qualitative study. Couples will be recruited with the aim of attaining maximum variation in the qualitative sample of the factors that may affect their experiences of the dance intervention, such as age, sex, and relationship with the dance partner.

Interviews

In-depth, semistructured, qualitative interviews will be conducted using an interview guide developed for the study. The interviews will be conducted in the home separately with the people with PD and their dance partners where possible (where couples are spouses this may not be possible) within 1 month of completing the dance program. With participants' consent, the interviews will be audiorecorded and fully transcribed. For people with PD, the interviews will explore the following issues: their perceptions of the impact of PD on their day-to-day lives and their experience of physiotherapy or any other interventions since diagnosis that were designed to promote activity; and experiences with exercise activity (dance or other exercise activity) before their diagnosis of PD. The following issues will be explored with people with PD and their dance partners: their reasons for deciding to take part in the dance program and their perceptions and expectations of it, the number of sessions they attended and reasons for missing any sessions or dropping out, what it was like to take part, enjoyment of the activity, maintaining enthusiasm for the activity, the implications of working with a partner, perceptions of the impact of participating in the dance program, interest in continuing with dance classes or other activity, and their perceived impact on their mobility. Participants will also be asked about any personal costs they experienced while participating.

Analysis

Facilitated by QSR International's NVivo 9.2 software, the data will be managed using Framework [35] and analyzed thematically to explore participants' views about the acceptability and appropriateness of the dance program. Features of grounded theorizing and constant comparison will be used to identify and develop themes [36]. Data analysis will be undertaken by experienced social science qualitative researchers (JR and RW).

The framework is a staged approach that is well-suited to applied health research. In the first stage, the researchers will identify topics for an initial analytic framework based on prior understanding of the issues and concepts arising from close reading of the transcripts. In the second stage, participants' accounts will be condensed on a case-by-case basis into charts according to the framework topics. The third stage will involve working through the data in detail to draw out themes or categories of experience that capture the full range of perspectives identifying commonalities and differences within and between participants.

The qualitative findings will be used to inform interpretation of the findings of the trial. Analysis of the qualitative data will take part in isolation from the trial researchers. Data from the qualitative study will be integrated at the end of the trial to avoid contamination.

Finally we will explore the views of those who choose not to take part in the study. Typically it is viewed as unethical or unnecessary to ask people to give reasons for declining to take part in research; however, in this study the information that is handed out as part of the recruitment process will give people the option to tell us if and why they find the dance intervention unattractive by completing an anonymous short questionnaire.

Economic Evaluation Substudy

Aim

Our aim is to inform a future economic evaluation for the Phase III trial. We will use the EQ5D to assess quality of life.

Methods

A questionnaire about resource use such as travel, refreshments, and clothing (dance shoes) costs will be completed at 6 months. This information will enable us to judge the feasibility of this type of measure for people with PD. We will also calculate the resources needed to provide the intervention such as cost of dance lessons, hire of a hall, and personal expenditures.

Results

Recruitment began in January 2013 and the last participant is expected to complete the trial follow-up in June 2014.

Discussion

The main aim of this study is to determine the methodological feasibility of conducting a definitive phase III trial to evaluate the benefits of dance in people with PD. Recruitment to the feasibility trial began in January 2013 and the last participant is expected to complete their follow-up assessment in June 2014. Findings from our study will provide a novel insight into the way people with PD become involved in dance, their views and opinions, and the suitability of our primary and secondary outcomes. We will report on the challenges of recruiting healthy dance partners as well as people with PD, and because we believe the dance partnership is key to the success of the dance experience, we look forward to understanding better the ingredients required for success. We suspect that threats to the viability of the feasibility trial are likely to come from poor recruitment of healthy partners to dance with people with PD, demands and difficulties related to traveling to the dance center, and reluctance of people with PD to dance twice a week for 10 weeks. We anticipate that ease of travel and access to facilities such as the availability of car parking and taxis as well as environmental hazards will affect the experience. We will consider the steps that need to be taken to ensure safety and we are keen to analyze the types of dances that are enjoyed and those that create challenges for people with PD. We look forward to evaluating the potential benefits and challenges of running the dance classes for people with PD as well as providing practical information, such as participants' preferences and experiences of the different dances, which has not previously been reported. With this study, we will be well placed to inform future research in this field.

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Conflicts of Interest

None declared.

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Abbreviations

BBS: Berg balance scale
CONSORT: Consolidated Standards of Reporting Trials
PD: Parkinson disease
SPIRIT: Standard Protocol Items: Recommendations for Interventional Trials
UPDRS: unified Parkinson’s disease rating score

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PMID:

Peer reviewed posters

Towards a better understanding of turning in people with Parkinson's.

Health Sciences

UNIVERSITY OF Southampton

Towards a better understanding of turning deficits in people with Parkinson's

Sophia Hulbert (smh1e11@soton.ac.uk), Malcolm Burnett, Ann Ashburn, Lisa Roberts, Geert Verheyden

Introduction

Parkinson's disease (PD) is a common, progressive, neurodegenerative movement disorder of the central nervous system, presenting with particular impairment of the motor system[1]. Clinically, people with PD **(PwPD)** demonstrate a **loss of axial rotation** of the spine[2] (**'moving "en bloc**'), with **little dissociation** between the head, trunk and lower limbs **whilst turning**. This is in contrast to the inter-segmental reciprocal movements seen in healthy controls (HC)[3]. Literature suggests that movement deficits of the head and trunk may drive secondary deficits seen in the limbs[4].

Aim

To examine the relation between head/trunk and limb movement during turning on-the-spot in PwPD and HC.

Method

Using 3-D movement analysis (Figure 1 & 2), five PwPD (median age 73, Hoehn & Yahr 1-3) and four healthy controls (median age 71) completed twelve **180° on-the-spot turns**, cued by a light system. Data were collected on:

- **Latency** (delay) and **change in horizontal movement** of the eyes, head, thorax, shoulders, pelvis and feet (Figure 2) from the light cue to the point of first foot movement.
- **Weight transference**
- **Time of the turn** and **step count** were recorded via the **SS180 test** (video analysis of a 180° turn)

Descriptive statistics were used to compare groups.

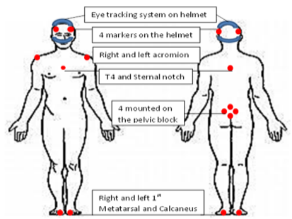

Figure 1: Marker placement for 3-D movement analysis.

SCREEN DEMONSTRATION

For a real time demonstration of the adjusted 3-D data used in this study when the screen is not present please use the following links.

Website: http://www.southampton.ac.uk/healthsciences/about/staff/smh1e11.page

Please scan:

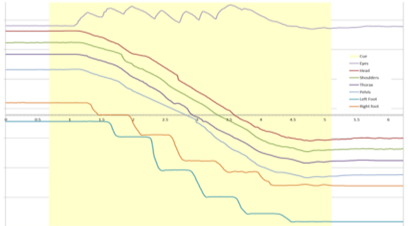

Figure 2: Adjusted 3-D movement analysis data output over time (case study).

Results

HC showed **shorter latencies** in all body segments (Figure 3) and **faster total turn time** compared to PwPD, replicated in the SS180. HC upper body-segments (eyes, head, shoulder, and thorax) showed a '**top down**' order, not seen in PwPD. HC also showed **greater weight transference** relative to base of support.

PwPD showed **greater rotation in the head** and **pelvis** compared to HC (which showed negative correlation) and **less rotation in the shoulders** and **thorax** (both showed correlation to the pelvis). The reverse occurred in HC (Figure 4). PwPD **took more steps**, which showed correlation to the change in angle of the head, shoulders and thorax, but not in HC (Figure 4).

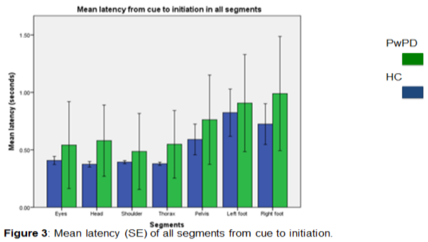

Figure 3: Mean latency (SE) of all segments from cue to initiation.

	Head	Shoulder	Thorax	Pelvis	Number of Steps
Head					
Shoulder	0.60 0.87				
Thorax	0.60 0.92	0.96 0.99			
Pelvis	-0.10 0.76	0.63 0.34	0.72 0.47		
Number of Steps	0.66 -0.10	0.82 0.21	0.77 0.05	0.28 -0.54	

Figure 4: Correlations between rotation of body segments at initial stages of the turn and number of steps to complete the turn (r values).

Discussion

- PwPD showed a tendency towards altered co-ordination, with a slower 'en bloc' pattern of axial segments and corresponding perpendicular deficits of increased step number compared to HC.
- In agreement with recent literature[5], the head and pelvis appear to play a key role in driving the rotation of other body segments and corresponding footsteps in PwPD. This supports the notion of axial deficits driving perpendicular deficits. Further investigation is required to better understand the underlying mechanisms of such interplay.

Key Point

The turning difficulties experienced by people with Parkinson's disease may be influenced to a greater extent by the deficits in speed and co-ordination of the axial body segments than previously thought. Focus on these should be made in rehabilitation programmes.

Future Studies

Further research investigates the effects of ballroom dancing on turning, including the effects of prediction and preference of turn direction, from a sample of 24 PwPD in a RCT.

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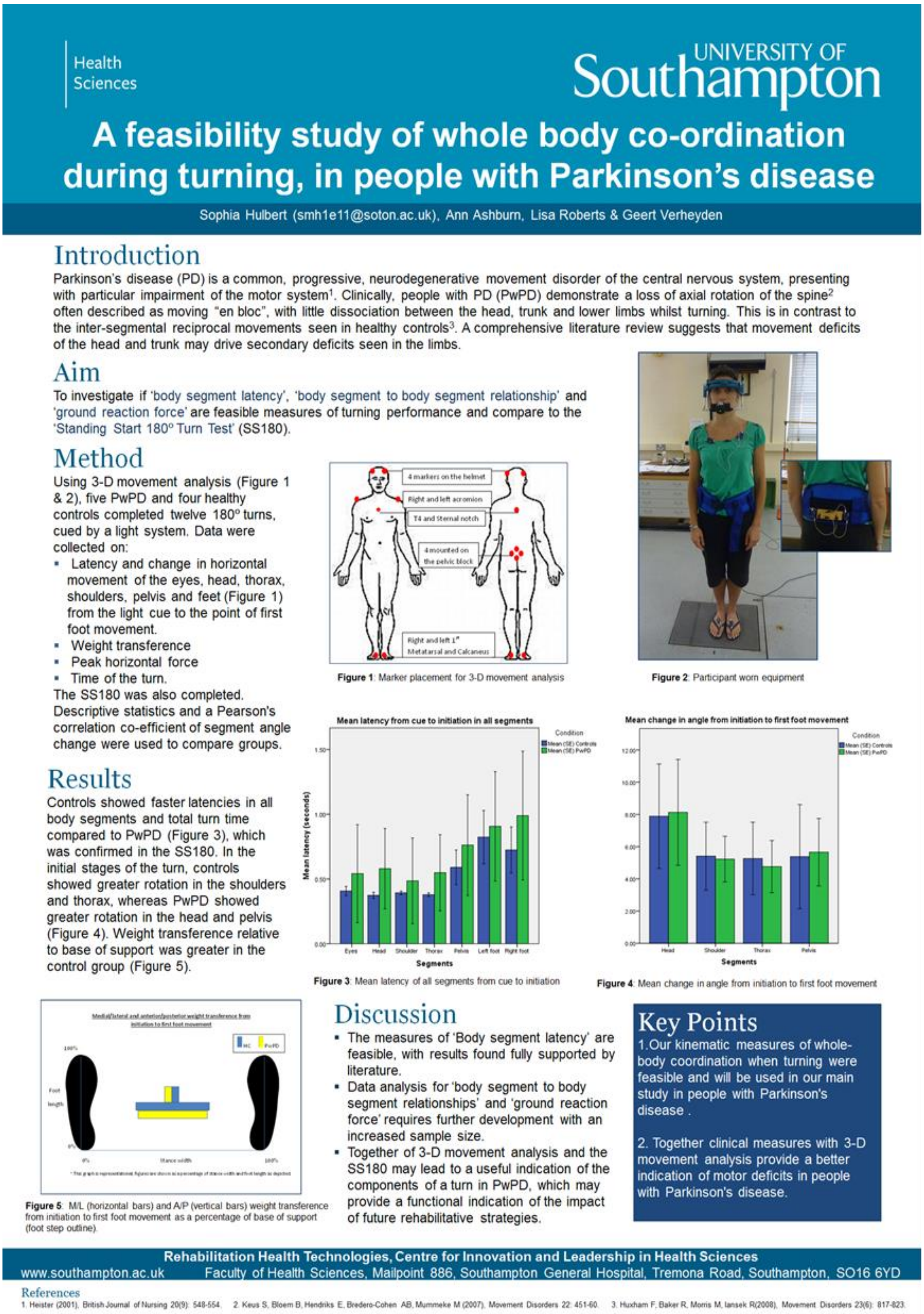
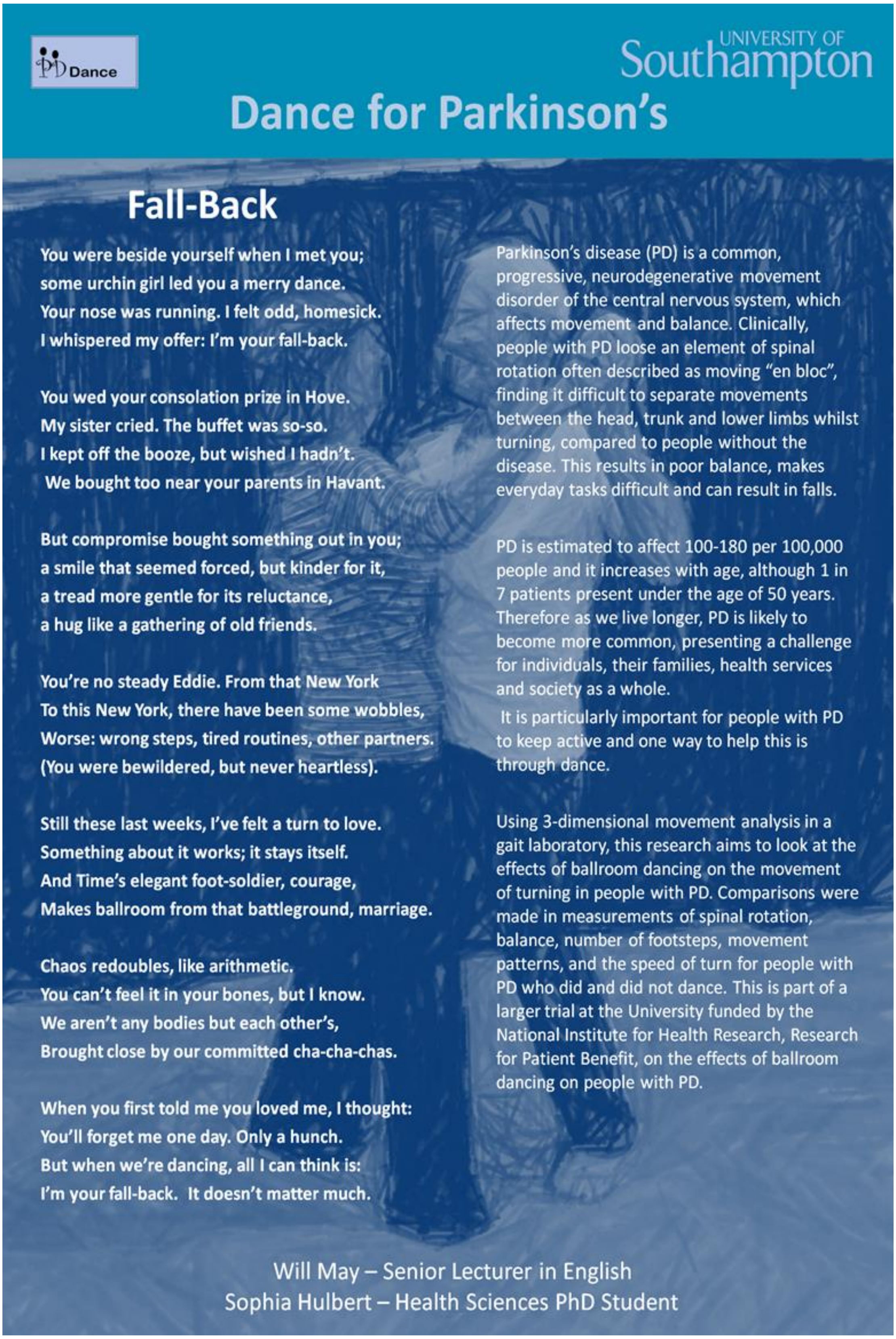
Rehabilitation Health Technologies, Centre for Innovation and Leadership in Health Sciences, Faculty of Health Sciences, Mailpoint 886, Southampton General Hospital, Tremona Road, Southampton, SO16 6YD

A feasibility study of whole body coordination during turning, in people with Parkinson’s disease.

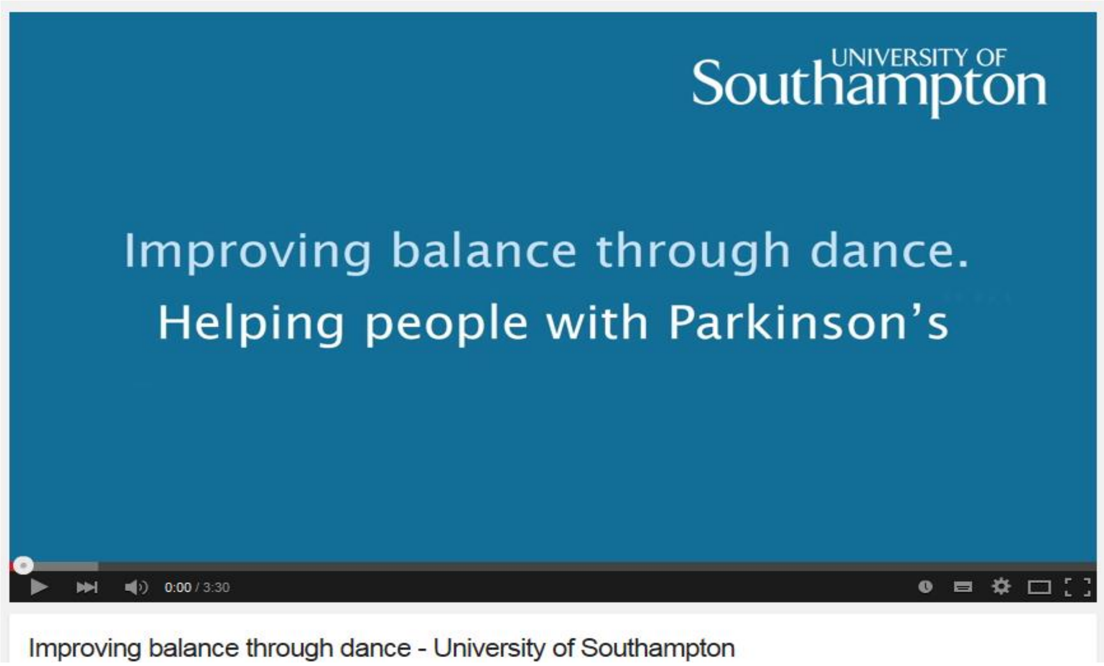


University of Southampton – Litmus Project.



Online media

Dancing with Parkinson's - Youtube clip.



https://www.youtube.com/watch?v=YWJxKge86vU

Parkinson's Dance – The effects on turning – '3 Minute Thesis Competition'.

Sophia Hulbert 'Parkinson's Dance - The effects on turning'

https://www.youtube.com/watch?v=A3qzTL00TYQ

Appendix 2 – Literature search methods

Literature search terms for the effects of dance for people with Parkinson's.

A literature search was conducted using the bibliographic databases: Cumulated Index of Nursing and Allied Health Literature (CINAHL), International Bibliography of the Social Sciences Medline, the Allied and Complementary Medicine Database (AMED), Psych Info, Web of Science (Core Collection), Cochrane and Physiotherapy Evidence Database (PEDro) between the period 2000 and March 2015. This broad spectrum of databases was selected to gain coverage of those articles that may be sited in the 'Arts' or 'Medical' literature base, as it is likely that 'Dance as therapy' may lie in either of these paradigms.

The search terms 'Parkinson*' and 'Danc*' with truncations were used with the Boolean operator 'AND'. The additional filter of 'English language' was also used. Using a set of predetermined keywords that describe the major topics of each article as a controlled vocabulary search (where available) did not provide additional articles. Hand searching and citation searches of key papers provided additional papers of interest.

A total of 304 papers were identified across all database searches. Initial review of the combined search results by title and abstract lead to 130 papers deemed to be appropriate to the topic, with 84 being selected for review after duplicates. Reviewing the reference list of key papers provided 17 additional papers of interest. As a variety of experimental methods were used in the articles selected, it was not appropriate to use a general literature review tool such as the Critical appraisal skills programme (CASP) checklists (Critical appraisal skills programme 2013). Due to the explorative nature of this review, papers considered poor in quality (i.e. small sample size, methodical difficulties and case reports) were not excluded and this is considered throughout the discussion of literature in Chapter 2.

Literature search terms for the exploration of teaching experiences in dance for people with Parkinson's.

A literature search was conducted using the bibliographic databases: Cumulated Index of Nursing and Allied Health Literature (CINAHL), International Bibliography of the Social Sciences, the Allied and Complementary Medicine Database (AMED), Psych Info and Web of Science (Core Collection) between the period January 2000 and March 2015. This broad spectrum of databases was selected to gain coverage of those articles that may be sited in the 'Arts' or 'Medical' literature base.

The search terms 'Teach*' and 'Danc*' with truncations were used with the Boolean operator 'AND', this search was then combined with the search term 'Parkinson*', resulting in 17 papers in total (excluding duplicates) across all databases. The additional filter of 'English language' was also used.

In addition to this, advice was sort from an expert academic in this field (Dr Sara Houston) on relevant material and thus the Journal 'Research in Dance Education', which was not included in the initial searches, was hand-searched from 2000-2015 by the terms 'Parkinson' and 'disability' resulting 2 and 40 papers respectively. Hand-searching and citation searches of key papers provided one book chapter of interest.

The websites of 'Dance for Parkinson's network UK' and 'Dance for PD' (Brooklyn, New York) were also reviewed.

A total of 59 papers were identified, excluding duplicates. The majority of these papers were related to the implementation and practical delivery of the class, rather than the experience of the teacher, with only two papers and one book chapter commenting on the teachers experience and therefore included in the review in Section 3.2.

Literature search terms for turning performance in people with Parkinson's

A literature search was conducted using the bibliographic databases: Cumulated Index of Nursing and Allied Health Literature (CINAHL), Medline, Web of Science (Core collection), Cochrane and Physiotherapy Evidence Database (PEDro) between January 2000 and March 2015.

The search terms 'Parkinson*' and 'Turn*' with truncations were searched and combined with the Boolean operator 'AND' for all databases apart from Cochrane, which was searched for by Parkinson* only, due to limited material. The additional filter of 'English language' was also used.

After completing the electronic search, papers were reviewed through title and abstract. Due to the broad search specifications for this topic, all papers investigating physical parameters in PwP were included initially, and then further refined to include only papers regarding turning specifically. The reference lists of included papers were also searched, for papers not identified in the electronic search.

A total of 2713 papers were identified after excluding 998 duplicates. Initial review of the combined search results by title and abstract lead to 171 papers being selected for all physical parameters. Exclusion of papers at this stage was due to their focus on the pharmaceutical management and biochemistry of deficits in Parkinson's. The search was then refined to 57 papers with specific focus on turning and Parkinson's. Papers at this stage were excluded due to their focus being on gait rather than turning. Reviewing the reference list of key papers provided 20 additional papers of interest. A total of 77 papers were reviewed in full. As a variety of experimental methods were used in the articles selected, it was not appropriate to use a general literature review tool such as the Critical appraisal skills programme (CASP) checklists (Critical appraisal skills programme 2013). Due to the explorative nature of this review, papers considered poor in quality (i.e. small sample size, methodical difficulties and case reports) were not excluded and this is considered in the discussion of literature in Sections 4.3 and 4.4.

Literature search terms for external influencing factors on turning in people with Parkinson’s

A literature search was conducted using the bibliographic databases: Cumulated Index of Nursing and Allied Health Literature (CINAHL), Medline, Web of Science (Core collection), Cochrane and Physiotherapy Evidence Database (PEDro). The International Bibliography of the Social Sciences was also searched as this may gain coverage of those articles more related to the social implications of the condition.

The search terms ‘task*, environment*, quality of life* and cue*’ with truncations were used, with the Boolean operator ‘AND’ to link each variable to the search terms ‘Parkinson* and turn*’. Additional filter of ‘English language’ was also used. Hand searching and citation searches of key papers provided an additional four papers of interest.

A total of 291 articles were identified by these search methods. Abstract review of all resulted with 15 being appraised and considered for the purposes of this section of the review.

It is important to note that this is an area with significant research and evidence base in PwP that cannot be exhaustively covered, with only key papers of interest being discussed in Section 4.5.

Appendix 3 – Developmental work

Developmental work from the pilot study of the RfPB study (and this PhD)

Selection of dances to be included in the intervention

Dance	Reason for selection in pilot study	Outcome for RfPB study	Adaptations required and reason
Social Foxtrot	Easy to begin and complete full dance around the room. Encompassed side stepping.	Included	None needed.
Waltz	Basic step can be taught in a simplified manor and advanced as required. Encompassed turning steps in hold.	Included	Substituted ‘spin turn’ (fast stepped turn) for ‘whisk and chassé’ step (alternating forwards and backwards walking step)
Argentine Tango	Encompassed backwards walking. Well researched in the literature.	Substituted for ballroom tango	Overly complicated steps and a falls risk with complicated backwards stepping.
Cha cha cha	Strong cue from the music. Encompassed side stepping and turning steps.	Included and rumba added	Difficulty found in the speed of the side steps. Added the rumba to practice slower side step.
Jive	Familiar music with strong cue. Encompassed side stepping and turns.	Substituted for Rock ‘n’ Roll	Difficulty with speed of the steps, ‘bounce’ action and turn.

Table 24 – Selection of dances from Pilot RfPB study

Summary of Feasibility study of whole body coordination during turning in people with Parkinson's

It was necessary to complete a feasibility study of the possible outcome measures to be used for this study. Whilst some of the measures had been used successfully by the research group (Stack & Ashburn 2005; Stack et al. 2002b; Ashburn et al. 2010), it was necessary to establish if all the measures were feasible in collaboration. This also allowed investigation of the possible relationship they had to one another and gave an accurate insight into the experience of the measures and analysis.

Using 3-dimensional movement analysis, five people with Parkinson's (PwP) and four healthy controls (HC) completed the testing procedure in the Gait laboratory on one occasion. This included twelve 180 degree turns, used to collect data on 1) latency and angular horizontal movement of the eyes, head, thorax, shoulders, pelvis and feet from initiation to the point of first foot movement (FFM); (2) weight transference; (3) peak lateral force and (4); total time of the turn. An additional two turns were completed for use with the Standing start 180 degree turn test (SS180).

Feasibility was determined by the ability of the participants to complete the assessment, and the researcher to collect, extract and analyse the data. Descriptive statistics were used to describe the relationships between variables and differences between PwP and HC.

Results indicated all components of feasibility were met for all measures.

The measures of 'body segment latency' and SS180 were thought suitable for this subsequent study, with results found fully supported by specific and relevant literature.

The data collection and extraction process for 'body segment horizontal movement' and 'weight transference' were feasible, however the data analysis process required additional development in order to give clinically meaningful results. These measures required the use of the FFM as a specific point in the turn to measure the relationship of the rotation of body segments and ground reaction forces, which provided a feasible measure of ‘wind-up’ (amount of rotation of each body segments from start to release of the foot).

The maximum interplay between ground reaction forces and the body segment position was a difficult performance variable to analyse. The use of the peak lateral horizontal force in relation to the FFM was feasible to collect and extract, however results were highly variable and meaningful difference between the groups was not evident. Therefore this measure was not carried through to this study.

The collaboration of clinical outcome measures (SS180) alongside the laboratory based measures (‘Body segment latency’, ‘Body segment horizontal movement’, ‘and ‘Ground reaction forces’), did provide a useful indication of the relationship of the axial and perpendicular deficits experienced in turning for PwP and thus the clinical measure was continued forward for use in this study with the addition of the Berg balance scale (BBS) for a clinical representation of balance performance.

From the findings of the feasibility study, the following measures were established for this study:

Measure	**Body Segment**	**Output**	**Data collection method**
Body segment latency	Eyes Head Shoulders Thorax Pelvis Feet (left and right)	Time (sec) delay from cue* to initiation of movement for each segment.	Kinematic – Coda 3-dimensional movement analysis of cue to initiation of movement
Change in body segment angle	Head Shoulders Thorax Pelvis	Angular change (degrees) from initiation to FFM for each segment.	Kinematic – Coda 3-dimensional movement analysis of cue to FFM
Weight transference	Whole body	Medial/Lateral weight transference (% stance) Anterior/Posterior weight transference (% stance) Total weight transference (mm) Position of weight	Kinematic – Force plate analysis of cue to FFM

		(anterior/posterior) Stance width (mm)	
Total time of turn	Whole body	Time (sec)	Kinematic – Shoulder initiation to stop time
SS180	Whole body	Time (sec) Number of footsteps (n) Type of turn (category) Quality of turn (rated/5)	Clinical measure with video analysis
BBS	Whole body	Balance score (rated/56)	Clinical measure as part of the RfPB study
Demographics	N/A	Age Preferred turn direction Leg dominance Hand dominance H&Y score Years since diagnosis	Participant pre-assessment screening

Table 25 – Table of measures selected from the feasibility study.

* A ‘cue’ in this instance is the point at which the light in front of the participant is illuminated, giving the signal to turn.

The results from the feasibility study, alongside the literature, supported the possibility of axial deficits driving perpendicular deficits in PwP. PwP had a tendency towards a slower, altered coordination, ‘en bloc’ pattern of axial segments with corresponding perpendicular deficits of increased step number compared with HC. It was not possible to elaborate on the exact mechanism of this interplay as the study was not powered for such analysis.

Appendix 4 – Contact letter and Information sheet for dance teachers

Health Sciences

UNIVERSITY OF Southampton

Southampton General Hospital
Rehabilitation Research
Room 113, Level E, Centre Block
Tremona Road
Southampton
SO16 6YD

Telephone: 02380 798669

Date:

Dear:

I am writing to you to inform you about a research study that you are invited to take part in, '**What are the experiences of dance teachers delivering ballroom dance classes to people with Parkinson's disease?**. This is part of a larger study '**Parkinson's and Dance**' by the University of Southampton.

Attached to this letter is an information sheet that explains in more detail what the study involves. If you have any questions that are not answered in the information sheet please do not hesitate to contact me.

If you are interested in taking part in this study and would like further information, I would be most grateful if you could complete the reply slip below and return it in the stamped addressed envelope provided. This will not commit you to taking part in the study.

Thank you,

Yours faithfully

Sophia Hulbert

Health
Sciences

UNIVERSITY OF Southampton

Southampton General Hospital
Rehabilitation Research
Room 113, Level E, Centre Block
Tremona Road
Southampton
SO16 6YD

Telephone: 02380 798669

PARTICIPANT INFORMATION SHEET

For the teachers of the Dance class

'**What are the experiences of dance teachers delivering ballroom dance classes to people with Parkinson's disease'**

We would like to invite you to take part in our research study. Before you decide whether or not to take part, we would like you to understand why the research is being carried out and what it will involve. Please take time to read the following information carefully. If you would like further information, please do not hesitate to contact me on the telephone number given on this information sheet.

What is the purpose of this study?

Dance for people with Parkinson's disease has been shown to be beneficial for the participants by a number of research studies. However, there is little information available regarding the experience of the class for those delivering it. An improved understanding of what it is like to deliver the class may not only help the experience for the participants but also the teachers for subsequent classes.

The purpose of this small study is to gain an understanding of what it is like to deliver a ballroom dance class for people with Parkinson's disease. We hope to look at the experience of delivering a new class with participants that have not danced before. We will use the information to gain an understanding of the experience of dance teachers delivering a ballroom dance class for people with Parkinson's disease.

The study is in collaboration with a larger study run by the University of Southampton looking at many aspects of ballroom dance for people with Parkinson's disease, including balance, mobility, turning and the experience of the participants.

Why have I been invited?

You have been invited as you have been identified by the Diamont School of Dance to deliver a new ballroom dance class for people with Parkinson's as part of the larger research project.

Do I have to take part?
It is up to you to decide to join the study. By returning the reply slip with this letter you are only agreeing to be contacted by the researcher at this point. We will describe the study and go through this information sheet. If you agree to take part, we will then ask you to sign a consent form. You are free to withdraw at any time without giving a reason.

What will happen to me if I take part?
If you return the attached form saying you are interested in taking part then you will be contacted by the researcher, preferably by telephone although arrangements can be made if this is not convenient. The researcher will again describe the process of your involvement and you will have further opportunity to ask questions.

The process:
In order to gain as much information about your experience of delivering the classes the researcher will need to meet with you for an interview. They will have a number of questions to ask you about your thoughts and experiences and you will also have opportunity to talk about any other aspect of the class that you wish. This will take approximately an hour, however this time can be flexible.

The researcher will need to meet with you once before you start to deliver the classes and once after all the classes have finished.

If you agree, the interview will be recorded on audiotape and then written. All meeting times will be made at a time and place convenient to you.

What are the possible benefits of taking part?
There will be no direct benefit to you from taking part in the study. However it is hoped that the information collected will allow us to gain a better understanding of the experience for dance teachers involved in delivering ballroom dance to people with Parkinson's disease.

Are there any risks involved?
There should be no risks from taking part in the study. You will be able to stop the discussion at any point should you wish without giving reason.

What if there is a problem or I have a complaint?
If you feel you any concerns or a complaints about this study you should contact Professor Ann Ashburn (Address: Southampton General Hospital, Level E, Centre Block, MPT 886, SO166YD; Tel: +44 (0)23 8079 6469; Email: ann@soton.ac.uk) . If you remain unhappy and wish to complain, Ann will

provide you with details of the University of Southampton and University Hospital Southampton NHS Foundation Trust Complaints Procedure.

Who is organizing the research & reviewing the study?
The study is being run by the University of Southampton and has been reviewed by the South Central- Southampton A Research Ethics committee.

Will my participation be kept confidential?
All information which is collected about you during the course of the research will be kept strictly confidential. Each person will be allocated an ID number by which any documentation will be identifiable to the researchers only. All information will be kept in a locked filing cabinet in accordance with storage of medical records. The results from the study will be entered into a university computer, accessible only to the researchers. Any information about you which is used in research reports or publications will have your name and address removed so that you cannot be recognised from it.

What will happen to the results of the research?
At the end of the research, the data collected will be securely stored at the University of Southampton for 10 years. The results will be presented at conferences and may be published in research papers for scientific journals. If you would like a copy of the published results at the end of the study please let us know.

Contact for further information:
If you would like any further information please contact Sophia Hulbert on (023) 8079 8669.

Thank you once again for taking the time to read this information.

Appendix 5 - Dance teachers reply slip

Health
Sciences

UNIVERSITY OF
Southampton

Southampton General Hospital
Rehabilitation Research
Room 113, Level E, Centre Block
Tremona Road
Southampton
SO16 6YD

Telephone: 02380 798669

Reply Slip

What are the experiences of dance teachers delivering ballroom dance classes to people with Parkinson's?

I would like further information about this study and am happy for the researcher to contact me.

I agree for you to contact me (Please initial the box) ☐

Please use the following contact details to contact me: (Please Print)

Name: ______________________________

Telephone Number: ______________________________

OR Address: ______________________________

____

____

____

____

OR e-mail: ______________________________

Please return the reply slip in the stamped addressed envelope.
Thank you very much for your interest.

Yours faithfully, Sophia Hulbert

Appendix 6 – Pre-class interview topic guide

Dancing with Parkinson's – Qualitative study with Dance teachers
Interview Schedule

Topics to explore prior to the classes starting:

1) Prior Knowledge:

- Can I start by asking what you know about Parkinson's?
  Prompts:
  - Do you know anyone with the disease?
  - Have you read anything about the disease?
- Have you ever taught anyone with PD to dance, that you are aware of?
  Prompts:
  - Have you worked with anyone with a movement difficulty?
  - What was it like?

2) Expectations:

- What are your expectations of delivering a dance class to people with Parkinson's?
  Prompts:
  - Do you think it will be different from delivering your usual dance class?
  - What will be the highlights?
  - What will be the challenges?
- What dances do you think will be the best for people with Parkinson's to do?
- Why have you chosen these?
  - Do you think they will be able to do all types of ballroom dancing?
  - Are there particular parts of each dance that you think may be too difficult?

3) Impact:

- In general what do you think the benefits of dancing are?
  Prompts:
  - Physical benefits
  - Social and Psychological benefits
- Are there any negative aspects of dancing for people with Parkinson's that you can think of?
  Prompts:
  - Physically
  - Emotionally
- Do you think these benefits will be the same for people with Parkinson's?
  Prompts:
  - Are there aspects of each dance that will specifically help them?
  - How do you think it might help them?

4) Was there anything else you would like to add?

5) Thank you for your time.

Appendix 7 – Post-class interview topic guide

Dancing with Parkinson's – Qualitative study with Dance teachers

Interview Schedule

Topics to explore after the classes:

1) Experience
- How did you get on delivering the class?
  - What were the highlights?
  - What were the challenges?

- Was it like you had expected?
  Prompts:
  - What aspects were easier?
  - What aspects were harder?

2) Impact
- Did you notice any changes in the participants over the course of the class?

Prompts:
- Were there certain moves that had a greater effect?
- Were there types of dance that seems more beneficial?
- Were there certain types of dance that seems less beneficial?
- Were the effects just physical or did you see any other effects?

3) Future
- What would you change if you were to deliver the class again?
  Prompts:
  - Was the length of time appropriate?
  - Was the number of classes appropriate?
  - Was the type of dance you chose appropriate?

- What advice would you give to teachers of a Parkinson's dance class?
  Prompts:
  - using your experiences discussed above

- How would you summarise your experience?

Prompts:
- Using three words
- In a paragraph?

4) Was there anything else you would like to add?

5) Thank you for your time

Appendix 8 – Qualitative study consent form

Health
Sciences

UNIVERSITY OF
Southampton

Southampton General Hospital
Rehabilitation Research
Room 113, Level E, Centre Block
Tremona Road
Southampton
SO16 6YD

Telephone: 02380 798669

CONSENT FORM

Title of Project: What are the experiences of dance teachers delivering ballroom dance classes to people with Parkinson's disease?

Name of Researcher: Sophia Hulbert

Please initial box

1. I confirm that I have read and understand the information sheet Dated 24/08/13 (version.1.) for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my legal rights being affected. ☐

3. I understand that at the end of the study data collected from me will be securely stored at the University of Southampton for 10 years. ☐

4. I agree to take part in the above study. ☐

5. I understand that my name will not be identifiable in any reports, papers or presentations arising from this research. ☐

6. I agree to anonymous information to be used for teaching purposes and at conferences. ☐

________________	________________	________________
Name of Participant	Signature	Date
________________	________________	________________
Name of Researcher	Signature	Date

1 for participant, 1 for researcher

Appendix 9 – Example of Framework analysis for interview data

Category	Prior Knowledge				
Sub Catergory	**Physiological (medical based)**	**Functional (practical issues**	**Psychological**	**Social**	**Where knowledge was gathered from**
01 Pre	Movement wise - bit shuffly with their feet, swaying, slower, not very good facial expression, (17-19) Shake (but not seen in people she knows) (26-27) Believes there are two types of PD - ones where they shake and one where they don't (28-29) Aware that it is more prevalent in Males (260)	not very good minor motor skills - buttons terrible handwritting (20-21) Not diagnosed until later on in some cases (36-37)		Quite a bit of knowledge as best friend's Dad had PD (5-6). The best friend's Mum got quite involved (6-7) , lots of research in PD, knows research team (7), part of a PD association (9).	EXPERENTIAL - Friends Dad - discussion with her friends Mum. Seeing her Nan (who has PD)
02 Pre	Understand very little/no idea really (21) "I am not a medical person, I'm purely a dancing teacher" (17-18) Know that it is something that happens in the brain - as a result of the mini strokes that his mother had (21-24) but don't know what that does (24) medication helps quite a lot (27) gradual decline (108) Shuffly walk (116) could dance normally so possibly this made different part of the brain work (125-126) Be a bit slower (421) moving forward seems to be a struggle for most(670)	one minute they can do something and the next they can't (88-89)	doesn't change their personality (419), so if you have a competative instinc beofre PD then you still will have (423)	houmour is still there but there is a delay in the reponce (104)	dance client and mother both have PD pilot classes

Appendix 10 – Dance intervention pictures

The 'ballroom hold'

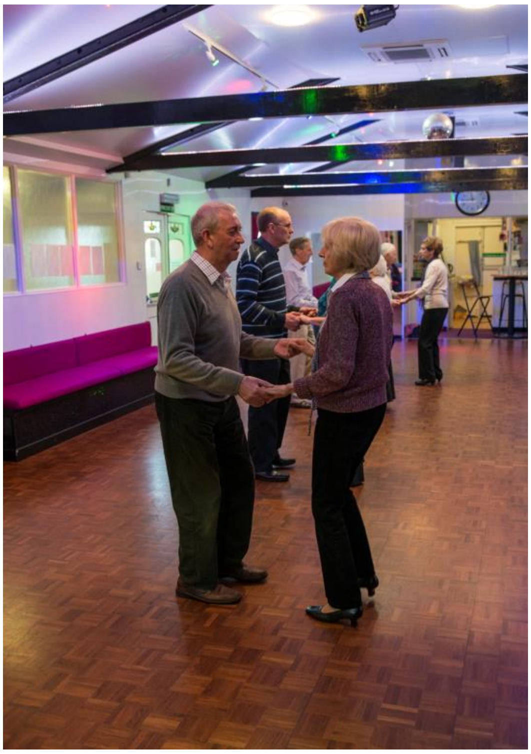
Promenade in tango

'New York' step in the Cha Cha

Ladies under-arm turn

Guidance of a turn by the partner

Side stepping in the Cha Cha



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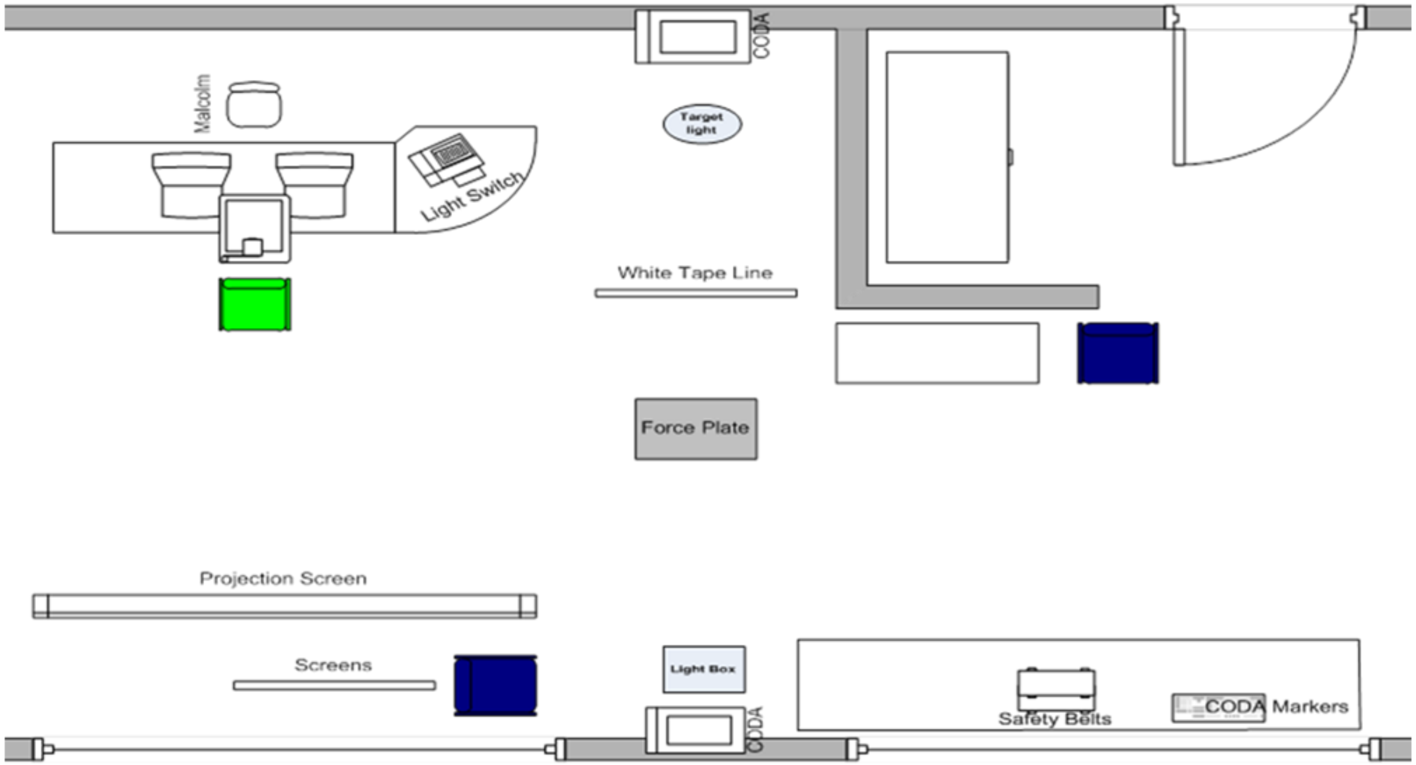
Appendix 11 – Laboratory set up



Appendix 12 – Demographic assessment sheet

Health Sciences

UNIVERSITY OF Southampton

Southampton General Hospital
Rehabilitation Research
Room 113, Level E, Centre Block
Tremona Road
Southampton
SO16 6YD

Telephone: 02380 798669

Telephone/Lab screening checklist sheet

Participant's ID:…………………………………………………………………………………………….

Date:………………………….

1. Diagnosis of Parkinson's disease: No ☐ Yes ☐

Consultants Name…………………………………………………………

2. Stage I – III on Hoehn and Yahr Scale: No ☐ Yes ☐
3. Visual problems: present ☐ absent ☐
4. Ability to understand/remember instructions:

   unable ☐ able ☐
5. Ability to stand/turn: unable ☐ able ☐
6. Other neurological problems: present ☐ absent ☐
7. Musculoskeletal problems: present ☐ absent ☐

'To be included in the study, all the boxes on the right need to be ticked

Through both telephone conversation and reviewed at point of consent'

Further Screening Information

8. Initial side of onset………………………..

9. Current symptoms and duration

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

10. Current Medications

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

11. Optimum medication time (time of day)……………………………………...

12. Age at testing………………………………………………...……………

13. Hand dominance……………………………………………………………….

(Assessed as hand used to write with)

14. Foot dominance *(Trial 1…………..2…………..3…………)* …………………

(Assessed as foot used to kick a foam ball whilst seated – repeated three times)

15. Relevant Past Medical History

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

Appendix 13 – SS180 assessment sheet

SS 180 Assessment

Eye, Head, Body Coordination while Turning

ID

Date of Lab Meeting	

Section 1; Steps & Time

	DU Turn	DS Turn	Mean
Turning Steps (n)			
Turn Time (sec)			

Section 2; Turn Type (circle one)

DU Turn	DS Turn
Toward Pivotal Lateral Incremental Delayed	Toward Pivotal Lateral Incremental Delayed

Section 3; Turn Quality (Yes = 0, No = 1)

	DU Turn	DS Turn	
Independence			
Clearance			
Stability			
Continuity			
Posture			
Total			Mean:

Page 1

Appendix 14 – Berg balance scale assessment sheet

Berg balance scale

The Berg Balance Scale (BBS) was developed to measure balance among older people with impairment in balance function by assessing the performance of functional tasks. It is a valid instrument used for evaluation of the effectiveness of interventions and for quantitative descriptions of function in clinical practice and research. The BBS has been evaluated in several reliability studies. A recent study of the BBS, which was completed in Finland, indicates that a change of eight (8) BBS points is required to reveal a genuine change in function between two assessments among older people who are dependent in ADL and living in residential care facilities.

Description:
14-item scale designed to measure balance of the older adult in a clinical setting.

Equipment needed: Ruler, two standard chairs (one with arm rests, one without), footstool or step, stopwatch or wristwatch, 15 ft walkway

Completion:
Time: 15-20 minutes

Scoring: A five-point scale, ranging from 0-4.
"0" indicates the lowest level of function and "4" the highest level of function.
Total Score = 56

Interpretation: 41-56 = low fall risk
21-40 = medium fall risk
0 –20 = high fall risk
A change of 8 points is required to reveal a genuine change in function between 2 assessments.

Berg Balance Scale

Name: ______________________________ Date: __________________

Location: ____________________________ Rater: __________________

ITEM DESCRIPTION	SCORE (0-4)
Sitting to standing	________
Standing unsupported	________
Sitting unsupported	________
Standing to sitting	________
Transfers	________
Standing with eyes closed	________
Standing with feet together	________
Reaching forward with outstretched arm	________
Retrieving object from floor	________
Turning to look behind	________
Turning 360 degrees	________
Placing alternate foot on stool	________
Standing with one foot in front	________
Standing on one foot	________

Total ________

GENERAL INSTRUCTIONS

Please document each task and/or give instructions as written. When scoring, please record the lowest response category that applies for each item. In most items, the subject is asked to maintain a given position for a specific time. Progressively more points are deducted if:

- the time or distance requirements are not met
- the subject's performance warrants supervision
- the subject touches an external support or receives assistance from the examiner

Subject should understand that they must maintain their balance while attempting the tasks. The choices of which leg to stand on or how far to reach are left to the subject. Poor judgment will adversely influence the performance and the scoring.

Equipment required for testing is a stopwatch or watch with a second hand, and a ruler or other indicator of 2, 5, and 10 inches. Chairs used during testing should be reasonable height. Either a step or a stool of average step height may be used for item # 12.

Berg Balance Scale

SITTING TO STANDING

INSTRUCTIONS: Please stand up. Try not to use your hand for support.

( ) 4 able to stand without using hands and stabilize independently

( ) 3 able to stand independently using hands

( ) 2 able to stand using hands after several tries

( ) 1 needs minimal aid to stand or stabilize

( ) 0 needs moderate or maximal assist to stand

STANDING UNSUPPORTED

INSTRUCTIONS: Please stand for two minutes without holding on.

( ) 4 able to stand safely for 2 minutes

( ) 3 able to stand 2 minutes with supervision

( ) 2 able to stand 30 seconds unsupported

( ) 1 needs several tries to stand 30 seconds unsupported

( ) 0 unable to stand 30 seconds unsupported

If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL

INSTRUCTIONS: Please sit with arms folded for 2 minutes.

( ) 4 able to sit safely and securely for 2 minutes

( ) 3 able to sit 2 minutes under supervision

( ) 2 able to able to sit 30 seconds

( ) 1 able to sit 10 seconds

( ) 0 unable to sit without support 10 seconds

STANDING TO SITTING

INSTRUCTIONS: Please sit down.

( ) 4 sits safely with minimal use of hands

( ) 3 controls descent by using hands

( ) 2 uses back of legs against chair to control descent

( ) 1 sits independently but has uncontrolled descent

( ) 0 needs assist to sit

TRANSFERS

INSTRUCTIONS: Arrange chair(s) for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.

( ) 4 able to transfer safely with minor use of hands

( ) 3 able to transfer safely definite need of hands

( ) 2 able to transfer with verbal cuing and/or supervision

( ) 1 needs one person to assist

( ) 0 needs two people to assist or supervise to be safe

Berg Balance Scale continued…

STANDING UNSUPPORTED WITH EYES CLOSED

INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.

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

STANDING UNSUPPORTED WITH FEET TOGETHER

INSTRUCTIONS: Place your feet together and stand without holding on.

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

REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING

INSTRUCTIONS: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at the end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)

( ) 4 can reach forward confidently 25 cm (10 inches)
( ) 3 can reach forward 12 cm (5 inches)
( ) 2 can reach forward 5 cm (2 inches)
( ) 1 reaches forward but needs supervision
( ) 0 loses balance while trying/requires external support

PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION

INSTRUCTIONS: Pick up the shoe/slipper, which is in front of your feet.

( ) 4 able to pick up slipper safely and easily
( ) 3 able to pick up slipper but needs supervision
( ) 2 unable to pick up but reaches 2-5 cm (1-2 inches) from slipper and keeps balance independently
( ) 1 unable to pick up and needs supervision while trying
( ) 0 unable to try/needs assist to keep from losing balance or falling

TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING

INSTRUCTIONS: Turn to look directly behind you over toward the left shoulder. Repeat to the right. (Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.)

( ) 4 looks behind from both sides and weight shifts well
( ) 3 looks behind one side only other side shows less weight shift
( ) 2 turns sideways only but maintains balance
( ) 1 needs supervision when turning
( ) 0 needs assist to keep from losing balance or falling

Berg Balance Scale continued…

TURN 360 DEGREES

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

( ) 4 able to turn 360 degrees safely in 4 seconds or less
( ) 3 able to turn 360 degrees safely one side only 4 seconds or less
( ) 2 able to turn 360 degrees safely but slowly
( ) 1 needs close supervision or verbal cuing
( ) 0 needs assistance while turning

PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED

INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.

( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3 able to stand independently and complete 8 steps in > 20 seconds
( ) 2 able to complete 4 steps without aid with supervision
( ) 1 able to complete > 2 steps needs minimal assist
( ) 0 needs assistance to keep from falling/unable to try

STANDING UNSUPPORTED ONE FOOT IN FRONT

INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width.)

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

STANDING ON ONE LEG

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

( ) 4 able to lift leg independently and hold > 10 seconds
( ) 3 able to lift leg independently and hold 5-10 seconds
( ) 2 able to lift leg independently and hold L 3 seconds
( ) 1 tries to lift leg unable to hold 3 seconds but remains standing independently.
( ) 0 unable to try of needs assist to prevent fall

(   )TOTAL SCORE (maximum = 56)

Appendix 15 – Raw data sheet

Appendix 15 - Raw data sheet

Descriptive Statistics

	Type of turn	All											
	Group	Controls PRE			Controls POST			Dance PRE			Dance POST		
	Descriptive	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Latency	Eye	0.705	0.723	0.253	0.668	0.592	0.236	0.57	0.54	0.24	0.56	0.52	0.22
	Head	0.477	0.467	0.111	0.48	0.451	0.135	0.461	0.426	0.106	0.467	0.423	0.143
	Shoulder	0.451	0.556	0.076	0.455	0.436	0.13	0.453	0.448	0.109	0.5	0.452	0.221
	Thorax	0.47	0.436	0.13	0.443	0.418	0.113	0.452	0.443	0.104	0.45	0.439	0.125
	Pelvis	0.676	0.626	0.23	0.591	0.634	0.2	0.621	0.659	0.129	0.639	0.63	0.16
	First Foot	0.743	0.706	0.224	0.743	0.706	0.272	0.687	0.72	0.149	0.684	0.648	0.177
	Second Foot	1.118	1.089	0.272	1.14	1.077	0.291	1.09	1.08	2.159	1.088	1.066	0.258
Time	Coda	4.013	3.507	1.317	3.93	3.534	1.154	3.835	3.771	0.749	3.77	3.858	0.871
Angle change	Head	9.24	8.98	3.63	9.92	11.08	4.9	8.63	7.15	5.67	8.4	8.2	4.12
	Shoulder	6.51	5.71	3.54	6.82	5.54	4.09	6.15	6.2	2.89	5.46	4.93	2.97
	Thorax	6.21	5.99	3.03	7.27	5.77	4.53	7.09	6.99	4.53	6.47	6.45	3.2
	Pelvis	4.62	4.69	1.8	5.9	5.64	3.12	4.27	4.12	1.96	3.98	3.72	1.93
Force	M/L weight transfer	44.47	43.42	11.4	44.51	44.55	9.57	43.72	43.9	7.75	44.97	44.87	6.4
	Total weight transfer	137.95	126.63	45.15	145.45	132.53	49.11	135.15	132.83	35.12	140.02	137.18	38.88
	Stance width	172.87	162.98	42.42	179.06	169.46	40.66	183.433	173.49	49.78	184.86	196.6	41.33
	A/P Weight transfer	14.9	15.17	5.16	15.65	15.05	6.39	13.16	13.63	5.37	14.57	3.86	6.77
	A/P position												
SS180	Time (mean)	2.218	1.843	1.202	2.132	1.65	0.966	2.295	2.038	0.865	2.237	2.283	0.578
	Time (DU)	2.307	1.91	1.233	2.229	1.92	0.956	2.33	2.035	0.99	2.238	2.28	0.421
	Time (DS)	2.13	1.84	1.195	2.035	1.53	1.02	2.261	2.065	0.792	2.237	2.125	0.935
	Steps (DU)	4.58	4	2.275	4.42	4	2.021	4.08	4	0.9	4.75	4.5	1.712
	Steps (DS)	4.25	3.5	2.454	4.42	3	2.314	4.17	3.5	1.586	4.58	4	2.466
	Steps (mean)	4.417	3.75	2.31	4.42	3.5	2.1	4.13	4	1.04	4.67	4.5	1.92
	Quality (mean)	4.38	4.25	0.64	4.42	4.75	0.9	4.33	4.5	0.75	4.17	4	0.75
	Type of turn (DU/DS) - Toward	0/3			1/1			1/1			0/2		
	Pivotal	1/1			0/1			0/1			0/0		
	Lateral	2/1			3/5			2/3			4/1		
	Incremental	7/5			6/3			7/5			3/6		
	Delayed	2/2			2/2			2/2			5/3		
Berg Balance	Total score	51.92	54.4	6.4	50.42	54	2.17	50.5	52.5	1.45	5.3	5.5	1.78
	Age	71.2	71	5.63				73.42	73.5	4.91			
	H&Y	1.8	1.5	0.92	1.8	1.5	0.92	1.92	2	0.9	1.92	2	0.9
	Yrs since Dx	6.05	5.5	4.153	5.95	5	4.167	5.3	6	3.85	5.3	6	3.85

Key

	Controls	Dancers
All turns =		
Predicted/ Preferred turns =		
Predicted/ Un-preferred turns=		
Un-predicted/ Preferred turns =		
Un-predicted/ Un-preferred turns =		

	Type of turn	PPr											
	Group	Controls PRE			Controls POST			Dance PRE			Dance POST		
	Descriptive	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Latency	Eye	0.711	0.614	0.315	0.62	0.47	0.361	0.561	0.54	0.165	0.591	0.527	0.22
	Head	0.418	0.445	0.203	0.521	0.395	0.098	0.399	0.388	0.092	0.413	0.402	0.082
	Shoulder	0.419	0.411	0.104	0.428	0.396	0.119	0.404	0.423	0.072	0.524	0.432	0.382
	Thorax	0.521	0.445	0.203	0.42	0.403	0.131	0.41	0.416	0.089	0.409	0.383	0.103
	Pelvis	0.61	0.585	0.133	0.633	0.606	0.139	0.616	0.605	0.164	0.582	0.569	0.097
	First Foot	0.639	0.653	0.084	0.699	0.684	0.211	0.632	0.665	0.13	0.628	0.585	0.177
	Second Foot	1.041	1.034	0.175	1.072	1.078	0.224	1.067	1.078	0.201	1.045	0.988	0.266
Time	Coda	3.908	3.33	1.3	3.957	3.603	1.081	3.71	3.729	0.801	3.6	3.8	0.89
Angle change	Head	8.58	8.87	5.42	9.07	7.79	5.84	8.86	6.22	7.35	7.39	7.51	3.95
	Shoulder	5.95	5.5	2.4	6.48	5.5	3.69	5.42	5.29	3.08	6.18	5.29	2.79
	Thorax	5.79	5.91	2.1	6.76	5.87	3.83	5.91	6.45	3.32	6.93	6.84	4.99
	Pelvis	5.27	5.05	1.97	3.92	3.58	2.88	4.07	3.95	1.91	4.11	3.82	2.16
Force	M/L weight transfer	47.75	44.74	17.41	46.62	44.21	12.71	45.3	45.58	10.47	46.66	46.15	8.9
	Total weight transfer	129.14	136.48	30.89	147.96	148.27	55.6	129.22	120.77	31.28	133.41	137.43	41.37
	Stance width	175.04	160.8	43.59	178.58	165.15	41.8	185.98	172.8	48.76	184.18	179.52	43.22
	A/P Weight transfer	17.44	16.56	8.43	16.32	15.37	9.24	11.39	11.8	3.73	12.26	11.85	5.46
	A/P position	8 Ant			6 Ant			5 Ant			8 Ant		

	Type of turn	PUPr											
	Group	Cont PRE			Cont POST			Dance PRE			Dance POST		
	Descriptive	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Latency	Eye	0.658	0.656	0.221	0.63	0.547	0.28	0.482	0.513	0.383	0.556	0.487	0.207
	Head	0.483	0.43	0.18	0.415	0.4	0.092	0.445	0.404	0.0145	0.437	0.348	0.153
	Shoulder	0.421	0.398	0.102	0.423	0.41	0.079	0.429	0.402	0.159	0.442	0.398	0.14
	Thorax	0.483	0.411	0.203	0.391	0.371	0.086	0.428	0.428	0.127	0.385	0.371	0.096
	Pelvis	0.688	0.608	0.297	0.375	0.558	0.818	0.56	0.578	0.125	0.586	0.539	0.195
	First Foot	0.768	0.698	0.422	0.725	0.622	0.4	0.659	0.679	0.139	0.639	0.593	0.211
	Second Foot	1.182	1.135	0.421	1.077	1.008	0.355	1.073	1.118	0.185	1.024	0.939	0.297
Time	Coda	4.066	3.492	1.415	3.724	3.317	1.209	3.907	4.035	0.886	3.837	3.513	1.209
Angle change	Head	9.35	8.82	5.77	9.47	10.21	6.45	9.42	9.63	5.78	8.14	5.48	5.73
	Shoulder	7	6.5	4.54	4.38	7.56	7.6	7.39	6.98	4.11	5.43	4.33	4.09
	Thorax	6.65	6.7	4.2	4.86	8.14	7.61	7.54	7.44	3.95	6.71	6.12	4.15
	Pelvis	5.16	4.4	3.89	3.85	7.44	8.21	4.41	3.32	2.47	4.75	3.62	3.72
Force	M/L weight transfer	43.03	45.73	13.77	47.29	43.23	24.45	46.25	47.47	11.49	42.71	43.67	12.88
	Total weight transfer	140.97	130.9	80.11	136.22	125.23	50.97	137.9	134.95	41.13	134.71	123.92	68.27
	Stance width	170.43	159.63	45.94	176.56	169.47	48.9	185.06	176.3	51.19	193.43	197.55	53.94
	A/P Weight transfer	13.81	13.6	7.38	15.25	13.45	7.42	12.83	12.45	4.94	13.41	13.88	6.11
	A/P position	7 Ant			6 Ant			5 Ant			7 Ant		

	Type of turn	UPPr											
	Group	Controls PRE			Controls POST			Dance PRE			Dance POST		
	Descriptive	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Latency	Eye	0.837	0.767	0.425	0.718	0.596	0.337	0.546	0.591	0.608	0.594	0.504	0.342
	Head	0.541	0.472	0.153	0.493	0.431	0.198	0.502	0.503	0.107	0.518	0.446	0.167
	Shoulder	0.47	0.414	0.157	0.473	0.42	0.13	0.505	0.505	0.148	0.513	0.454	0.196
	Thorax	0.479	0.458	0.136	0.432	0.423	0.123	0.484	0.463	0.142	0.523	0.528	0.187
	Pelvis	0.698	0.635	0.348	0.634	0.583	0.135	0.653	0.634	0.148	0.697	0.688	0.196
	First Foot	0.752	0.73	0.266	0.743	0.687	0.245	0.751	0.774	0.199	0.757	0.765	0.219
	Second Foot	1.138	1.033	0.331	1.17	1.109	0.342	1.14	1.12	0.269	1.146	1.167	0.311
Time	Coda	4.066	3.388	1.496	4.048	3.578	1.235	3.811	3.793	0.827	3.642	3.499	0.725
Angle change	Head	10.18	8.24	6.5	8.79	6.74	5.77	9.44	6.52	7.65	8.83	6.41	7.3
	Shoulder	6.88	6.24	5.5	6.57	5.68	3.62	6.18	4.43	4.32	5.93	4.5	4.99
	Thorax	6.22	5.54	4.29	7	5.76	4.06	9.27	4.7	10.7	7.03	6.64	4.38
	Pelvis	4.35	3.43	3.27	3.9	3.64	1.93	4.54	3.49	3.86	3.51	2.94	2.84
Force	M/L weight transfer	44.58	45.32	14.41	46.44	43.35	11.57	43.92	47.15	11.82	47.14	46.51	12.95
	Total weight transfer	144.97	136.27	50.95	146.83	153.27	47.21	136.69	146.17	49.27	155.45	135.6	48.87
	Stance width	172.3	161.68	38.9	180.61	172.32	38.36	180.15	165.34	52.03	176.62	170.63	40.55
	A/P Weight transfer	14.86	14.71	5.38	15.73	15.94	6.82	12.72	13.8	3.76	18.65	12.15	20.17
	A/P position	9 Ant			10 Ant			4 Ant			7 Ant		

	Type of turn	UPUPr											
	Group	Controls PRE			Controls POST			Dance PRE			Dance POST		
	Descriptive	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Latency	Eye	0.629	0.703	0.405	0.73	0.681	0.271	0.674	0.595	0.469	0.482	0.528	0.204
	Head	0.487	0.488	0.094	0.496	0.436	0.154	0.496	0.488	0.15	0.5	0.433	0.207
	Shoulder	0.494	0.478	0.101	0.496	0.433	0.147	0.473	0.438	0.15	0.535	0.439	0.225
	Thorax	0.495	0.476	0.122	0.494	0.461	0.156	0.486	0.488	0.125	0.484	0.42	0.211
	Pelvis	0.704	0.662	0.194	0.725	0.678	0.161	0.656	0.693	0.169	0.69	0.671	0.213
	First Foot	0.723	0.767	0.198	0.828	0.742	0.372	0.72	0.708	0.164	0.689	0.603	0.2
	Second Foot	1.128	1.188	0.291	1.257	1.183	0.44	1.1	1.118	0.232	1.073	0.992	0.257
Time	Coda	3.992	3.896	1.068	3.985	3.62	1.25	3.911	4.013	0.785	3.983	3.845	1.089
Angle change	Head	8.85	9.36	7.04	11.62	8.7	9.28	7.86	6.28	5.39	10.59	8.06	7.36
	Shoulder	6.19	4.81	5.24	6.69	5.39	5.04	6.44	5.79	3.9	5.66	4.52	4.54
	Thorax	6.2	4.82	4.9	7.18	5.2	6.77	6.52	5.25	4.62	6.14	6	3.65
	Pelvis	3.7	4.33	1.67	8.35	6.18	6.71	4.48	3.29	2.98	4.02	2.73	3.73
Force	M/L weight transfer	42.62	42.27	13.61	37.86	39.24	10.95	39.33	41.07	10.42	43.31	42.31	13.27
	Total weight transfer	137.17	116.37	50.35	150.65	154.35	60.01	139.14	129.12	54.72	136.94	126.82	52.89
	Stance width	173.93	161.65	45.27	181.03	168.62	37.11	182.72	184.25	49.05	185.14	185.75	42.28
	A/P Weight transfer	13.21	12.33	6.81	15.35	13.8	6.8	15.93	13.55	11.66	14.05	14.29	5.8
	A/P position	7 Ant			8 Ant			6 Ant			7 Ant		

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