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WALKING BIOMECHANICS IN PARKINSON'S DISEASE: FROM THE CHARACTERIZATION TO THE GESTURAL SPECIFICITY PROMOTED BY DIFFERENT INTERVENTIONS

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Orientador: Prof. Dr. Leonardo Alexandre Peyré Tartaruga

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Dedicada aos meus pais.

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RESUMO

A doença de Parkinson (DP) é uma desordem motora progressiva e neurodegenerativa, sendo a segunda doença neurodegenerativa mais comum e é mais prevalente após os 60 anos de idade. Em pessoas com DP, a caminhada é alterada quando comparada a indivíduos saudáveis e destaca-se a menor velocidade de caminhada, menor velocidade para mover os segmentos, menor amplitude de movimento (ADM) de membros superiores e inferiores, e em alguns casos é possível observar assimetrias no comprimento e frequência de passada entre o membro mais afetado e menos afetado. Além disso, esta população apresenta maior flexão anterior de tronco, maior rigidez e menor coordenação de tronco e pelve no plano transverso apresentando caminhada em bloco, ou seja, em fase. Com isso, a presente dissertação tem o objetivo de analisar os parâmetros coordenativos axiais e segmentares da caminhada de pessoas com DP. No capítulo 1 foram compiladas informações sobre as características da caminhada de pessoas com DP e como diferentes intervenções podem auxiliar na melhora dos parâmetros alterados. Resultados conflitantes e lacunas identificadas na literatura motivaram a escrita de três estudos originais. Os objetivos dos estudos foram: 1) Realizar uma revisão sistemática e metanálise para comparar os parâmetros espaço temporais e angulares de membros inferiores entre a marcha de pessoas com DP e pessoas saudáveis (Capítulo dois). 2) Comparar a simetria da marcha de pessoas com DP após 11 semanas de treinamento de caminhada nórdica (CN) (Capítulo três). 3) Comparar durante a caminhada, em diferentes velocidades, a coordenação transversal de tronco e pelve, a ADM do tronco e pelve (sagital, frontal e transversal), variáveis espaço-temporais e índice de reabilitação locomotor de pessoas com DP após intervenções de dança e CN (Capítulo quatro). Para revisão sistemática, diferentes bases de dados foram utilizadas e um total de 3027 sujeitos foram incluídos. Nos estudos experimentais, foram avaliadas pessoas com DP praticantes de dança e CN e controles, os sujeitos foram avaliados antes e após 22 sessões de intervenções, a análise 3D da marcha foi realizada em esteira em diferentes velocidades. Nossa revisão sistemática mostrou que, em comparação com o grupo saudável, as pessoas com DP têm menor velocidade, maior cadência, menor comprimento da passada, maior tempo de duplo contato e menor ADM de quadril. No capítulo três, foi possível observar que a CN foi capaz de melhorar a assimetria do joelho e do quadril. Além

disso, no capítulo quatro, a biomecânica da marcha foi melhorada em ambas as intervenções. Enquanto que, a coordenação de tronco e pelve (ou axial) é melhorada apenas com a CN. Nossos resultados são importantes para entender as diferenças nos parâmetros da marcha em pessoas com DP e grupos controle e para auxiliar os profissionais da saúde a controlar as mudanças nos padrões de caminhada que acontecem em seus sujeitos. Além disso, a presente dissertação apresentou que a dança e a CN são intervenções em potencial na manutenção e na melhora da independência da caminhada de pessoas com DP.

Palavras-chave: Dança, caminhada nórdica, doença de Parkinson, caminhada, biomecânica, coordenação motora.

ABSTRACT

Parkinson's disease (PD) is a progressive neurodegenerative movement disorder and is the second most common neurodegenerative condition in people over the age of 6. People diagnosed with PD have an altered walk pattern in comparison with healthy people, demonstrate a lower speed, lower segmental velocities, and a lower range of motion (ROM) for both the upper and lower limbs. Further, some cases show asymmetries in stride length and frequency between the most and least affected sides. This population shows significant anterior flexion of the trunk during walking, greater rigidity and lower rotation coordination between the trunk and pelvis, and their motions are in-phase. The present dissertation analyzes the axial and segment gait parameters of people with PD. In Chapter 1, information about the characteristics of the walk of people with PD and how different interventions can aid in the improvement of parameters is presented. To resolve and understand conflicting results and gaps identified in the literature, we undertook three original studies. The aims of these studies were: 1) To undertake a systematic review and meta-analysis comparing the PD to healthy group spatiotemporal and lower limbs angular gait parameters (Chapter 2), 2) To compare the gait symmetry of people with PD after 11 weeks in Nordic walking (NW) training (Chapter 3), and 3) To compare the trunk and pelvis coordination (axial coordination) of PD subjects during walking, trunk and pelvis range of motion (ROM) (sagittal, frontal and transverse), spatiotemporal and locomotor index rehabilitation at different speeds, after dance and NW interventions (Chapter 4). For this review, several databases were used, and 3027 subjects were included. For the studies on the effects of interventions, we selected two groups of individuals with PD, with the first group being practitioners of dance and NW and the second group consisting of non-practitioners. These subjects were evaluated before and after 22 sessions of interventions, and 3D gait analysis was performed on a treadmill at different speeds. Our analysis indicated that compared with a healthy control group, people with PD have lower speeds, higher cadence, shorter stride lengths, higher double limb support phases, and lower hip ROMs. In Chapter 3, we observed that NW was able to improve knee and hip asymmetry. In Chapter 4, we observed that both interventions improved the walking biomechanics, but only NW helped improve the trunk and pelvis coordination (or axial). These results are essential to understand the differences in gait parameters between people with PD and control groups, and also to aid health

professionals to understand the changes in gait that occur with their subjects. Finally, this study shows that dance and NW are useful interventions for the maintenance and improvement of walking abilities in people with PD. If these people are able to walk without any external support, it will allow them to lead an independent lifestyle.

Keywords: Dance, Nordic walking, Parkinson's disease, walking, biomechanics, motor coordination.

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

LIST OF ABBREVIATIONS

%	Percentage
´	Minutes
°	Degrees
2D	Two-dimensional
3D	Three-dimensional
6MWT	six-minute walking test
a.m	In the morning
A1	Who walk at 50% of the 6MWT
A2	Who walk at 70% of the 6MWT
A3	Who walk at 100% of the 6MWT
ADM	Amplitude of movement
BORG	Rating of perceived exertion
BPMs	Beats per minute
CAAE	Certificate of Presentation for Ethical Appreciation
CG	Control group
CIs	Confidence intervals
cm	Centimeter
CONSORT	Consolidated Standards of Reporting Trials
CRP	Continuous relative phase
DG	Dance group
ES	Effect size
ESEFID	School of Physical Education, Physiotherapy and Dance
FW	Free walking
GEE	Generalized Estimating Equations
H&Y	Hoehn and Yahr scale
HC	Healthy control
kg	Kilograms
LAPEX	Exercise Research Laboratory

LRI	Locomotor Rehabilitation Index
m	Meters
m.s	Meter for seconds
MDs	Standardized mean differences
mm	Millimeter
MoCA	Montreal Cognitive Assessment
MOOSE	Guidelines for Meta-Analyses and Systematic Reviews of Observational Studies
NW	Nordic walking
NWG	Nordic walking group
OFF	Medication not Effect Period
ON	Medication Effect Period
PD	Parkinson disease
PPT- PARKINSON	Prevention and Treatment Program of Parkinson Disease
PROSPERO	Prospective Register of Systematic Reviews
ROM	Range of motion
SPSS	Statistical Package for Social Sciences
SSWS	self-selected speed
Std diff	Standardized difference.
UFRGS	Universidade Federal do Rio Grande do Sul
UPDRS	Unified Parkinson's disease Rating Scale
VICON	Vicon Motion Systems
α	Alfa
β	Beta

Summary

CHAPTER 1

GENERAL INTRODUCTION

This chapter comprises four sections: General Presentation, Problem and Importance of Research, Aims, and Literature Review.

1.1 GENERAL PRESENTATION

1.1.1 Contextualization and Delimitation of the Study

The work is an outcome of the project “PPT- PARKINSON (Prevention and Treatment Program of Parkinson Disease)”, that was focused on dance, deep water running and Nordic walking programs performed by people with Parkinson’s disease (PD). The project was conceived at the Exercise Research Laboratory (LAPEX) of the School of Physical Education, Physiotherapy and Dance (ESEFID) at the Universidade Federal do Rio Grande do Sul (UFRGS). The project is coordinated by Dr. Aline Nogueira Hass, Dr. Flávia Gomes Martinez, and Dr. Leonardo Alexandre Peyré Tartaruga; it is a continuation of work being done by the research group LOCOMOTION since 2013. This work has several approvals from ethics committees. Several public announcements and scientific products have already resulted from the research performed by this group.

I became aware of Nordic walking in people with PD after a lecture on Nordic walking and PD at the Biomechanics Congress in 2017. After this lecture, I developed an interest in this topic and decided to study more about it. This theme was my motivation to do post-graduation studies after graduating with a physiotherapy degree from the Universidade Estadual do Oeste do Paraná. During these two years pursuing my Master’s Degree, I have had the opportunity to get involved in different research projects, as well as coordinate the Nordic walking extension/outreach project and co-advise the scientific initiation. The present dissertation is an outcome of my involvement in these ventures. Several other researchers are involved in this project and the key people are - Ivan Oliveira dos Santos (Scientific Initiation), Georgio Anibal Alves Micaella (Scientific Initiation), Mariana Wolffenbuttel (Scientific Initiation), Marcela Zimmermann Casal (Master’s student), Rebeca Guimenes Donida (Master’s student), Alex de Oliveira Fagundes (Doctoral candidate), Marcela Delabary (Doctoral candidate), Valéria Feijó Martins (Doctoral candidate), Elren Passos Monteiro

(Professor) and more than eighty people with PD that participated in the PPT-PARKINSON studies.

1.1.2 Structure of the dissertation

This study was developed at the Biodynamics sector of the LAPEX of the ESEFID of UFRGS. The work is structured as follows. The first chapter gives a general introduction and lays out the aims of the remaining chapters.

The second chapter provides a systematic review and meta-analysis of the literature regarding the spatiotemporal and lower limb angles of PD subjects during walking and comparisons with those of healthy control subjects. The third chapter presents a quasi-experimental study that of the walking symmetry of people with PD after Nordic walking training.

The fourth chapter details a non-randomized controlled clinical trial that aims to evaluate the effects of gesture specificity promoted by dance and Nordic walking on the coordinative and mechanical aspects of walking in people with PD. The fifth chapter summarizes the results of the three studies. The sixth chapter lists the published studies during master´s degree period.

1.2 CENTRAL QUESTION

Parkinson disease (PD) is a progressive and neurodegenerative movement disorder (MAK et al., 2017) and it is the second most common neurodegenerative condition in men aged over 60 years old (PRINGSHEIM et al., 2014). In this disease, the most common non-motor symptoms are apathy, fatigue, depression, sleep disturbance, and cognitive impairment (CUSSO et al., 2016). The motor symptoms such as bradykinesia, akinesia, rest tremor, postural changes, freezing, muscle weakness, segmental asymmetries, axial stiffness and intersegmental affect the development and maintenance of activities of daily living, such walking (VAN EMMERIK et al., 1999; MAK et al., 2017; LIN & WAGENAAR, 2018).

Human walking is composed of complex and integrated movements. It involves the upper limb, lower limb, and trunk coordination in order to propel the body forward. The ability to walk without help is key to an independent life. Advancing age and the onset of diseases, especially neurological ones, make it more likely for individuals to

develop degradations in their normal walking patterns (MASSION, 1992; CRUSE et al., 1995; PEEL et al., 2012).

A variety of studies have shown the differences in the biomechanical gait of patients suffering from PD; and they have observed lower speed, asymmetries, incoordination, lower rotations of trunk and pelvis, higher anterior trunk flexion, lower shoulder, elbow, trunk, hip, pelvis, knee and ankle motion. Spatiotemporal changes, such higher stride frequency, and step width, lower stride length, and asymmetries on upper and lower limbs have also been observed. The reductions in the cortical output to muscles impairs the availability of motor units and can cause abnormal muscle activation patterns, resulting in bradykinesia and muscle weakness. These alterations are dependent on age, phase of medication, disease duration, disease stage, task, and evaluation methods. Very few studies are found in the literature that has systematized these differences, especially examining the aspects mentioned above. However**,** it is possible to find observational studies and clinical trials comparing people with PD and healthy subjects, but no systematic review was found to quantify these differences (VAN EMMERIK et al., 1999; MORRIS et al., 2001; HUANG et al., 2010; PETERSON & HORAK, 2016; MAK et al., 2017; MONTEIRO et al., 2017b; ŠVEHLÍK et al., 2009; LIN & WAGENAAR, 2018).

The gold standard of therapy to minimize the symptoms of the disease is still the pharmacological treatment. Conversely, over the years, pharmacological treatment can aggravate the motor symptoms, mainly gait freezing. Thus, the exercises are being eminently studied in this population, and the evidence show that the motor benefit may be similar the effects of the medication (PETERSON & HORAK, 2016; MAK et al., 2017; KLEMANN et al., 2018).

Many activities have been used in people with PD, dance and Nordic walking (NW) interventions are capable of improvement and maintenance of static and dynamic balance, increased stride length and self-selected speed (SSWS) (SHARP & HEWITT, 2014; NARDELLO et al., 2017; MAK et al., 2017; MONTEIRO et al., 2017a; FRANZONI et al., 2018). Studies also indicate that improvements in the parameters of axial and segmental coordination are observed after NW (GOUGEON, ZHOU & NANTEL, 2017; WARLOP et al., 2017).

However, there are no studies that directly evaluated temporal and angular variables before and after NW exercise program in people with PD in order to analyze symmetry and axial and segmental coordination. Dance studies for people with PD are

recent and most of them evaluate qualitative and functional parameters (MCNEELY et al., 2015; DE NATALE et al., 2017; DOS SANTOS et al., 2018). It was found just one study that evaluated the PD gait after a dance program (SOWALSKY et al., 2017). The study of Sowalsky et al. (2017) evaluated just one subject and angular variables were not measured. Therefore, biomechanical studies are needed to understand the effect of dance intervention on motor symptoms in this population.

Both NW and dance require rhythm, synchronicity, and posture from the participants. Each activity has gestural specificity that can improve walking biomechanics and motor function in individuals with PD. Both techniques require attention to dual tasks, which can increase central learning in people with PD (GOODWIN et al., 2008; REUTER et al., 2011; SHARP & HEWITT, 2014; SHU et al., 2014; SHANAHAN et al., 2015; MONTEIRO et al., 2017a; ARCILA et al., 2018). Another benefit of dance and NW is that they are group activities and may help provide social interaction and social support for subjects (GALLO, EWING & GARBER, 2011). Recognizing that the ability to walk without assistance is key to the independence of individuals and for the treatment of PD, it is crucial to study biomechanical findings that describe, analyze, and compare the effect of gesture specificity promoted by different therapies on the spatiotemporal and angle aspects of walking in people with PD, with the goal of improving and maintaining the walking functionality, and therefore, the independence of these individual.

1.3 AIMS

1.3.1 General aim

The main aim of the study is to characterize the biomechanical patterns related to the walking of individuals with PD. The study also aims to evaluate the effects of gesture specificity promoted by dance and NW on coordinative and mechanical aspects of walking in people with PD.

1.3.2 Specific Aims

- Systematically review the literature on the spatiotemporal and lower limb sagittal angles of PD subjects during walking and comparisons with healthy control subjects.

- Compare the symmetry angles and spatiotemporal variables of more affected and less affected segments of PD subjects during walking, after NW intervention.

- Compare the trunk and pelvis (or axial) coordination, ROM of trunk and pelvis, and spatiotemporal variables of PD subjects during walking, after dance and NW interventions.

1.4 LITERATURE REVIEW

1.4.1 Biomechanical Walk Parameters

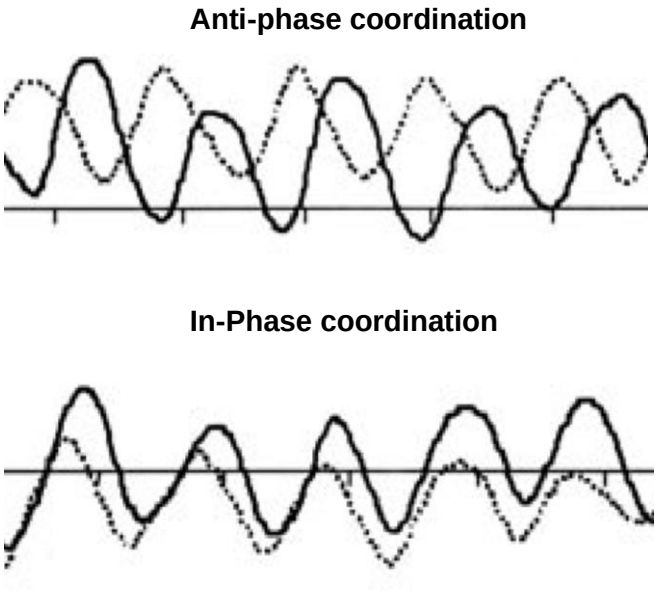
Walking involves several body segments and requires only 50% higher energy than that used during resting (CRUSE et al., 1995; SAIBENE & MINETTI, 2003). To improve energy recovery during walking, a walking gait that maintains symmetry in the upper and lower limbs (segmental), and the trunk and pelvis (axial) is important (PETERSON & HORAK, 2016; FORSELL et al., 2017; DA ROSA et al., 2018).

Gait related parameters can be measured by different techniques such as accelerometers, force platforms, and two-dimensional (2D) and three-dimensional (3D) motion capture analyses. Some of the critical motions studied during gait analysis are, in turn, pelvic and trunk rotation, pelvic tilt, and knee flexion during the contact phase. These movements are able to demonstrate an effective pattern of gait (SAUNDERS et al., 1953). Gait mechanics can be evaluated using spatiotemporal and angular variables (SAUNDERS et al., 1953; HUANG et al., 2010; ANGULO-BARROSO & FACIABÉN, de CASTRO, 2011 BOYER et al., 2017).

3D motion capture systems are widely used to accurately conduct gait analysis (PFISTER et al., 2014). Various mathematical methods have been developed to represent functional changes in gait (VAN EMMERIK et al., 1999; LAMB & STÖCKL, 2014; DA ROSA et al., 2018). The parameters sagittal ROM of hip, knee, ankle, shoulder, and elbow are essential to measure during the normal walking routine (MORRIS et al., 2005; LIN & WAGENAAR, 2018). Moreover, transverse angular variables are also important, and the axial coordination is a parameter that can represent mobility in people with PD (VAN EMMERIK et al., 1999). Coordination variables that represent the level of coordination between two segments are determined by several methods such as the discrete relative phase angle or phase difference that represents the angular reversal of two analyzed segments or the moment of angular phase change between two segments (VAN EMMERIK, HAMILL &

MCDERMOTT, 2005; DA ROSA et al., 2018). Coordination during a gait cycle is defined by the continuous relative phase (CRP), and this parameter can identify the stability and coordination of the movement during gait (LAMB & STÖCKL, 2014). There is assumed to be no coordination when the segments are in the same direction (in-phase rotation), and good coordination when variables are in the opposite direction (anti-phase) rotation.

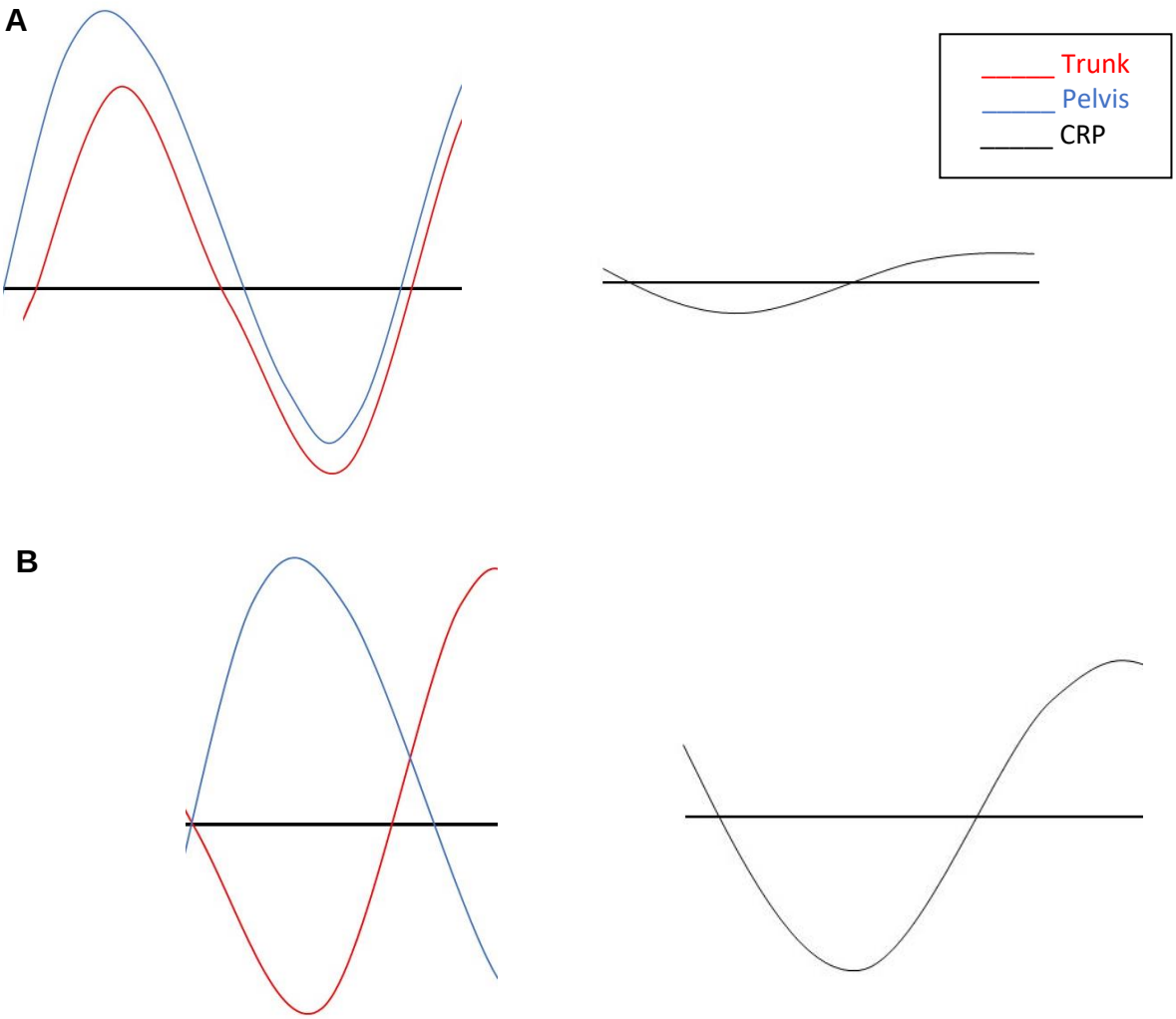
Figure 1.1 Angular segmental position fluctuations showing different patterns of intersegmental coordination.



NOTE: Adapted from VAN EMMERIK; HAMILL & MCDERMOTT, 2005.

The relative phase between segment rotations can vary from plus to minus 180 degrees. A value of plus or minus 180 degrees corresponds to antiphase rotation and a value of 0 degrees corresponds to in-phase rotation (VAN EMMERIK et al., 1999; LAMB & STÖCKL, 2014; PRINS et al., 2019). In this study trunk and pelvis rotation will variate from 0 degrees to 10 degrees, with this, values near zero corresponds to in-phase rotation (Figure 1.2 A) coordination and values far from zero corresponds to antiphase rotation (Figure 1.2B). Additionally, positive values mean that pelvis is in-front-of the trunk during the gait cycle, and negative values mean that trunk is in-front-of pelvis during the gait cycle.

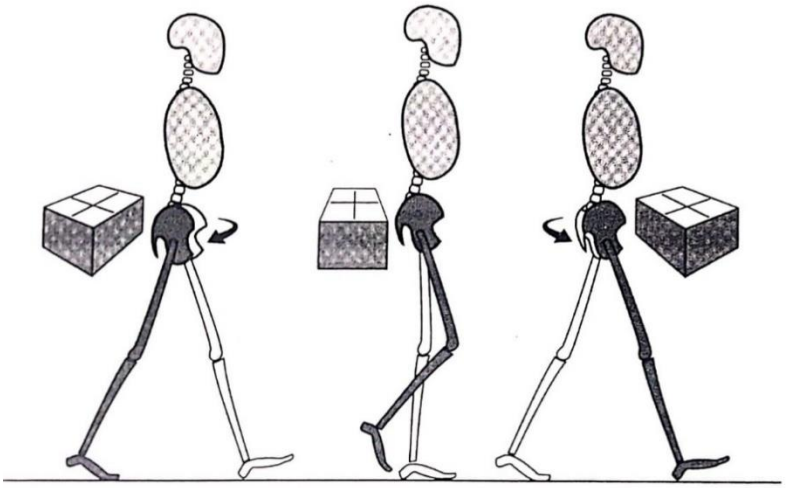
Figure 1.2 Trunk and pelvis rotations at the transverse plane and continuous relative phase (CRP) during the gait cycle. **A:** in-phase coordination. **B:** out-of-phase (or antiphase) coordination.



NOTE: From the author.

The axial CRP is measured based on the gait cycle during the stride (VAN EMMERIK et al., 1999). From the moment the foot comes off the ground to the time the heel touches the ground, the pelvis has a high degree of rotation (PERRY, 2005) (Figure 1.3). Therefore, CRP can also be calculated based on the periods of contact (CORNWALL, JAIN & HAGEL 2019). Studies such as that conducted by Van Emmerik et al., in 1999, have determined this variable in people with PD and suggested that it is essential to investigate this variable after interventions at fixed walking speeds.

Figure 1.3 Pelvis mobility on contact and balance phase of the gait.



Note: From Perry (2005).

1.4.2 Biomechanical changes in the walk of people with PD

People with PD have significantly different biomechanical behavior in comparison with healthy people, and these differences depend on the stage of the disease, disease duration, and the state of medication. These differences are characterized by lower speed of gait, lower speed to move segments, lower ROM of upper and lower limbs. It is also often possible to observe asymmetries in stride length, and frequency between the more affected and less affected sides. This population also shows significant anterior flexion of the trunk, high rigidity, and low rotation coordination of the trunk and pelvis. The axial rotation is also more in-phase in an older subject than in a younger subject (VAN EMMERIK, HAMILL & MCDERMOTT, 2005) and the axial coordination is 30-50% lower in subjects with PD (VAN EMMERIK et al., 1999; MORRIS et al., 2001). The decreased axial coordination becomes evident at lower speeds and tends to improve in VAS (VAN EMMERIK et al., 1992; VAN EMMERIK et al., 1999; LIN & WAGENAAR, 2018). This lower coordination promotes less variability in CRP subjects with PD, indicating a lower angular variation between the trunk and pelvis during gait (EMMERIK et al., 1999). These changes significantly affect functionality, increase the risk of falls, and decrease independence in this population (PETERSON & HORAK, 2016; MONTEIRO et al., 2017).

In most cases, pharmacological treatment is not effective at improving intersegmental coordination. For adequate coordination, the proximal and distal muscles and joints should activate and deactivate in a synchronized manner (VAN

EMMERIK et al., 1999; SOARES & PEYRÉ-TARTARUGA, 2010; PETERSON & HORAK, 2016). Hence, physical exercise has potential to improve the biomechanical performance, and consequently increase the functional performance and quality of life of individuals with PD (PETERSON & HORAK, 2016; MAK et al., 2017; KLEMANN et al., 2018).

1.4.3 Dance and NW kinematics

Studies that have focused on the therapeutic effect of dance on PD subjects typically use the tango as the specific dance taught to the subjects. Gains in mobility, balance, and walking speed have been observed in this population (SHARP & HEWITT, 2014; DOS SANTOS et al., 2018). Ballroom dancing is a complex sensorimotor activity that integrates skills such as rhythm, synchrony, balance, coordination, and spatial sense (FONSECA et al., 2014). Studies that present the biomechanics of Brazilian dances like the Forró and Samba have not been found. Dance sessions are considered as acyclic activities and have important movements in the non-sagittal planes and are characterized by rapid movements and constant changes in direction and can, therefore, improve the mobility of people with PD (HULBERT et al., 2017; DOS SANTOS et al., 2018). A review of the literature indicates that visual, auditory, and somatosensory rhythmic activities conducted in therapeutic sessions with subjects with PD result in increased speed, greater stride length and lower stride frequency (NIEUWBOER et al., 2007). In Sowalsky et al. (2017), after 16 weeks of dance training, one subject with PD demonstrated improvements in walking speed, double support, stride length and stride time.

Nordic Walking is an activity that employing poles while walking and is a cyclic activity that requires the use of the upper limbs (BOCCIA et al., 2018). The proper technique involves the subject looking forward, with an erect trunk and a small anterior inclination, slight elbow flexion, hands semi-open and poles held diagonally (NARDELLO et al., 2017).

The ROM angular parameters during the NW at speeds less than 7 $km.h^{-1}$ in health people with 40 years during the gait cycle varies 40 degrees to -20 degrees of ROM hip, 35 to 65 degrees ROM of knee, 5 degrees of ROM ankle, pelvic tilt of 6 degrees and ROM pelvic rotation between 2 to 6 degrees (DZIUBA et al., 2015). Nardello et al.(2017) showed that some people with PD fail to correctly perform the

movements of the NW technique. Therefore care should be taken at the time of teaching to ensure that the subjects use the correct technique. Arcila et al. (2018) proposed a sequence of steps for the NW technique that is most suitable for people with PD.

Both NW and dance, through their rhythmic, synchronized and planned movements have the potential for improvement in the ROM of angles and spatiotemporal parameters of individuals with PD, and can improve the coordination and symmetry of walking. Studies on the biomechanics of dance are not common, especially with Brazilian dances like the Forró and Samba. It is important to investigate and document the benefits that can be gained by using NW and dance to improve coordination and symmetry in individual with PD. These studies can help health professionals identify suitable rehabilitation plans for individuals with PD.

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CHAPTER 2

GAIT PARAMETERS OF PARKINSON´S DISEASE COMPARED WITH HEALTHY CONTROLS: A SYSTEMATIC REVIEW AND META-ANALYSIS

Abstract

Background: Gait parameters of people with Parkinson' disease (PD) seems to be different compared to healthy control (HC). Confounding factors associated with PD and aging process between normal and pathological gait are possible explanations for the current inconclusive findings. **Objective:** We aimed to undertake a systematic review and meta-analysis to compare the spatiotemporal and lower limbs angular gait parameters between individuals with PD and HC group. Secondarily, we tested the role of condition treadmill and ground in the outcomes. **Methods:** Four electronic databases were searched (November 2018 and updated in January 2019). Two authors identified studies that evaluated gait parameters measured quantitatively during self-selected walking speed (free walking or treadmill) and using different devices in PD subjects. Risk of bias was assessed using a customized quality checklist based on an instrument proposed by Downs & Black (1998). Pooled effects were reported as standardized mean differences (MDs) and 95% confidence intervals (CIs) using a random-effects model. **Results:** A total of 73 studies involving 3027 participants (1510 with PD and 1517 HC) met the inclusion criteria. In general, the self-selected walking speed, stride length, swing time and hip sagittal angle were lower in people with PD compared with HC. Additionally, PD subjects presented higher cadence and double support phase in comparison with HC. The self-selected walking speed was higher when gait was evaluated using free walking in comparison to treadmill method. **Conclusion:** There are differences in PD gait parameters compared with HC. We suggest physical interventions to restore the appropriate gait mechanics of PD individuals (PROSPERO protocol CRD 42018113042).

Keywords: Walking; Biomechanical; Spatiotemporal; Angle.

2.1 INTRODUCTION

Parkinson's disease (PD) is a chronic neurodegenerative condition, characterized by decreased dopamine production occurring in the compact part of the substantia nigra (SCHNEIDER & ALCALAY, 2017). In addition, developed deficiency in dopamine production reflects changes in the cortex region of the planning and sequencing of the movements (PETERSON & HORAK, 2016).

In Brazil, the incidence of disease in 2005 was around 16 million, and the projection is that number can double in 2030 (DORSEY et al., 2007). Factors such as aging, male gender, and geographic location may increase the incidence of PD. It is known that prevalence is higher after 79 years and in South American residents (PRINGSHEIM et al., 2014). Although the causes for the manifestation of PD are unknown, some studies show an association with genetic and environmental factors (ASCHERIO & SCHWARZSCHILD, 2016; ELBAZ et al., 2016).

Some motors symptoms such as, bradykinesia, postural instability, rest tremor, rigidity and slowness of movement are present in PD (SVEINBJORNSDOTTIR, 2016). These cardinal symptoms promote alteration in gait parameters in subjects with PD (MORRIS et al., 1994; VAN EMMERIK et al., 1999; DIPAOLA et al., 2016). The literature has indicated that self-selected walking speed (SSWS) is lower in people with PD (MORRIS et al., 1994; VAN EMMERIK et al., 1999) when compared to matched healthy control group (MORRIS et al., 1994).

Particularly, individuals with PD walk with higher cadence, shorter stride length, higher double limb support phase, higher asymmetry of upper and lower limbs, axial rigidity and lower range of hip, knee and ankle motions during walking (VAN EMMERIK et al., 1999; CARPINELLA et al., 2007; DIPAOLA et al., 2016; MONTEIRO et al., 2017).

Although the literature indicates some characteristics of PD gait, several evaluation methods are applied resulting in different reference values (VAN EMMERIK et al., 1999; CARPINELLA et al., 2007; DIPAOLA et al., 2016). The different evaluation methods, disease duration, disease stages, phase of medication and aging process may hamper clarity over these biomechanical

parameters and possibly greater difficulty in proposing more efficient rehabilitation programs.

A recent review showed the gait impairments in PD (MIRELMAN et al., 2019), however they aimed to study the assessment, mechanisms, and interventions to improve gait and no metanalysis was performed. A systematic review and meta-analysis conducted by Creaby and Cole (2018) showed that spatiotemporal and kinematic characteristics representing the risk of falls in individuals with PD (CREABY & COLE, 2018). Still, spatiotemporal and kinematic analyses during walking compared with the healthy control group was not performed. No systematic reviews with meta-analysis were found comparing spatiotemporal and kinematic analyses during Parkinson´s subjects walking with healthy control group. The quantitative characterization of gait parameters in individuals with PD might help researchers to analyze this population data and to help professionals to observe the gait evolution of PD after a rehabilitation program. Therefore, the aim of this study was to systematically review the literature about the spatiotemporal and lower limbs angles during walking on people with PD compared with healthy control subjects and perform meta-analyses. Our hypothesis is that the SSWS will be deteriorated, accompanied by a reduction in the stride length, swing time and lower limbs angles, and higher cadence, step width and double support in individuals with PD with respect to healthy controls.

2.2 METHODS

This systematic review has been reported according to the Guidelines for Meta-Analyses and Systematic Reviews of Observational Studies (MOOSE) (Supplementary material 2.1) (STROUP et al., 2000) and followed the recommendations proposed by the Cochrane Collaboration (HIGGINS, 2011) The study protocol was pre-registered on the International Prospective Register of Systematic Reviews (PROSPERO protocol CRD 42018113042).

2.2.1 Search strategy

The search was conducted in November 2018 and updated in January 2019. The searching electronic bibliographic databases were Cochrane library, Scopus, Pubmed and EMBASE. Abstracts or extended abstracts published from conferences, theses, dissertations, or studies not yet published in journals were not included. The following terms were used in combination and/or alone: ‘‘Parkinson disease,’’ “kinematics,” “joint kinematic,” “hip angles,” "knee angles," "ankle angles," "stride frequency," " stride length”. Boolean operators ‘‘OR’’ and ‘‘AND’’ were used to search the databases. Details of the PubMed search are shown in a supplementary material 2.2.

2.2.2 Inclusion and exclusion criteria

This review included cross-sectional studies, and clinical trials (from which only baseline values were extracted). To be considered eligible, studies should present: (1) a free or treadmill walking evaluation with kinematic analysis; (2) people with PD as sample (evaluated in “on” period of medication, regardless of age, sex, and disease stage); (3) a age- and sex-matched healthy control group; (4) values (means and standard deviations) of spatiotemporal outcomes (SSWS), walking distance, stride length, cadence, step width, double support, single support, swing moment, range of motion (ROM) sagittal of hip, knee and ankle, ROM initial contact of hip, knee and ankle evaluated in SSWS. Some studies were excluded when (1) No inform the variables; (2) When subjects presented essential tremor (3) Postural alterations, such as camptocormia and Pisa syndrome (4) De novo PD; (5) Parkinsonism (6) Freezing and (7) differences speeds to both lower limbs. There were no restrictions on date of publication for inclusion of studies in the review. Unpublished studies have not been included. Only studies published in English, Portuguese, or Spanish were included. Excluded Studies are in supplementary material 2.3.

2.2.3 Selection of Studies

The selection of studies was conducted by two independent reviewers (A.P.J. Z.; E.S.S.). First, titles and abstracts of studies found through the search strategy were evaluated considering the eligibility criteria. In the second phase, for the selected articles or those in doubt, the full-text reading was performed by the same two independent reviewers and the eligibility criteria were followed. Disagreements between reviewers were resolved by consensus, and when necessary by a third reviewer (R.R.C).

Data extraction was performed by the same two independent researchers who performed the studies selection. A standardized form containing the information of interest that should be extracted was delivered to each of the reviewers. The data extracted from the studies were: Age (years), weight (kg), height (m), Hoehn and Yahr scale (H&Y), score of the Unified Parkinson's disease Rating Scale (UPDRS), disease duration (years), type of walk test performed (free walking test or treadmill), SSWS ($m.s^{-1}$), walking distance (m). In addition, means and standard deviations of the outcomes were extracted to the standardized form: SSWS ($m.s^{-1}$), walking distance (m), stride length (m), cadence (step/min), step width (m), double support (%), single support (%), swing moment (%), ROM sagittal of hip (degree), knee (degree) and ankle (degree), ROM initial contact of hip (degree), knee (degree) and ankle (degree) evaluated in SSWS. The authors of the included studies were contacted by email aiming to access possible unclear data. If no answer was received, data in question was excluded from the analysis. In case of results presented through figures (graphics), the software Image-J (National Institute of Health, USA) was used to achieve the outcome data.

2.2.4 Assessment of risk of bias (Methodological Quality)

In this review, a customized quality checklist was developed applying an instrument proposed by Downs & Black (DOWNS & BLACK, 1998). Other authors have been using this checklist with adequate and customized questions (BATES & ALEXANDER, 2015; DIXON et al., 2017; MOUSAVI et al., 2019). It was originally designed to assess the methodological quality of randomized and non-

randomized studies of interventions. In this study just observational studies were evaluated. Therefore, the instrument was developed by removing items 4, 8, 9, 13, 14, 15, 16, 17, 19, 23, 24, 25 and 26 because the items were not relevant to these types of study. The included questions were 1, 2, 3, 5, 6, 7, 10, 11, 12, 18, 20, 21 and 22, resulting in a maximum score of 14. The computation of quality of studies was based on Ratcliffe et al. (2014), studies scored as high quality achieve a score > 66.8%, medium quality 33.4– 66.7%, and low-quality studies achieving < 33%.

2.2.5 Data analysis

The pooled effect estimates were computed from the difference scores between the gait parameters of Parkinson individuals and the healthy ones, their standard deviations, and the number of participants. The authors were contacted through emails for unreported data and, if no answer returned or if the data requested were not available, the studies were excluded.

The results are exhibited as standardized mean differences and calculations were performed using random effects models. Statistical heterogeneity of evaluations among studies was evaluated by Cochran's Q test and the I^2 inconsistency test; it was considered that values > 50% indicated high heterogeneity (HIGGINS 2011). In addition, sensitivity analyses were conducted to investigate the possible influence of the method selected to the assessment of gait parameters in the included studies on the differences between Parkinson and healthy people, separating the studies using free walking of those using treadmill. Meta-regression analyses were performed to investigate potential moderators: mean age (years), mean H&Y (scores), mean UPDRS (scores) and mean disease duration (years).

Furthermore, publication bias was assessed using funnel plots for each outcome (of each trial's effect size against the standard error). Funnel plot asymmetry was evaluated using Begg and Egger tests (EGGER et al., 1997) and significant publication bias was considered if the p-value < .05. Trim-and-fill computation was used to estimate the effect of publication bias on the interpretation of results.

Forest plots were generated indicating the pooled effects and standardized mean differences, with 95% confidence intervals (CIs) for each outcome. Values

of $p < .05$ were considered statistically significant. All analyses were performed using Comprehensive Meta-Analysis software version 3.3.07.

2.3 RESULTS

2.3.1 Studies Selection

A total of 2304 studies were identified during the literature search. After adjusting for duplicates, 1948 studies remained. After reading the abstracts, 1685 were removed, as they did not contain the key concepts of the study question. The full texts of 263 studies were read, and, from this analysis, 190 studies were excluded. Most of these studies were excluded either because (i) the study did not evaluate gait variables, (ii) evaluation performed in OFF medication, (iii) lack of control group, (iv) Post DBS, (v) characteristic of a preliminary study. Thus, 73 studies met the inclusion criteria and were included in the quantitative analysis (Figure 2.1). Of these, three trials were included twice because they had met the eligibility criteria for two comparison groups. No other search was performed.

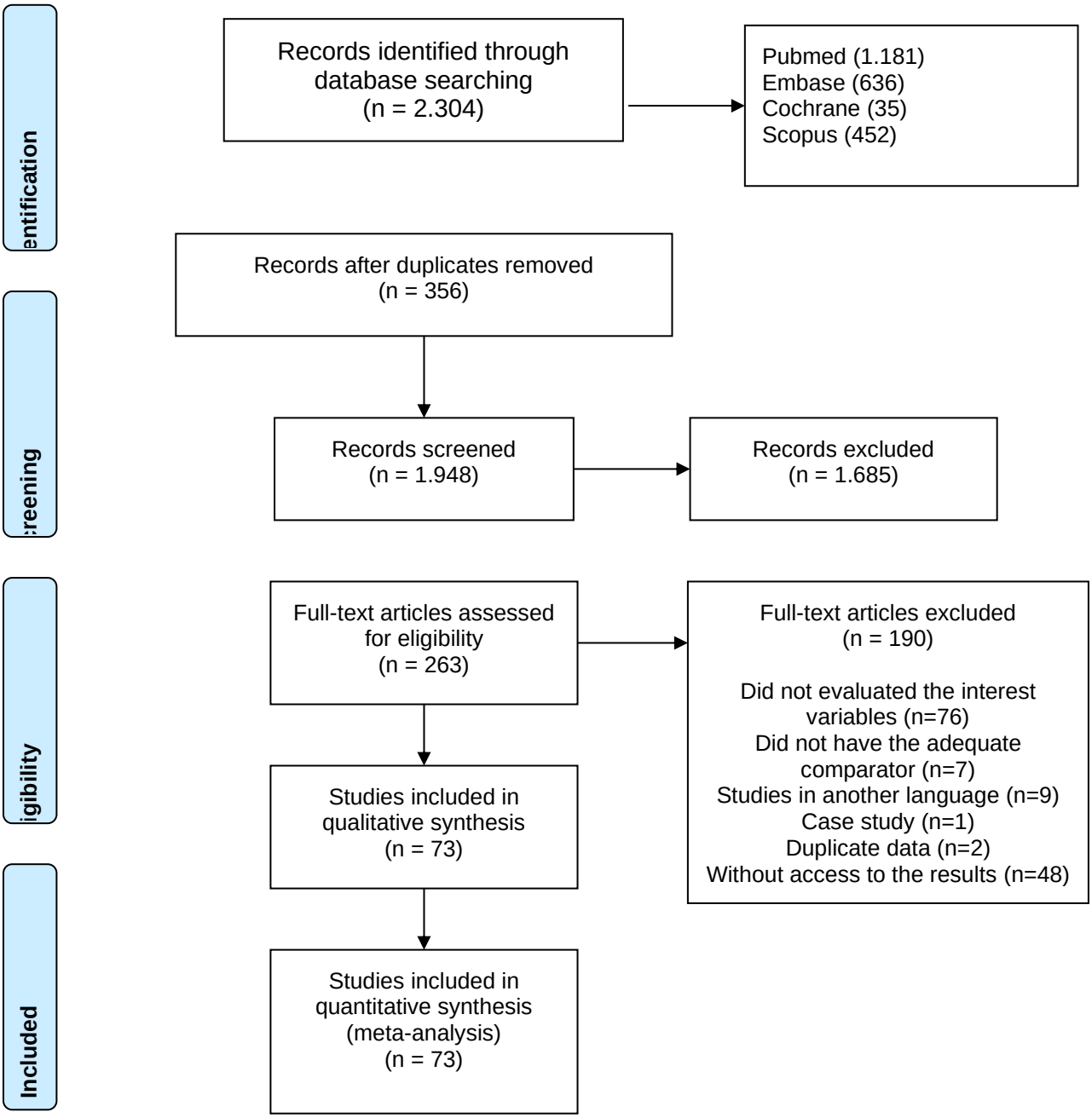

Figure 2.1 Flowchart of number of articles retrieved during the literature search and study selection

2.3.2 Characteristics of the included studies

In total, 73 studies and 76 comparison pairs were found. In this review, 3027 participants were included in the meta-analyses. Among these, 1510 and

1517 participants were from Parkinson disease groups and control groups, respectively. A total of 77% of the studies showed H&Y values, 66% provide UPDRS information, 62% of the studies exhibited the disease duration, 100% informed PD group age, and 1% did not provide this information about control group. The characteristics of the 73 included studies are available in table 2.1 and mean and standardize deviation of the variables of the included studies is showed in table 2.2.

Table 2.1 Characteristics of the included studies.

Study	Number of participants in PD; and in HC	Mean Age PD (years)	Mean Age HC (years)	H&Y (scores)	UPDRS (scores)	Disease duration (years)	Measurements	Device	Distance (m)
Arias & Cudeiro (2008)	PD = 25; HC = 10	65.9 ± 7.7	65.7 ± 7.7	2.5 ± .6	53.4 ± 21.3	9.0 ± 6.2	Free Walking	Photocells	30
Azulay et al.(1999)	PD =16; HC =16	68.8 ± 4.0	67.5 ± 5.0	2 to 3	Not reported	6.3	Free Walking	3D Gait Analysis	12
Azulay et al.(2002)	PD =21; HC =22	68.0 ± 11.0	67.5 ± 13.9	2.4 ± .5	Not reported	5.4 ± .7	Free Walking	3D Gait Analysis	12
Bhatt et al.(2013)	PD = 10; HC =10	72.3 ± 9.8	69.6 ± 7.5	Not reported	33.4 ± 1.4	Not reported	Free Walking	3D Gait Analysis	6
Blin et al.(1990)	PD = 21; HC =58	50 to 85	60 to 92	1 to 4	Not reported	1 to 17	Free Walking	Potentiometer	More than 10
Bond & Morn's (2000)	PD = 12; HC =12	65.1 ± 1.3	65.3 ± 1.4	Not reported	Not reported	9.4 ± 6.5	Free Walking	3D Gait Analysis	15
Brown et al.(2009)	PD = 10; HC = 10	66.6 ± 6.5	65.4 ± 6.3	2.3 ± .3	28.2 ± 2.4	6.4 ± 4.5	Free Walking	3D Gait Analysis	10
Bugalho et al.(2013)	PD = 40; HC = 30	74.3 ± 6.9	73.4 ± 7.1	2.2 ± .7	17.4 ± 12.3	5.8 ± 4.9	Free Walking	3D Gait Analysis	10
Caetano et al.(2009)	PD = 8; HC = 8	68.7 ± 6.6	69.7 ± 4.9	1.7 ± .9	26.9 ± 13.9	4.9 ± 5.5	Free Walking	3D Gait Analysis	5
Carpinella et al.(2007)	PD = 7; HC = 7	65.9 ± 4.8	68.4 ± 2.4	1 to 2	15.6 ± 3.0	Not reported	Free Walking	3D Gait Analysis	6
Castagna et al.(2016)	PD = 15; HC = 15	5.7 ± 11.5	49.2 ± 1.5	Not reported	15.2 ± 1.6	14.7 ± 7.1	Free Walking	3D Gait Analysis	6
Chen et al.(2011)	PD = 12; HC = 12	6.3 ± 6.7	56.4 ± 7.0	2.3 ± .3	2.2 ± 3.0	8.0 ± 4.8	Free Walking	2D Gait Analysis	6
Cole et al.(2010)	PD = 17; HC = 17	66.9 ± 8.7	65.1 ± 8.7	2.5 ± .8	26.6 ± 15.3	3.9 ± 2.5	Free Walking	3D Gait Analysis	12
Cole et al.(2017)	PD = 31; HC = 53	66.5 ± 7.8	69.6 ± 8.0	1.4 ± .6	29.4 ± 1.0	4.2 ± 3.3	Free Walking	3D Gait Analysis	9
Danoudis & Iansek (2014)	PD = 20; HC = 21	68.9 ± 8.8	71.7 ± 4.0	1 to 5	15 to 56	5.6 ± 5.5	Free Walking	Kinetics	12
De Nunzio et al.(2010)	PD = 15; HC = 14	68.4 ± 1.9	6.2 ± 11.6	2.5 ± .6	26.8 ± 1.2	5.4 ± 4.4	Free Walking	Kinetics	10
Del Din et al.(2016)	PD = 47; HC = 50	69.1 ± 8.3	69.8 ± 7.2	1 to 3	32.0 ± 1.1	Not reported	Free Walking	Accelerometer	10
Demonceau et al.(2015a)	PD = 32; HC = 32	64.5 ± 7.1	64.8 ± 9.9	1.7 ± .6	13.0 ± 6.2	1.5 to 5	Free Walking	Accelerometer	36
Demonceau et al.(2015b)	PD = 32; HC = 32	65.3 ± 8.5	64.8 ± 9.9	2 to 3	2.3 ± 8.4	8 to 14	Free Walking	Accelerometer	36
Dillmann et al.(2014a)	PD = 17; HC = 35	61.8 ± 9.8	6.8 ± 4.7	1 to 2	>20	Not reported	Treadmill	3D Gait Analysis	Not reported
Dillmann et al.(2014b)	PD = 19; HC = 35	64.3 ± 8.8	6.8 ± 4.7	2.5 to 4	>20	Not reported	Treadmill	3D Gait Analysis	Not reported
Ebersbach et al.(1999)	PD = 30; HC = 30	65.0 ± 9.3	6.9 ± 8.0	Not reported	Not reported	Not reported	Free Walking	Kinetics	10
Egerton et al.(2012)	PD = 20; HC = 20	68.3 ± 7.9	71.8 ± 4.1	Not reported	Not reported	6.6 ± 5.8	Free Walking	Kinetics	10
Eltoukhy et al.(2017)	PD = 8; HC = 11	71.0 ± 5.6	71.1 ± 7.5	1 to 3	Not reported	Not reported	Free Walking	3D Gait Analysis	5
Esser et al.(2013)	PD = 14; HC = 10	63.4 ± 7.7	66.4 ± 4.4	Not reported	Not reported	6.1 ± 4.8	Free Walking	Accelerometer	10
Esser et al.(2011)	PD = 29; HC = 10	63.4 ± 7.7	66.4 ± 4.4	Not reported	Not reported	6.1 ± 4.8	Free Walking	Accelerometer	10
Frenkel-Toledo et al.(2005) (1)	PD = 36; HC = 30	61.2 ± 9.0	57.7 ± 7.0	Not reported	Not reported	Not reported	Free Walking	Kinetics	35
Frenkel-Toledo et al.(2005) (2)	PD = 36; HC = 30	61.2 ± 9.0	57.7 ± 7.0	Not reported	Not reported	Not reported	Treadmill	Kinetics	Not reported
Galletly & Brauer (2005)	PD = 16; HC = 16	65.0 ± 9.5	65.0 ± 9.6	Not reported	Not reported	9.1 ± 4.5	Free Walking	Accelerometer	12
Hackney & Earhart (2009)	PD = 78; HC = 74	65.1 ± 9.5	65.0 ± 1.0	.5 to 3	27.5 ± 9.2	8.2 ± 5.0	Free Walking	Kinetics	5
Hackney & Earhart (2010)	PD = 78; HC = 74	65.1 ± 9.5	65.0 ± 1.0	.5 to 3	27.5 ± 9.2	8.2 ± 5.0	Free Walking	Kinetics	5
Hausdorff et al.(2007)	PD = 29; HC = 26	67.2 ± 9.1	64.6 ± 6.8	2.4 ± .4	15.8 ± 4.5	Not reported	Free Walking	Kinetics	100
Jaywant et al.(2016)	PD = 26; HC = 24	65.1 ± 7.9	62.5 ± 8.6	1 to 3	18.6 ± 8.0	Not reported	Free Walking	Accelerometer	11
Kimmeskamp & Hennig (2001)	PD = 24; HC = 24	63.8 ± 1.1	66.1 ± 9.2	Not reported	Not reported	Not reported	Free Walking	Kinetics	11
Kincses et al.(2017)	PD = 40; HC = 49	68.0 ± 8.1	65.6 ± 5.6	Not reported	31.3 ± 13.7	6.7 ± 4.5	Free Walking	2D Gait Analysis	4
Latt et al.(2009)	PD = 33; HC = 33	63.0 ± 4.0	67.0 ± 4.0	1.0 to 1.0	12.0 ± 3.0	7.0 ± 2.0	Free walking	Accelerometer	20
Lewis et al.(2000)	PD = 14; HC = 14	71.1 ± 7.6	7.5 ± 6.5	2.6 ± .8	Not reported	9.1 ± 5.7	Free Walking	3D Gait Analysis	10
Lin et al.(2016)	PD = 12; HC = 12	64.3 ± 8.6	51.3 ± 7.4	2.5 ± .6	26.2 ± 14.1	Not reported	Free Walking	Kinetics	4
Lohnes & Earhart (2011)	PD = 11; HC = 11	7.3 ± 6.8	7.8 ± 1.4	2 to 3	21.6 ± 6.7	9.1 ± 5.4	Free Walking	Kinetics	5
Lowry et al.(2009)	PD = 11; HC = 11	68.0 ± 7.7	68.9 ± 8.8	1.9 ± .8	Not reported	5.1 ± 4.1	Free Walking	Accelerometer	18

Maggioni et al.(2012)	PD = 14; HC = 14	67.9 ± 8.1	66.6 ± 5.3	2.0 ± .6	2.4 ± 15.4	6.2 ± 4.1	Free Walking	Kinetics	10
Mak (2013)	PD = 13; HC = 15	63.9 ± 7.2	61.8 ± 6.0	2.4 ± .4	22.8 ± 6.1	8.0 ± 5.3	Treadmill	Kinetics	Not reported
Mak et al.(2013)	PD = 15; HC = 13	63.0 ± 4.9	6.0 ± 7.1	2.1 ± .4	14.7 ± 3.8	7.7 ± 4.3	Free Walking	Kinetics	3.7
McIntosh et al.(1997)	PD = 21; HC = 10	71.0 ± 4.0	72.0 ± 5.0	2 to 4	Not reported	Not reported	Free Walking	Kinetics	15
McNeely et al.(2012)	PD = 22; HC = 20	71.3 ± 7.6	72.1 ± 6.1	2.2 ± .3	25.3 ± 6.9	7.0 ± 4.2	Free Walking	Kinetics	4.8
Morris et al.(1994) (1)	PD = 22; HC = 22	75.7 ± 6.7	> 60	3.1 ± .7	Not reported	Not reported	Free Walking	Kinetics	10
Morris et al.(1994) (2)	PD = 15; HC = 15	72.2 ± 6.2	72.5 ± 6.5	2.7 ± .7	Not reported	Not reported	Free Walking	Kinetics	12
Morris et al.(2005)	PD = 12; HC = 12	66.3 ± 9.4	50 to 78	Not reported	17.8 ± 9.4	Not reported	Free Walking	3D Gait Analysis	10
O'Shea et al.(2002)	PD = 15; HC =15	68.3 ± 6.6	67.7 ± 7.0	Not reported	Not reported	Not reported	Free Walking	2D Gait Analysis	14
Peppe et al.(2007)	PD = 16; HC = 13	66.5 ± 9.8	63.2 ± 11.2	2.3 ± .5	31.3 ± 1.0	6.7 ± 4.2	Free Walking	3D Gait Analysis	8
Pieruccini-Faria et al.(2013)	PD = 12; HC = 12	67.0 ± 6.2	Not reported	2.1 ± .6	26.7 ± 18.0	7.1 ± 5.5	Free Walking	3D Gait Analysis	8
Rabin et al.(2015)	PD = 16; HC = 16	71.0 ± 9.6	50 to 78	2.0 ± .5	3.5 ± 9.0	8.4 ± 5.5	Free Walking	3D Gait Analysis	6
Rafferty et al.(2017)	PD = 24; HC = 23	59.0 ± 4.6	61.2 ± 7.7	Not reported	Not reported	Not reported	Free Walking	Kinetics	10
Rochester et al.(2012)	PD = 22; HC = 22	7.2 ± 9.7	67.4 ± 8.4	1 to 3	29.1 ± 9.5	1.8 ± .1	Free Walking	3D Gait Analysis	7
Roiz Rde et al.(2010)	PD = 12; HC = 15	63.7 ± 8.3	59.1 ± 4.2	2.8 ± .5	Not reported	6.6 ± 4.3	Free Walking	3D Gait Analysis	10
Salazar et al.(2017)	PD = 19; HC = 13	66.3 ± 5.6	63.2 ± 4.5	1 to 3	2.6 ± 1.1	4.9 ± 4.2	Free Walking	3D Gait Analysis	1.4
Santos et al.(2016a)	PD = 10; HC = 10	67.0 ± 5.2	67.5 ± 6.5	2.0 ± .2	31.8 ± 6.9	4.6 ± 1.6	Free Walking	3D Gait Analysis	8
Santos et al.(2016b)	PD = 10; HC = 10	71.7 ± 5.0	71.4 ± 6.4	1.8 ± .2	29.1 ± 6.7	3.5 ± .8	Free Walking	3D Gait Analysis	8
Sofuwa et al.(2005)	PD = 15; HC = 9	63.1 ± 8.4	64.4 ± 4.6	2.6 ± .6	16.1 ± 6.4	11.3 ± 3.8	Free Walking	3D Gait Analysis	8
Stolze et al.(2001)	PD = 10; HC = 12	66.4 ± 6.7	74.6 ± 5.9	2.7 ± .4	29.6 ± 16.0	7.7 ± 4.8	Free Walking	3D Gait Analysis	13
Tramonti et al.(2017)	PD = 10; HC = 10	73.2 ± 8.1	68.8 ± 1.0	2.8 ± 1.0	26.1 ± 12.4	Not reported	Free Walking	3D Gait Analysis	10
Trojaniello et al.(2014)	PD = 10; HC = 10	73.8 ± 5.7	69.7 ± 5.8	Not reported	Not reported	Not reported	Free Walking	Kinetics	12
Turcato et al.(2018)	PD = 18; HC = 18	71.4 ± 8.0	72.7 ± 7.6	2.1 ± 1.8	9 to 27	8.6 ± 3.1	Free Walking	Kinetics	20
Van Wegen et al.(2006)	PD = 13; HC = 7	62.3 ± 9.8	59.2 ± 1.2	2.3 ± .5	52.9 ± 11.1	5.5 ± 3.5	Free Walking	3D Gait Analysis	10
Vaugoyeau et al.(2003)	PD = 10; HC = 5	62.2 ± 5.5	61.8 ± 5.4	3.3 ± .5	27.8 ± 5.4	13.2 ± 6.9	Free Walking	Kinetics	10
Vieregge et al.(1997)	PD = 17; HC = 33	68.8 ± 7.4	69.9 ± 7.0	2 to 3	37.5 ± 16.8	Not reported	Free walking	Kinetics	13
Vitório et al.(2010)	PD = 12; HC = 12	67.0 ± 6.2	67.0 ± 6.4	2.1 ± .6	3.9 ± 19.3	7.1 ± 5.5	Free Walking	3D Gait Analysis	8
Vitório et al.(2012)	PD = 12; HC = 12	69.8 ± 5.7	69.6 ± 6.0	1.4 ± .5	19.8 ± 12.2	Not reported	Free Walking	3D Gait Analysis	8
Vitório et al.(2014)	PD = 19; HC = 15	64.8 ± 9.3	66.8 ± 7.7	Not reported	24.3 ± 8.5	Not reported	Free Walking	3D Gait Analysis	8
Wahid et al.(2016)	PD = 28; HC = 29	68.5 ± 6.6	69.1 ± 6.4	2.5	Not reported	Not reported	Free Walking	3D Gait Analysis	10
Willems et al.(2006)	PD = 10; HC = 10	6.6 ± 6.2	63.6 ± 5.1	2.7 ± .6	24.7 ± 12.6	6.2 ± 3.0	Free Walking	3D Gait Analysis	8
Xu et al.(2018)	PD = 9; HC = 9	67.7 ± 7.1	67.7 ± 8.0	2.4 ± .3	36.1 ± 11.8	Not reported	Free Walking	3D Gait Analysis	7.3
Yang et al.(2008)	PD = 18; HC = 17	68.6 ± 11.1	68.9 ± 7.0	1 to 2	Not reported	Not reported	Free Walking	Kinetics	10
Zhang et al.(2016)	PD = 15; HC = 11	63.7 ± 5.6	65.2 ± 4.0	2.8 ± .4	1.9 ± 6.4	8.0 ± 3.0	Free Walking	3D Gait Analysis	5
Zhou et al.(2018)	PD = 12; HC = 12	61.6 ± 11.7	68.0 ± 6.4	1 to 3	11.0 ± 5.4	6.7 ± 3.9	Free Walking	3D Gait Analysis	5
Zijlstra et al.(1998)	PD = 10; HC = 8	44 to 74	55 to 60	1.5 to 3	Not reported	Not reported	Free Walking	3D Gait Analysis	10

Table 2.2 Mean and standardize deviation of gait variable of included studies.

Variables	**Parkinson Group** (mean±sd)	**Control Group** (mean±sd)
Speed (m.s)	1.11±.44	1.24±.37
Stride length (m)	1.23±.20	1.37±.15
Cadence (step/min)	101.90±1.56	101.23±9.37
Step width (m)	.11±.06	.09±.06
Double support (%)	22.10±4	2.58±4.98
Single support (%)	68.39±2.44	67.47±3.33
Swing support (%)	36.07±2.84	38.75±8.31
ROM Hip (degree)	39.39±6.38	45.08±5.32
ROM Knee (degree)	55.90±5.11	61.59±4.86
ROM Ankle (degree)	25.07±4.16	26.20±4.41
ROM Hip (initial contact) (degree)	25.22±7.50	32.22±5.60
ROM Knee (initial contact) (degree)	8.32±5.21	7.14±4.63
ROM Ankle (initial contact) (degree)	1.89±2.71	1.40±2.08

NOTE: sd: standardize deviation

2.3.3 Methodological Quality of the Included Trials

Of the 73 included studies, 100% showed the hypothesis/aim/objective clearly described, 97% described the primary outcomes, 59% showed the characteristics of participants clearly, 99% described principal confounders, 100% reported the main findings, 100% showed random variability in the data, 82% described probability values, in 75% of the studies the participants are representative of population, 93% measured the appropriate statistic, 100% measured the main outcome if accurate methods, 100% recruited the participants of the same population and 8% of the studies recruited the participants of the groups in the same period of time (Table 2.3).

Table 2.3 Methodological Quality of the Included Trials.

Studies	**Quality Index item Number**														**Percentage score (100%)**	**Quality category**
	1	**2**	**3**	**5**	**6**	**7**	**10**	**11**	**12**	**18**	**20**	**21**	**22**	**Total**		
Arias & Cudeiro (2008)	1	1	1	2	1	1	1	1	1	1	1	1	1	14	100	High
Azulay et al.(1999)	1	1	0	2	1	1	1	1	1	1	1	1	0	12	86	High
Azulay et al.(2002)	1	1	0	2	1	1	1	0	0	1	1	1	0	10	71	High
Bhatt et al.(2013)	1	1	0	2	1	1	1	1	1	1	1	1	0	12	86	High

Blin et al.(1990)	1	1	0	1	1	1	1	0	0	1	1	1	0	9	64	Medium
Bond & Morn's (2000)	1	1	0	2	1	1	1	1	1	1	1	1	0	12	86	High
Brown et al.(2009)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Bugalho et al.(2013)	1	1	1	2	1	1	1	1	1	1	1	1	1	14	100	High
Caetano et al.(2009)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Carpinella et al.(2007)	1	1	0	1	1	1	1	1	1	1	1	1	0	11	79	High
Castagna et al.(2016)	1	0	0	2	1	1	1	0	0	1	1	1	0	9	64	Medium
Chen et al.(2011)	1	1	1	1	1	1	0	1	1	1	1	1	0	11	79	High
Cole et al.(2010)	1	1	1	2	1	1	1	1	1	1	1	1	1	14	100	High
Cole et al.(2017)	1	1	1	2	1	1	1	1	1	1	1	1	1	14	100	High
Danoudis & Iansek (2014)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
De Nunzio et al.(2010)	1	1	1	2	1	1	1	0	0	1	1	1	0	11	79	High
Del Din et al.(2016)	1	1	1	0	1	1	1	1	1	1	1	1	1	12	86	High
Demonceau et al.(2015)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Dillmann et al.(2014)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Ebersbach et al.(1999)	1	1	0	2	1	1	1	1	1	1	1	1	0	12	86	High
Egerton et al.(2012)	1	1	0	2	1	1	1	1	1	1	1	1	0	12	86	High
Eltoukhy et al.(2017)	1	1	0	2	1	1	1	1	1	1	1	1	0	12	86	High
Esser et al.(2013)	1	1	0	2	1	1	1	0	0	1	1	1	0	10	71	High
Esser et al.(2011)	1	1	0	2	1	1	1	1	1	1	1	1	0	12	86	High
Frenkel-Toledo et al.(2005) (1)	1	1	0	2	1	1	1	0	0	1	1	1	0	10	71	High
Frenkel-Toledo et al.(2005) (2)	1	1	0	2	1	1	1	0	0	1	1	1	0	10	71	High
Galletly & Brauer (2005)	1	1	0	1	1	1	1	0	0	0	1	1	0	8	57	Medium
Hackney & Earhart (2009)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Hackney & Earhart (2010)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Hausdorff et al.(2007)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Jaywant et al.(2016)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Kimmeskamp & Hennig (2001)	1	1	0	2	1	1	1	1	1	1	1	1	0	12	86	High
Kincses et al.(2017)	1	1	1	2	1	1	0	1	1	1	1	1	0	12	86	High
Latt et al.(2009)	1	1	1	2	1	1	0	0	0	1	1	1	0	10	71	High
Lewis et al.(2000)	1	1	0	2	1	1	1	1	1	1	1	1	0	12	86	High
Lin et al.(2016)	1	1	1	2	1	1	0	1	1	1	1	1	0	12	86	High
Lohnes & Earhart (2011)	1	1	1	2	1	1	1	0	0	1	1	1	0	11	79	High
Lowry et al.(2009)	1	1	0	2	1	1	1	1	1	1	1	1	0	12	86	High
Maggioni et al.(2012)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Mak (2013)	1	1	1	2	1	1	1	0	0	1	1	1	0	11	79	High
Mak et al.(2013)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
McIntosh et al.(1997)	1	1	0	2	1	1	0	1	1	1	1	1	0	11	79	High
McNeely et al.(2012)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Morris et al.(1994)(1)	1	1	0	1	1	1	1	1	1	0	1	1	0	10	71	High
Morris et al.(1994)(2)	1	1	0	2	1	1	1	0	0	0	1	1	0	9	64	Medium
Morris et al.(2005)	1	1	0	2	1	1	1	1	1	1	1	1	0	12	86	High
O'Shea et al.(2002)	1	1	0	1	1	1	0	0	0	1	1	1	0	8	57	Medium
Peppe et al.(2007)	1	1	1	2	1	1	0	0	0	1	1	1	0	10	71	High
Pieruccini-Faria et al.(2013)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Rabin et al.(2015)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Rafferty et al.(2017)	1	1	0	1	1	1	1	1	1	1	1	1	1	12	86	High

Rochester et al.(2012)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Roiz Rde et al.(2010)	1	1	0	1	1	1	1	0	0	1	1	1	0	9	64	Medium
Salazar et al.(2017)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Santos et al.(2016)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Sofuwa et al.(2005)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Stolze et al.(2001)	1	1	1	2	1	1	0	1	1	1	1	1	0	12	86	High
Tramonti et al.(2017)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Trojaniello et al.(2014)	1	1	0	1	1	1	1	0	0	1	1	1	0	9	64	Medium
Turcato et al.(2018)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Van Wegen et al.(2006)	1	1	1	2	1	1	0	1	1	1	1	1	0	12	86	High
Vaugoyeau et al.(2003)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Vieregge et al.(1997)	1	1	1	2	1	1	0	1	1	1	1	1	0	12	86	High
Vitório et al.(2010)	1	1	1	2	1	1	1	1	1	1	1	1	0	13	93	High
Vitório et al.(2012)	1	1	1	1	1	1	1	1	1	1	1	1	0	12	86	High
Vitório et al.(2014)	1	1	0	1	1	1	1	1	1	1	1	1	0	11	79	High
Wahid et al.(2016)	1	1	0	1	1	1	1	0	0	1	1	1	0	9	64	Medium
Willems et al.(2006)	1	1	1	2	1	1	0	1	1	1	1	1	0	12	86	High
Xu et al.(2018)	1	1	1	1	1	1	1	1	1	0	1	1	0	11	79	High
Yang et al.(2008)	1	1	0	2	1	1	1	1	1	1	1	1	0	12	86	High
Zhang et al.(2016)	1	1	1	2	1	1	0	0	0	1	1	1	0	10	71	High
Zhou et al.(2018)	1	0	1	1	1	1	1	1	1	1	1	1	0	11	79	High
Zijlstra et al.(1998)	1	1	0	2	1	1	0	1	1	0	1	1	0	10	71	High

2.3.4 Gait Parameters of DP and Healthy

Meta-Analysis of Speed. Data concerning speed were available from 69 studies and 72 combination pairs, which compare the speed of Parkinson versus healthy group, in a total of 2932 participants. Meta-analysis showed that speed is approximately .17m.s^{-1} lower in people with Parkinson compared with healthy group (ES: -.913; 95% CI, -1.100 to -.725; $p < .001$; I^2: 81%) (Figure 2.2). However, the analysis of publication bias for this outcome identified a significant bias ($p = .003$), and thus the adjusted value of the effect size, according to the Duval & Tweedie's trim and fill test, resulted in -.619 (95% CI, -.809 to -.429).

Subgroup analysis of studies, which evaluated speed using free walking or treadmill, evidenced that this criterion did not influence gait speed differences between Parkinson and healthy groups. The lowest walking speed in Parkinson's subjects is found both: when the evaluation is performed on free walking (66 studies; 68 combination pairs; ES: -.914; 95% CI, -1.113 to -.716; $p < .001$; I^2: 82%; -.17m.s^{-1}) and when it is performed on a treadmill (3 studies; 4 combination pairs; ES: -.919; 95% CI, -1.376 to -.462; $p < .001$; I^2: 54%; -.13m.s^{-1}). According to the results of meta-

regression analysis, mean age, H&Y, UPDRS, and disease duration do not influence the gait speed difference between Parkinson subjects and healthy groups (Table 2.4).

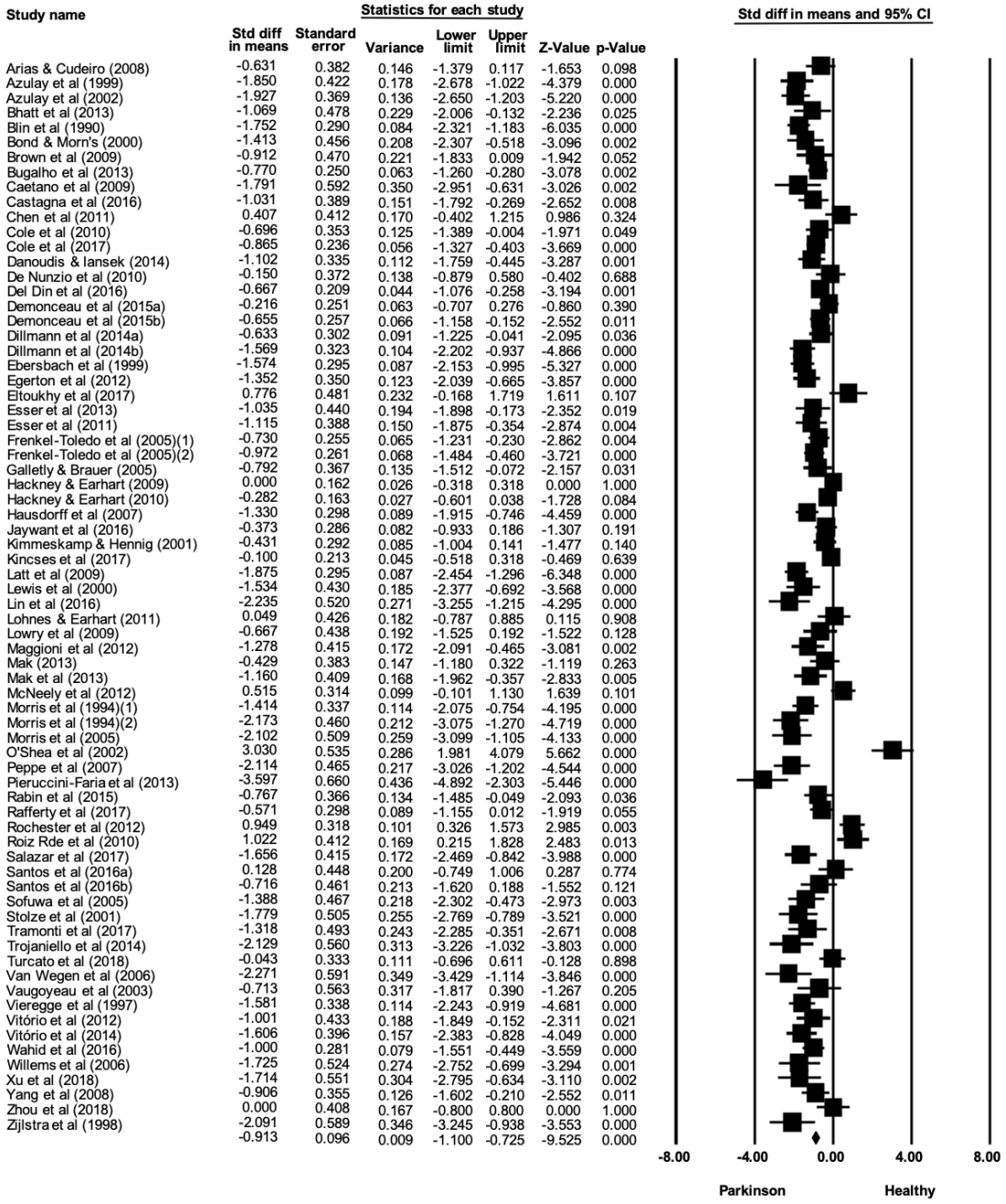

Figure 2.2 Standardized mean differences on gait speed between Parkinson and healthy individuals. CI: confidence interval; Std diff: standardized difference.

Meta-Analysis of Stride Length. Data concerning stride length were available from 52 studies and 54 combination pairs, which compare stride length of Parkinson versus healthy group, in a total of 2188 participants. Meta-analysis demonstrated that stride

length is approximately .16 m lower in Parkinson compared with healthy groups (ES: -1.032; 95% CI, -1.198 to -.866; $p < .001$; I^2: 67%) (Figure 2.3). However, the analysis of publication bias for this outcome identified a significant bias ($p = .003$), and thus the adjusted value of the effect size, according to the Duval & Tweedie's trim and fill test, resulted in -.836 (95% CI, -1.017 to -.655).

It was not possible to perform subgroup analysis by separating studies that assessed the stride length by free walk or treadmill because no studies were found performing this evaluation on the treadmill. Also, the meta-regression analysis showed that mean age, H&Y, UPDRS, and disease duration did not influence the stride length difference between individuals with Parkinson and healthy controls (Table 2.4).

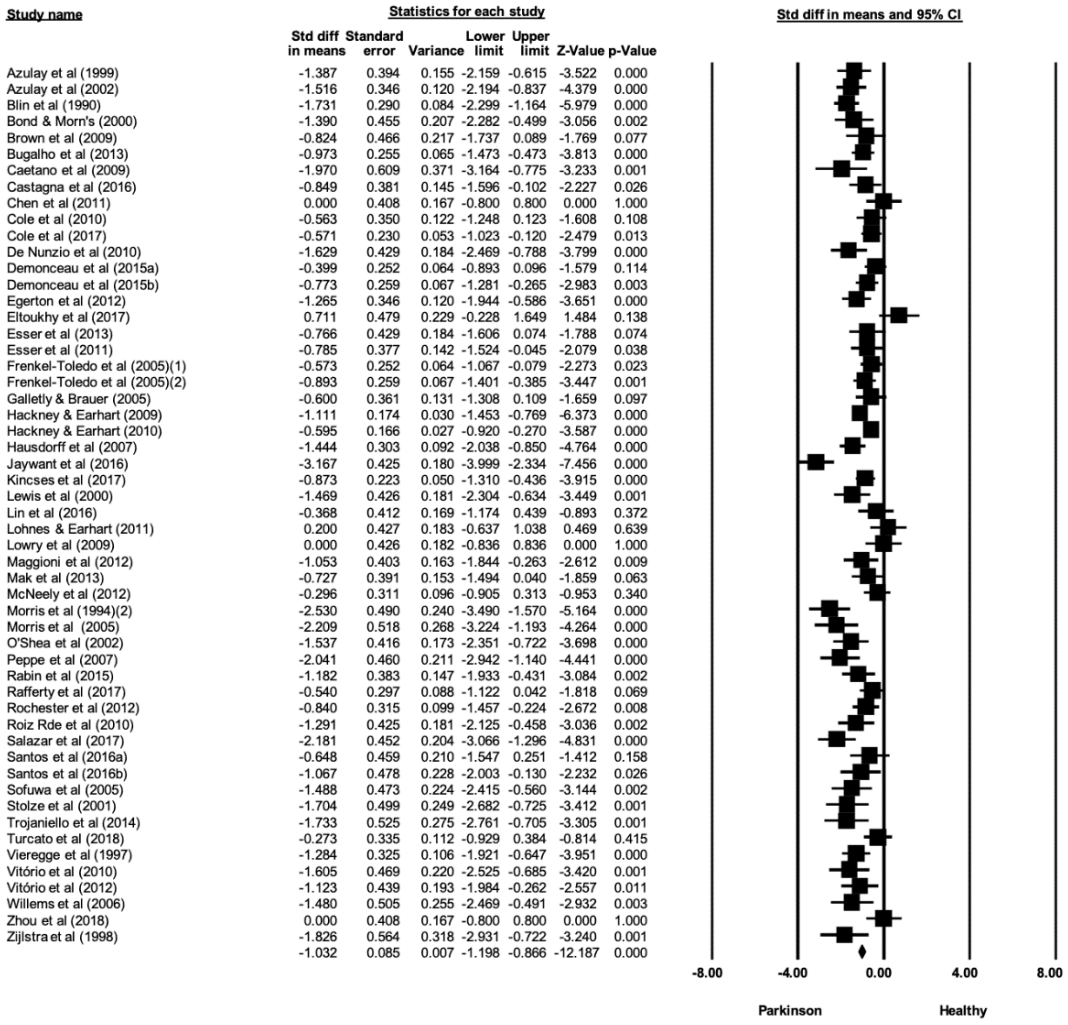

Figure 2.3 Standardized mean differences on stride length between Parkinson and healthy individuals. CI: confidence interval; Std diff: standardized difference.

Meta-Analysis of Cadence. Data concerning cadence were available from 50 studies and 51 combination pairs, which compare cadence of Parkinson versus healthy group, in a total of 1936 participants. Meta-analysis showed that cadence is approximately 1.75 step/min higher in Parkinson compared with healthy groups (ES: -.212; 95% CI, -.377 to -.048; p = .011; I^2: 66%) (Figure 2.4). The analysis of publication bias for this outcome showed no significant bias (p = .074).

Subgroup analysis of studies, which evaluated cadence using free walking or treadmill, evidenced that this criterion influences the gait differences between Parkinson and healthy groups. Studies adopting free walking strategy to evaluate this variable demonstrated that cadence is 1.86 steps/min higher in Parkinson´s subjects compared to healthy groups (ES: -.228; 95% CI, -.402 to -.054; P < .001; I^2: 67%). In contrast, studies using the treadmill to evaluate the cadence (3 studies) did not show difference between the cadence of Parkinson and healthy groups (ES: -.023; 95% CI, -.550 to .503; p = .931; I^2: 52%). Furthermore, the results of meta-regression analysis demonstrated that mean age, H&Y, UPDRS, and disease duration do not influence the cadence difference between Parkinson´s subjects and healthy groups (Table 2.4).

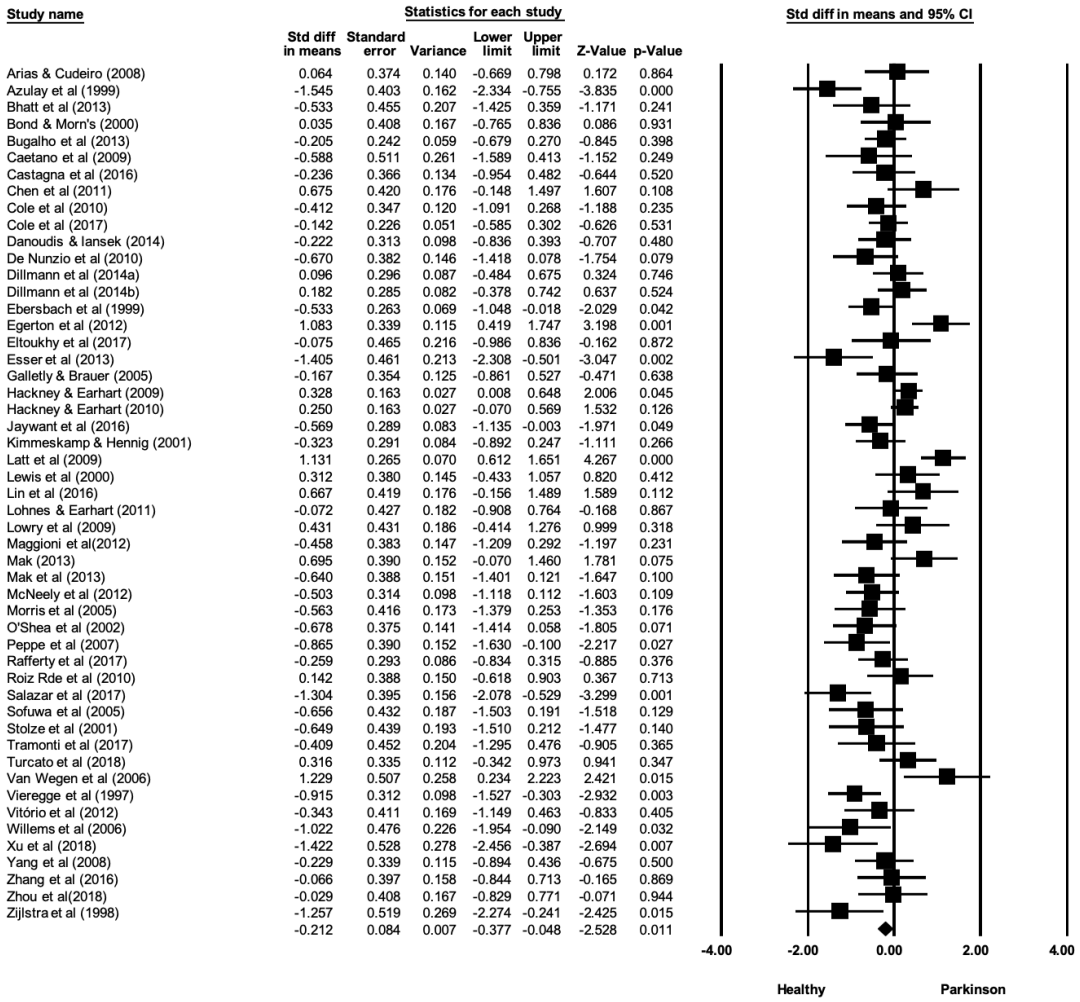

Figure 2.4 Standardized mean differences on gait cadence between Parkinson and healthy individuals. CI: confidence interval; Std diff: standardized difference.

Meta-Analysis of Step Width. Data concerning step width were available from 18 studies and 19 combination pairs, which compare the step width of Parkinson versus healthy group, in a total of 628 participants. Meta-analysis demonstrated that step width did not differ between Parkinson and healthy groups (ES: .104; 95% CI, -.153 to .361; p = .426; I^2: 59%) (Figure 2.5). The analysis of publication bias for this outcome showed no significant bias (p = .327).

It was not possible to perform subgroup analysis by separating studies that assessed the step width by free walk or treadmill because no studies were found performing this evaluation on the treadmill. Besides, the meta-regression analysis

showed that mean age, H&Y, UPDRS, and disease duration do not influence the step width difference between individuals with Parkinson and healthy controls (Table 2.4).

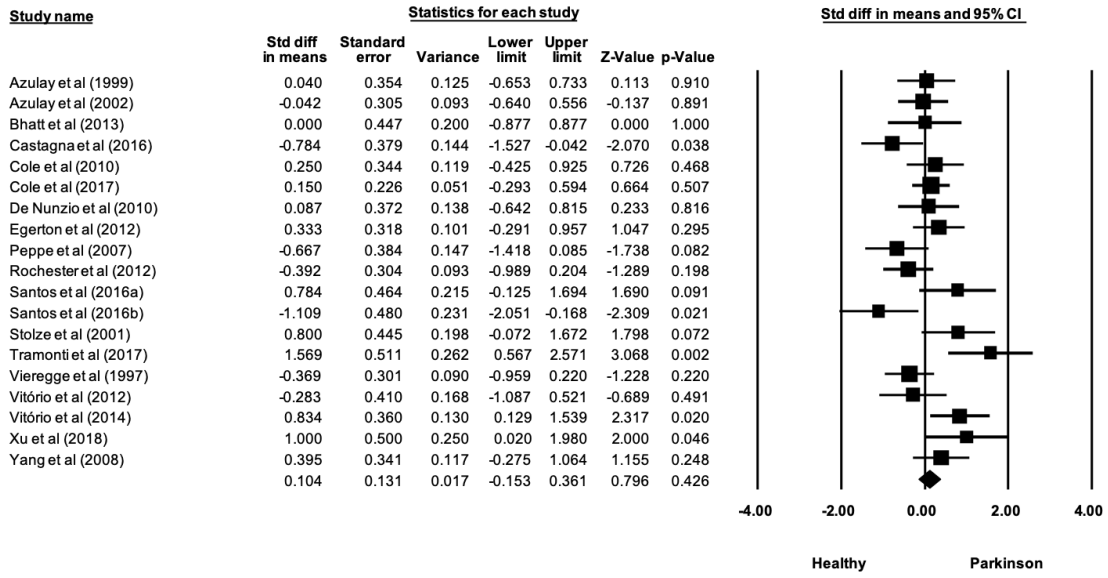

Figure 2.5 Standardized mean differences on step width between Parkinson and healthy individuals. CI: confidence interval; Std diff: standardized difference.

Meta-Analysis of Double Support Time. Data concerning double support time were available from 15 studies and 16 combination pairs, which compared the double support time of Parkinson versus control groups, in a total of 562 participants. Meta-analysis showed that double support time is approximately 1.79% longer in Parkinson compared with healthy groups (ES: .489; 95% CI, .137 to .841; $p < .001$; I^2: 73%) (Figure 2.6). The analysis of publication bias for this outcome showed no significant bias ($p = .260$).

It was not possible to perform subgroup analysis by separating studies that assessed the double support time from free walk or treadmill because no studies were found performing this evaluation on the treadmill. Also, the meta-regression analysis showed that mean age, H&Y, UPDRS, and disease duration do not influence the double support time difference between Parkinson´s subjects and healthy groups (Table 2.4).

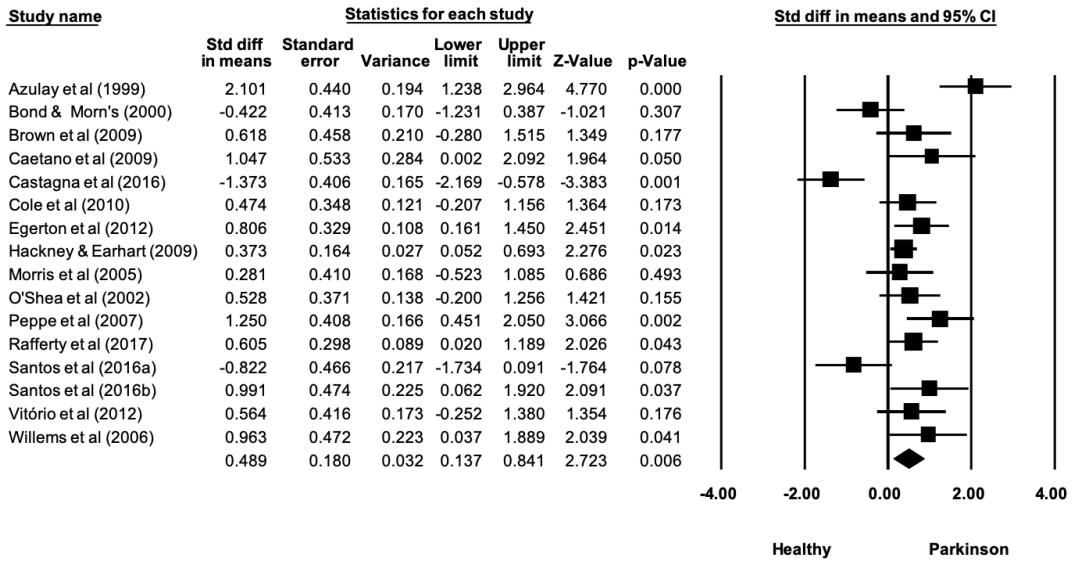

Figure 2.6 Standardized mean differences on double support time between Parkinson and healthy individuals. CI: confidence interval; Std diff: standardized difference.

Meta-Analysis of Single Support Time. Data concerning single support were available from 10 studies, which compared single support time between individuals with Parkinson versus healthy group, in a total of 366 participants. Meta-analysis demonstrated that single support time did not differ between Parkinson and healthy groups (ES: .273; 95% CI, -.204 to .750; p = .262; I^2: 83%) (Figure 2.7). The analysis of publication bias for this outcome showed no significant bias (p = .720).

It was not possible to perform subgroup analysis by separating studies that assessed the single support time by free walk or treadmill because no studies were found performing this evaluation on the treadmill. In addition, the meta-regression analysis showed that mean age, H&Y, UPDRS, and disease duration do not influence the single support time difference between Parkinson´s subjects and healthy groups (Table 2.4).

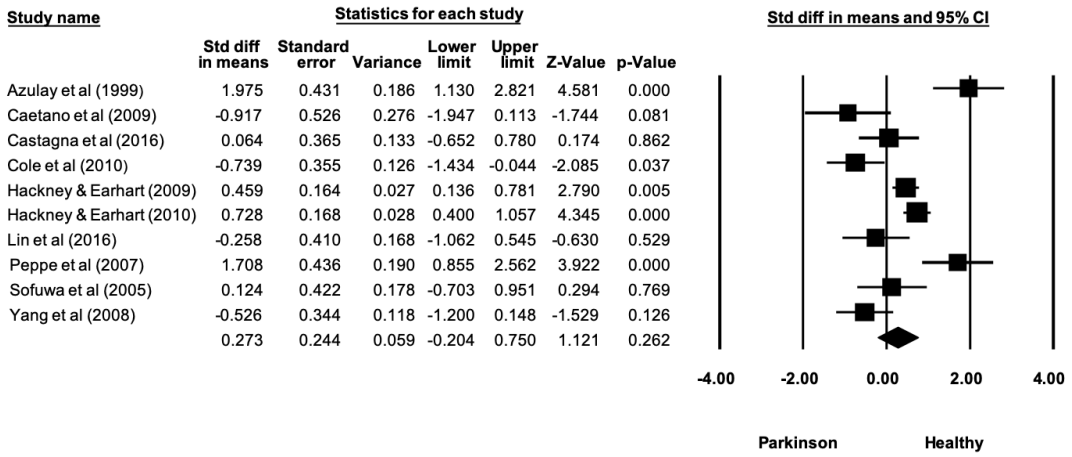

Figure 2.7 Standardized mean differences on single support time between Parkinson and healthy individuals. CI: confidence interval; Std diff: standardized difference.

Meta-Analysis of Swing Time. Data concerning swing phase time were available from 11 studies, which compare swing time of Parkinson versus healthy group, in a total of 661 participants. Meta-analysis showed that swing time is there about 1.76% lower in Parkinson compared with healthy groups (ES: -.715; 95% CI, -1.096 to -.334; $p < .001$; I^2: 79%) (Figure 2.8). The analysis of publication bias for this outcome showed no significant bias ($p = .087$).

It was not possible to perform subgroup analysis by separating studies that assessed the swing time by free walk or treadmill because no studies were found performing this evaluation on the treadmill. According to the results of meta-regression analysis, mean age and disease duration do not influence the swing time difference between Parkinson´s subjects and healthy groups. On the other hand, the disease stage, evaluated by H&Y plays a significant role on the swing phase time difference between Parkinson and healthy groups (β: 2.535; 95% CI, .084 to 4.987 $p = .042$; $R^2 = .57$). Therefore, the larger the H&Y values, the larger is the difference between swing phase time in Parkinson compared with healthy groups. In addition, there is a significant influence of UPDRS on the swing phase difference between Parkinson and healthy groups (β: -.149; 95% CI, -.247 to -.052 $p = .002$; $R^2 = .67$). Therefore, the lower the UPDRS, the higher is the swing phase time difference between Parkinson and healthy groups (Table 2.4).

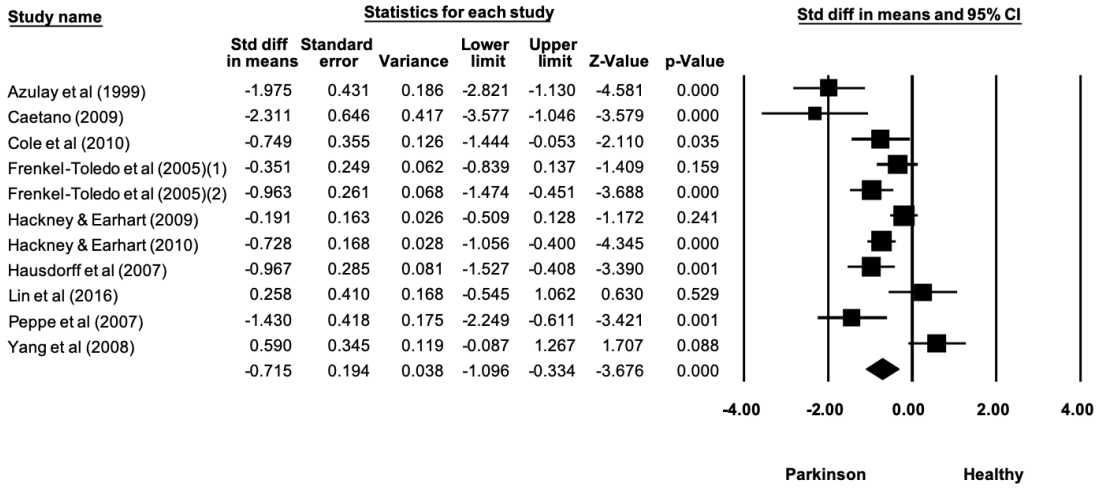

Figure 2.8 Standardized mean differences on swing time between Parkinson and healthy individuals. CI: confidence interval; Std diff: standardized difference.

Meta-Analysis of ROM Hip. Data concerning ROM Hip were available from 3 studies, which compare ROM Hip of Parkinson versus healthy group, in a total of 76 participants. Meta-analysis demonstrated that ROM Hip is 5.29 degrees lower in Parkinson compared with healthy groups (ES: -.860; 95% CI, -1.333 to -.388 $p < .001$; I^2: 0%) (Figure 2.9). Subgroup and meta-regression analyses were not performed because there are not enough studies.

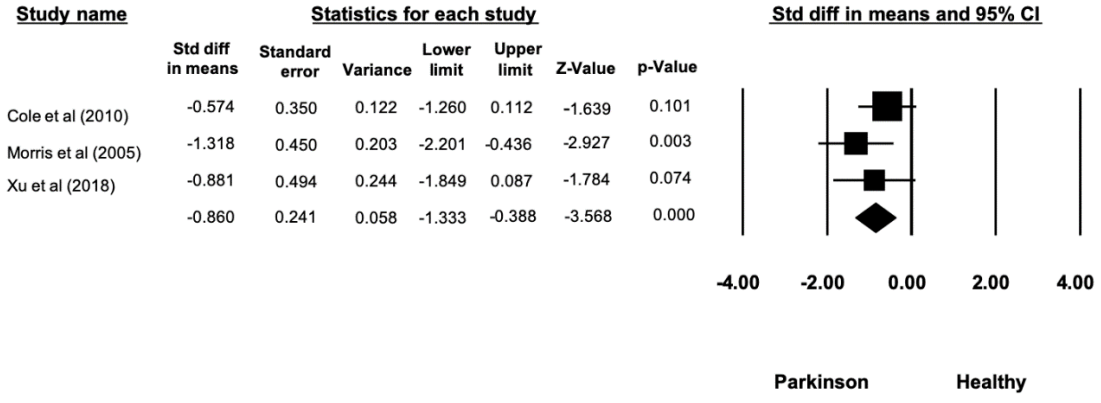

Figure 2.9 Standardized mean differences on range of hip motion between Parkinson and healthy individuals. CI: confidence interval; Std diff: standardized difference.

Meta-Analysis of ROM Knee. Data concerning ROM Knee were available from 2 studies, which compare ROM Knee of Parkinson versus healthy groups, in a total of

52 participants. Meta-analysis showed that ROM Knee did not differ between Parkinson and healthy groups (ES: -1.033; 95% CI, -2.564 to .498; p =.186; I^2: 82%) (Figure 2.10). Subgroup and meta-regression analyses were not performed because there are not enough studies.

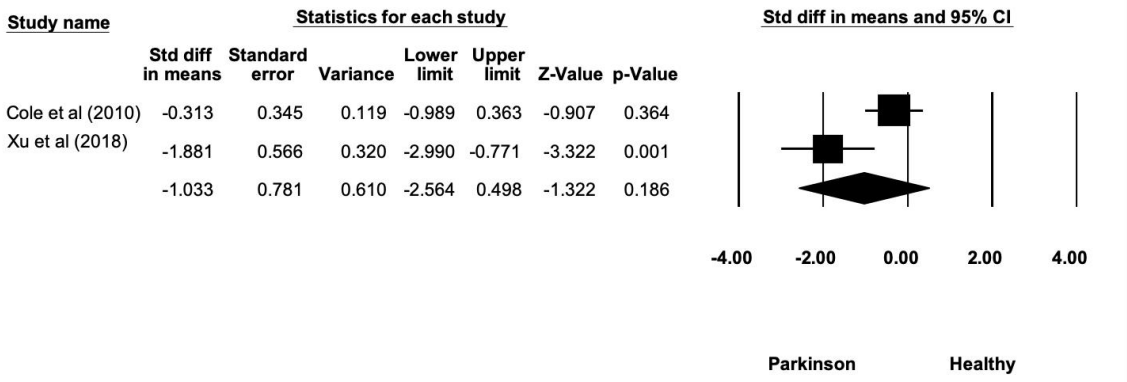

Figure 2.10 Standardized mean differences of range of knee motion between Parkinson and healthy individuals. CI: confidence interval; Std diff: standardized difference

Meta-Analysis of ROM Ankle. Data concerning ROM Ankle were available from 3 studies, which compare ROM Ankle of Parkinson versus control groups, in a total of 76 participants. Meta-analysis demonstrated that ROM Ankle did not differ between Parkinson and healthy groups (ES: -.216; 95% CI, -.896 to 465; p = .534; I^2: 53%) (Figure 2.11). Subgroup and meta-regression analyses were not performed because there are not enough studies.

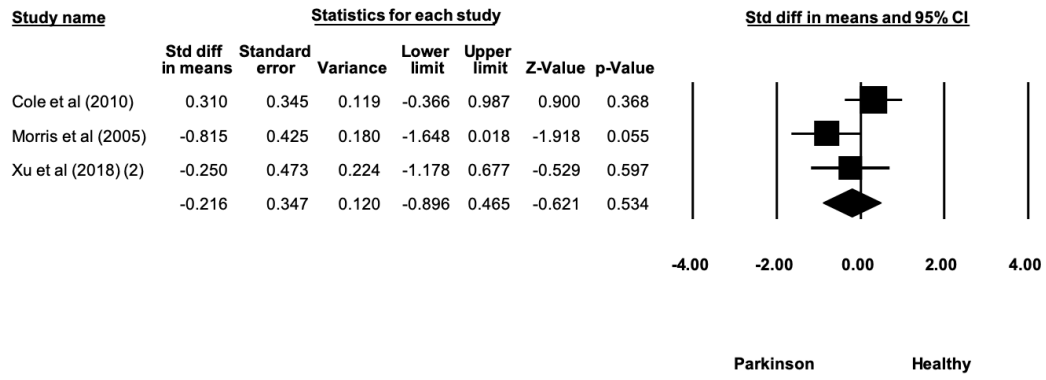

Figure 2.11 Standardized mean differences of range of ankle motion between Parkinson and healthy individuals. CI: confidence interval; Std diff: standardized difference.

Meta-Analysis of Hip Angle at Initial Contact. Data concerning Hip angle at initial contact were available from 3 studies, which compared Hip angle at initial contact of Parkinson versus control groups, in a total of 70 participants. Meta-analysis demonstrated that Hip angle at initial contact did not differ between Parkinson and healthy groups (ES: -1.023; 95% CI, -2.291 to .245; p = .114; I^2: 83%) (Figure 2.12). Subgroup and meta-regression analyses were not performed because there are not enough studies.

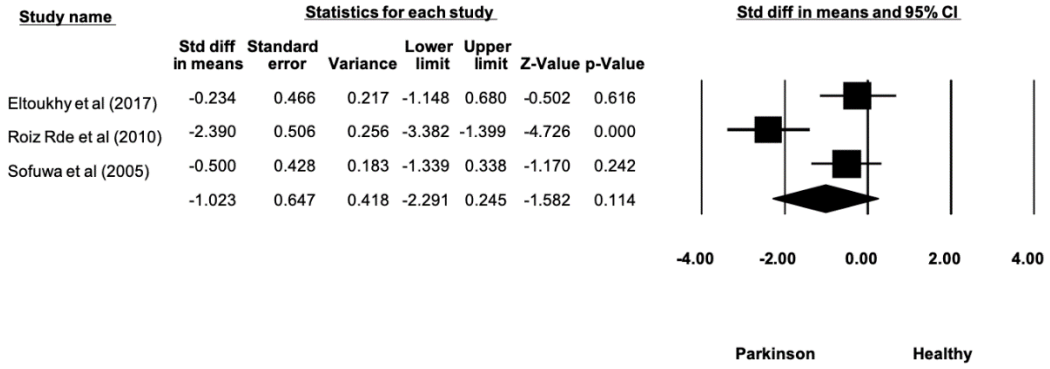

Figure 2.12 Standardized mean differences between hip angle at initial contact of Parkinson and healthy individuals. CI: confidence interval; Std diff: standardized difference.

Meta-Analysis of Knee Angle at Initial Contact. Data concerning Knee angle at initial contact were available from 3 studies, which compared the Knee angle at initial contact of Parkinson versus healthy group, in a total of 70 participants. Meta-analysis showed that Knee angle at initial contact did not differ between Parkinson and healthy groups (ES: .210; 95% CI, -.395 to .814; p = .496; I^2: 35%) (Figure 2.13). Subgroup and meta-regression analyses were not performed because there are not enough studies.

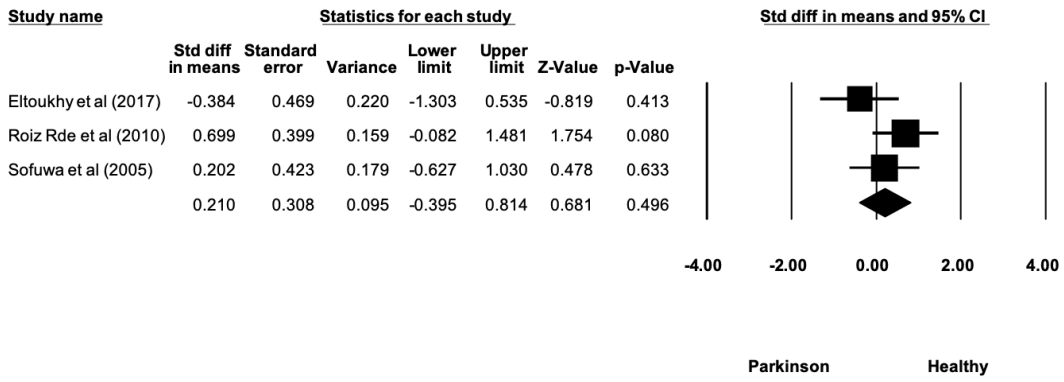

Figure 2.13 Standardized mean differences between knee angle at initial contact of Parkinson and healthy individuals. CI: confidence interval; Std diff: standardized difference.

Table 2.4 Meta-Regression of Moderators of the Gait parameters of Parkinson´s disease

Outcome/moderator	Number of study estimates	β	95% CI	p value	R^2
Speed					
Age	26	.053	.033 to .140	.227	.01
H&Y	26	.124	.546 to .814	.722	-.04
UPDRS	26	.013	.045 to .018	.414	-.05
Disease duration	26	.020	.131 to .173	.789	-.05
Stride lenght					
Age	21	-.001	-.080 to .080	.997	-.11
H&Y	21	-.586	-1.283 to .110	.098	.15
UPDRS	21	-.022	-.061 to .015	.244	.00
Disease duration	21	.003	-.146 to .152	.960	-.10
Cadence					
Age	16	.041	.137 to .055	.400	-.05
H&Y	16	.558	.191 to .075	.084	.23
UPDRS	16	.003	.026 to .032	.840	-.08
Disease duration	16	.061	.124 to .247	.515	-.05
Step Width					
Age	7	.230	.121 to .469	.058	.37
H&Y	7	.371	.779 to 1.522	.526	-.54
UPDRS	7	.005	.264 to .253	.967	-.31
Disease duration	7	.106	.233 to .447	.539	-.29

Double Support					
Age	7	.001	.183 to .179	.986	-.32
H&Y	7	.170	.469 to 1.811	.838	-.31
UPDRS	7	.006	.107 to .120	.913	-.31
Disease duration	7	.026	.053 to .001	.058	.49
Single Support					
Age	4	.163	.836 to .509	.633	-.40
H&Y	4	.940	2.887 to 4.768	.630	-.37
UPDRS	4	.020	.173 to .132	.794	-.46
Disease duration	4	.134	.340 to .609	.579	-.40
Swing Time					
Age	11	.069	.226 to .086	.381	-.12
H&Y	4	2.535	.083 to 4.987	**.042**	.57
UPDRS	6	.149	.246 to .052	**.002**	.67
Disease duration	5	.177	.115 to .469	.234	.06

Meta-Analysis of Ankle angle at initial contact. Data concerning Ankle angle at initial contact were available from 3 studies, which compared the Ankle angle at initial contact of Parkinson versus control groups, in a total of 70 participants. Meta-analysis showed that the Knee angle at initial contact did not differ between Parkinson and healthy groups (ES: .188; 95% CI, -.290 to .666; p = .440; I^2: 0%) (Figure 2.14). Subgroup and meta-regression analyses were not performed because there are not enough studies.

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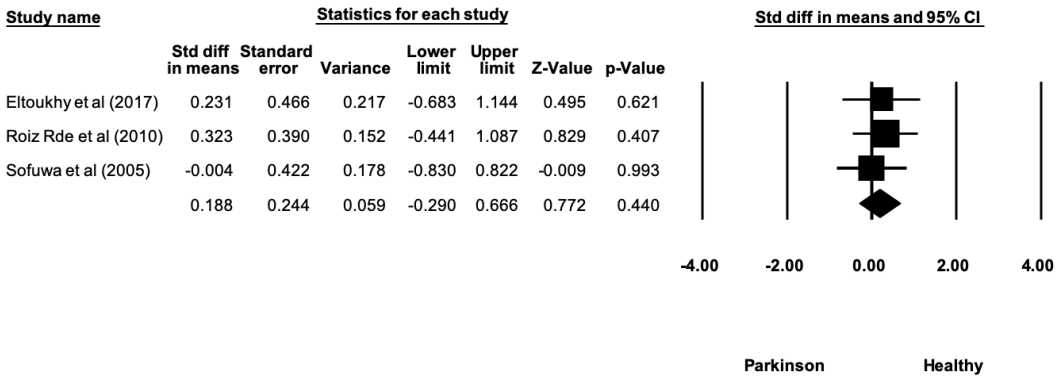

Figure 2.14 Standardized mean differences on ankle angle at initial contact between Parkinson and healthy individuals. CI: confidence interval; Std diff: standardized difference

2.4 DISCUSSION

To the best of our knowledge, this is the first meta-analysis of published studies about the spatiotemporal and lower limb angles during SSWS on people with PD compared with healthy control subjects. The main results agree with our hypotheses showing that SSWS, stride length, cadence, double support, swing time and sagittal hip angle were different in people with PD compared with healthy control participants and in some cases the method of evaluation of walk can influence these variables. The justification for exclusion is in supplementary material 2.3.

Spatiotemporal Variables

Walking speed is an important parameter of functional activities in daily life. Also, this parameter is an easy and cheap measurement that can help to monitor the mobility of people with PD (FRITZ & LUSARDI, 2009). In this review, 69 studies included speed in analysis, and it was possible to observe that PD SSWS is .17m.s^{-1} slower than healthy control group, due to bradykinesia and rigidity associated with physical inactivity (PEPPE et al., 2007). Slower speeds are associated with mortality, hospitalization, frailty and risk of falling (FRITZ & LUSARDI, 2009; LINDEMANN, 2019). Creaby & Cole (2018) revealed that lower walking speeds denoting compensation to avoid fallings, causing alterations especially in spatiotemporal variables in individuals with PD (MIRELMAN et al., 2019).

Gait speed is directly related with stride length and cadence (THOMAS et al., 2017). In individuals with PD, our systematic review with metanalysis showed that gait is performed at slower speeds through a largely lower stride length (16 centimeters) and a higher cadence (1.75 step/minutes). Our results showed that in free walking evaluations this difference is 1.86 steps/min higher in people with PD compared with control group. No differences were found when treadmill was performed, and it can be explained by the fact of small effect size and because just three included studies evaluated the cadence on the treadmill.

Therefore, the speed, stride length and cadence compensations decrease walking recovery in PD. In other words, this gait strategy adopted by PD subjects reduces the external mechanical work without changing the inverted pendulum mechanism (index of exchange between the potential and kinetic energies from the center of mass) due to shorter stride length and higher knee extension in last phase of the contact (DIPAOLA et al., 2016). Besides the knee (DIPAOLA et al., 2016), the

reduced excursion of hip plays a role on lower external mechanical work of people with PD.

The findings of double support and swing time may express gait instability in people with PD. In the Peppe's study, the higher double support time was attributed to an inability to adequately transfer weight in preparation for stepping. In addition, swing time was lower in people with PD compared with healthy control group, as a consequence of lower walking speed, lower stride length and higher cadence and double support time, resulting in reduced dynamical stability of gait in PD. In our meta-regression analysis, H&Y and UPDRS were associated with swing phase time of PD gait. As higher the H&Y values, higher the difference on swing phase between individuals with PD and healthy groups. Regarding to UPDRS, an unexpected result showed that as higher the UPDRS values, lower the difference between swing phase in PD compared with healthy groups. The H&Y and UPDRS are tools to classify the evolution of PD, and evaluators in their daily laboratory routine uses visual observations of motor symptoms qualitatively. These methods, however, do not evaluate directly walking pattern quantitatively. It may have influenced in swing phase with H&Y and UPDRS association. It has been suggested to include more sensitive measurements to associate the PD stage and their consequences on gait pattern (BLOEM et al., 2015).

Likewise, the single support and step width are associated with postural dynamic stability. A shorter time on simple support prevents the PD from staying in situations that increase the risk of falls, allowing an enhanced postural control (OWING & GRABINER, 2004). The non-difference in simple support and step width compared to healthy subjects may be explained by the lack of individuals with PD in advanced stages of the disease.

When analyzed speed by free walking and treadmill separately, the performance is remained between people with PD and control. However, in treadmill the difference between groups was lower than free walking. Nevertheless, treadmill is a safe equipment and can be used for assessing gait kinematics, though there is the necessity of individualized familiarization before conducting tests (MALATESTA, CANEPA & FERNANDEZ, 2017).

Mostly, gait alterations on people with PD occur the early disease stage, evolving from uni to bilateral alteration (MIRELMAN et al., 2019). The participants evaluated from the studies were somewhat homogeneous and, therefore resulting in

low relation between disease stage and gait performance. Future studies in this field should include advanced stages and young PD as well as analysis with ON and OFF phase of medication (MIRELMAN et al., 2019).

Angular Variables

In addition to the spatiotemporal variables, angular measurements are important to characterize the walking parameters. The pelvic rotation, tilt and lateral oscillation, knee flexion in stance phase, foot on touch down and touch off are determinants to recovery energy and avoid compensations during walking (SAUNDERS et al., 1953). The range of hip motion was reduced by 5 degrees during SSWS for individuals with PD in comparison to controls, resulting in knee and ankle compensations, such as less knee extension in stance phase (DIPAOLA et al., 2016). Additionally, there is a lower activity of *gastrocnemius medial* and higher activity of *tibialis anterior*, accompanied by a higher co-contraction of these ankle muscles during gait (MONTEIRO et al., 2017). These alterations influence in adequately transfer weight in preparation for stepping and it can reflect in the behavior of spatiotemporal variables and higher energetic cost of the gait (SAUNDERS et al., 1953; DIPAOLA et al., 2016, MONTEIRO et al., 2017).

No differences in ROM knee and ankle sagittal and in initial contact of hip, knee and ankle were found between people with PD compared with healthy control group. However, in DiPaola et al. (2016), they found that ROM knee is critical, influencing the pendular mechanism of walking. Few studies analyzed these variables therefore precluding the meta-regression analysis. The walking parameters in individuals with PD may be improved, and the variables that showed alterations in the present study should be the focus of rehabilitation and exercise interventions (SHU et al., 2014; LAHUE, COMELLA & TANNER, 2016). For example, the dance programs that combine auditory stimulus and rhythmicity with changes of direction and Nordic Walking that combine coordination and large ROM of the segments for the pole uses, both interventions have potencial to improve spatiotemporal, kinematics and energetics during gait in people with DP (SHARP et al., 2014; GOUGEON, ZHOU & NANTEL, 2017).

An important contribution of the present analysis to the literature is the comparison of gait between people of PD in ON phase medication and healthy control group, which was showed quantitatively how much the variables differ from people with PD and healthy group. It was possible to affirm that SSWS, stride length, swing time,

ROM hip sagittal are lower and cadence and double support are higher during gait in people with PD. These findings can support healthy professionals to monitor the interventions in order to improve the gait parameters.

Finally, we highlight that this is the first systematic review with sensitivity analysis and meta-regression that measured the differences in gait of people with PD compared with healthy control group. The high heterogeneity of some comparisons is a limitation of the present study. However, in general the studies showed high methodological quality. In addition, more original studies are needed to explore the possible alterations in angular parameters. Nevertheless, the present study strongly contributes to the literature regarding PD gait characteristics, addressing measures that were not yet elucidated, such as (1) speed is .17m.s^{-1} lower, (2) stride length is .16m lower, (2) cadence is 1.75 step/minutes higher; (3) double support time is 1.79% longer, (4) swing time is 1.76% lower, and (5) ROM sagittal hip is 5 degrees lower in people with PD compared with healthy control group. This review selected studies with ON phase of medication because these population usually do the daily life in this phase of medication, however, more investigations are needed to explore the role of medication on gait.

2.5 CONCLUSION

The present meta-analysis showed that people with PD have differences in gait characteristics compared with healthy control group. Different evaluation methods can influence some biomechanical parameters, though the main alterations from the PD are sensible in free and on treadmill setups. Based on our results, the subjects were homogeneous and meta-regression analysis showed that age, disease duration, H&Y and UPDRS in general, did not exerting influence over walking biomechanics.

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Conflicts of interest: The authors declare that they have no conflicts of interest relevant to the content of this review.

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Supplementary material 2.1

MOOSE (Meta-analyses Of Observational Studies in Epidemiology) Checklist

A reporting checklist for Authors, Editors, and Reviewers of Meta-analyses of Observational Studies. You must report the page number in your manuscript where you consider each of the items listed in this checklist. If you have not included this information, either revise your manuscript accordingly before submitting or note N/A.

Reporting Criteria	Reported (Yes/No)	Reported on Page No.
Reporting of Background		
Problem definition	Yes	31
Hypothesis statement	Yes	31
Description of Study Outcome(s)	Yes	31
Type of exposure or intervention used	Yes	31
Type of study design used	Yes	32
Study population	Yes	31
Reporting of Search Strategy		
Qualifications of searchers (eg, librarians and investigators)	Yes	32
Search strategy, including time period included in the synthesis and keywords	Yes	32
Effort to include all available studies, including contact with authors	Yes	33
Databases and registries searched	Yes	31
Search software used, name and version, including special features used (eg, explosion)	Yes	32
Use of hand searching (eg, reference lists of obtained articles)	Yes	35
List of citations located and those excluded, including justification	Yes	38/68
Method for addressing articles published in languages other than English	Yes	32
Method of handling abstracts and unpublished studies	Yes	33
Description of any contact with authors	Yes	33/34
Reporting of Methods		
Description of relevance or appropriateness of studies assembled for assessing the hypothesis to be tested	Yes	33
Rationale for the selection and coding of data (eg, sound clinical principles or convenience)	Yes	33
Documentation of how data were classified and coded (eg, multiple raters, blinding, and interrater reliability)	Yes	34
Assessment of confounding (eg, comparability of cases and controls in studies where appropriate	Yes	34

Reporting Criteria	Reported (Yes/No)	Reported on Page No.
Assessment of study quality, including blinding of quality assessors; stratification or regression on possible predictors of study results	Yes	33/40
Assessment of heterogeneity	Yes	34
Description of statistical methods (eg, complete description of fixed or random effects models, justification of whether the chosen models account for predictors of study results, dose-response models, or cumulative meta-analysis) in sufficient detail to be replicated	Yes	34
Provision of appropriate tables and graphics	Yes	43 to 54
Reporting of Results		
Table giving descriptive information for each study included	Yes	38
Results of sensitivity testing (eg, subgroup analysis)	Yes	40
Indication of statistical uncertainty of findings	Yes	34
Reporting of Discussion		
Quantitative assessment of bias (eg, publication bias)	Yes	54
Justification for exclusion (eg, exclusion of non–English-language citations)	Yes	54
Assessment of quality of included studies	Yes	57
Reporting of Conclusions		
Consideration of alternative explanations for observed results	Yes	58
Generalization of the conclusions (ie, appropriate for the data presented and within the domain of the literature review)	Yes	58
Guidelines for future research	Yes	58
Disclosure of funding source	Yes	58

Once you have completed this checklist, please save a copy and upload it as part of your submission. DO NOT include this checklist as part of the main manuscript document. It must be uploaded as a separate file.

Supplementary material 2.2

PubMed search

Parkinson Disease"[Mesh] OR "Parkinson Disease" OR "Idiopathic Parkinson's Disease" OR "Lewy Body Parkinson Disease" OR "Lewy Body Parkinson's Disease" OR "Primary Parkinsonism" OR "Parkinsonism, Primary" OR "Parkinson Disease, Idiopathic" OR "Parkinson's Disease" OR "Parkinson's Disease" OR "Parkinson's Disease, Idiopathic" OR "Parkinson's Disease, Lewy Body" OR "Idiopathic Parkinson Disease" OR "Paralysis Agitans")) AND (Kinematic OR "joint kinematic" OR "hip angles" OR "knee angles" OR "ankle angles" OR "stride frequency" OR "length of stride")

Supplementary material 2.3

Excluded Studies

Study	EXCLUSION JUSTIFICATION
Albani et al.(2016)	No variables
Andrew (2002)	No full text
Afsar et al.(2016)	No variables
Agosti et al.(2016)	No variables
Albani et al.(2012)	No variables
Allert et al.(2001)	OFF medication
Almeida et al.(2007)	No variables
Auvinet et al.(2014)	No variables
Azulay et al.(1996)	No full text
Barbieri et al.(2016)	No variables
Barbieri et al.(2018)	No variables
Bayle et al.(2016)	No variables
Beaulieu et al.(2018)	off medication
Bekkers et al.(2017)	No variables
Bello et al.(2008)	OFF medication
Bertoli et al.(2018)	No variables
Beuter et al.(1992)	No variables
Bjarnason et al.(2005)	No control group
Blin et al.(1990)	Pilot study
Brodie et al.(2015)	Pilot study
Bryant et al.(2015)	No control group
Buckley et al.(2008)	No variables
Cao et al.(2017)	No variables
Capato et al.(2012)	No variables
Carpinella et al.(2007)	Post DBS
Castagna et al.(2012)	No variables
Castagna et al.(2013)	No variables
Chastan et al.(2009)	No variables
Chawla et al.(2014)	No control group
Chee et al.(2009)	OFF medication
Cho et al.(2010)	No variables
Cole et al.(2011)	Duplicate data
Conradsson et al.(2017)	No variables
Costa-Ribeiro et al.(2017)	Pilot study
Cowie et al.(2012)	Post DBS
Crenna et al.(2007)	No variables
Crenna et al.(2008)	Post DBS
De Aguiar Yamada et al.(2016)	No control group
Delval et al.(2006)	No variables
Delval et al.(2008)	OFF medication
Delval et al.(2010)	OFF medication
Dibble et al.(2004)	No variables
Dietz et al.(1995)	No variables
Dipaola et al.(2016)	OFF medication
Doan et al.(2013)	No variables
Djuric-Jovicic et al.(2017)	De novo subjects
Ehgoetz Martens et al.(2015)	No variables

Ewenczyk et al., 2017	No variables
Faist et al.(2001)	Post DBS
Fernandez-del-Olmo & Sanchez (2015)	Letter
Ferrarin et al.(2002)	Pilot study
Ferrarin et al.(2004)	piloto
Ferrarin et al.(2006)	No variables
Fino et al.(2018)	OFF medication
Galli et al.(2018)	Pilot study
Galna et al.(2013)	No variables
Gilmore et al.(2015)	Post DBS
Gigot et al.(2016)	No variables
Ginis et al.(2017)	Pilot study
Grajic et al.(2015)	De novo
Halliday et al.(1998)	No variables
Hanakawa et al.(1999)	OFF medication
Harrison et al.(2018)	No control group
Hatanaka et al.(2016)	No variables
Horak et al.(2016)	No variables
Huang et al.(2012)	No variables
Hundza et al.(2014)	No variables
Huxham et al.(2008)	No variables
Jeon et al.(2008)	No variables
Johnsen et al.(2009)	Post DBS
Kemoun et al.(2003)	Another language
Kirchner et al.(2014)	No variables
Kleiner et al.(2015)	OFF medication
Kleiner et al.(2017)	No variables
Kluge et al.(2017)	No variables
Kwon et al.(2017)	De novo subjects
Knutsson (1972)	No variables
Krystkowiak et al.(2006)	Case study
Lee et al.(2012)	OFF medication
Lewek et al.(2010)	OFF medication
Lin & Wagenaar (2018)	No variables
Lin et al.(2011)	No variables
Lin et al.(2014)	No variables
Lin et al.(2016)	No variables
Luessi et al.(2012)	No variables
Magdalini et al.(2013)	Arabic
Mak et al.(2008)	No variables
Mancini et al.(2012)	OFF medication
Mancini et al.(2017)	OFF medication
Maquet et al.(2010)	No variables
Maranesi et al.(2015)	No variables
Mariani et al.(2013)	No variables
Martelli et al.(2017)	No variables
Mazzone et al.(2014)	Post DBS
McNeely & Earhart (2012)	No variables
McVey et al.(2013)	No variables
Mellone et al.(2016)	No variables
Melnick et al.(2002)	No full text
Memar et al.(2018)	No variables
Merello et al.(2010)	OFF medication
Mezzarobba et al.(2015)	No variables
Mezzarobba et al.(2018)	No variables
Mian et al.(2011)	OFF medication
Mico-Amigo et al.(2017)	Post DBS

Mirek et al.(2003)	Another language
Mirek et al.(2007)	Another language
Mitoma (1997)	Another language
Mizuno et al.(2010)	Another language
Mohammadi et al.(2015)	No variables
Moreno Catala et al.(2016)	No variables
Moreno Izco et al.(2005)	OFF medication
Morris et al.(2001)	No full text
Morris et al.(1996)	No variables
Morris et al.(1996)	No variables
Morris et al.(1998)	No variables
Murray et al.(1978)	Parkinsonism
Nanhoe-Mahabier et al.(2011)	OFF medication
Nanhoe-Mahabier et al.(2013)	OFF medication
Nardello et al.(2017)	No variables
Nieuwenhuijzen et al.(2006)	No variables
Novak & Novak (2006)	Pilot study
Otte et al.(2017)	No variables
Orcioli-Silva et al.(2018)	Essential Tremor
Paquet et al.(2003)	Another language
Pedersen et al.(1997)	No full text
Pestana et al.(2016)	No variables
Pagnussat et al.(2018)	No variables
Pasluosta et al.(2018)	No variables
Pieruccini-Faria et al.(2014)	No variables
Pieruccini-Faria et al.(2016)	No variables
Pistacchi et al.(2017)	No variables
Rahimi et al.(2013)	No variables
Ren et al.(2015)	No variables
Robles-Garcia et al.(2015)	OFF medication
Rochester et al.(2017)	No variables
Rodriguez et al.(2013)	No variables
Roemmich et al.(2013)	No variables
Rosas et al.(2015)	No variables
Rossi & Bacchini (2000)	No variables
Rosin et al.(1997)	No variables
Rossi et al.(2009)	No variables
Salarian et al.(2004)	Post DBS
Salarian et al.(2010)	OFF medication
Scandalis et al.(2001)	OFF medication
Schlachetzki et al.(2017)	No variables
Schubert et al.(2005)	No full text
Sejdic et al.(2014)	No variables
Serrao et al.(2018)	No variables
Serrao et al.(2018)	No variables
Shah et al.(2018)	No variables
Smith et al.(2013)	No variables
Shoushtarian et al.(2011)	OFF medication
Smpiliris et al.(2013)	No variables
Son et al.(2017)	OFF medication
Speciali et al.(2012)	No variables
Stathis et al.(2012)	No variables
Stegemoller et al.(2012)	No variables
Stocchi et al.(2015)	OFF medication
Suputtitada & Saguanrungsirikul (2012)	No variables
Svehlik et al.(2009)	OFF medication
Szlufik et al.(2014)	No variables
Tan et al.(2011)	No variables

Tavakoli et al.(2011)	No variables
Terashi et al.(2015)	No variables
Thaut et al.(1996)	No control group
Tupa et al.(2015)	No variables
Ueno et al.(1993)	No variables
Vacherot et al.(2010)	OFF medication
Vaillancourt et al.(2006)	Post DBS
Vallabhajosula et al.(2013)	No variables
Van Emmerik et al.(1999)	OFF medication
Van Uem et al.(2016)	OFF medication
Vercruysse et al.(2012)	OFF medication
Vervoort et al.(2015)	OFF medication
Vitorio et al.(2013)	No variables
Vitorio et al.(2014)	No variables
Vysata et al.(2013)	No variables
Vitorio et al.(2016)	No variables
Volpe et al.(2017)	No control group
Von Papen et al.(2014)	No variables
Wahid et al.(2015)	No variables
Wang et al.(2014)	Another language
Warlop et al.(2017)	Pilot study
Wells et al.(1999)	OFF medication
Wolfsegger et al.(2011)	Another language
Xia et al.(2016)	No variables
Xu et al.(2018)	Duplicate data
Young et al.(2010)	No variables
Zampieri et al.(2011)	Pilot study
Zijlmans et al.(1996)	OFF medication

CHAPTER 3

Effects of Nordic Walking on gait symmetry in mild Parkinson's disease

Abstract

Background: Individuals with Parkinson disease (PD) have asymmetric degeneration of dopaminergic nigral neurons. This characteristic may promote gait asymmetries in people with PD and exercises may reduce the differences between more and less affected side. The Nordic walking (NW) is a candidate modality that may be responsible to reduce the asymmetry in upper and lower limb movements in people with PD. We compared the effects of 11 weeks of NW training on gait symmetry in subjects with mild Parkinson's disease. **Methods:** Fourteen subjects with idiopathic Parkinson disease, age 66.85 ± 9.68 years old and Hoehn and Yard stage of 1.5 points were enrolled in this study. The kinematic analysis was performed pre and post intervention of NW. Data were collected at two randomized walking speed (.28 $m.s^{-1}$ and .83 $m.s^{-1}$) during 5 minutes on treadmill without poles. The more affected and less affected body side symmetries (lower than 5% between segments) of angular kinematics and spatiotemporal gait parameters were calculated. For statistical analysis, Generalized Estimating Equations with Bonferroni post-hoc (α= .05) were carried out. **Results**: Regarding to spatiotemporal gait parameters we did not find differences between the more affected and less affected side of the segment in the subjects with mild PD. In addition, the NW intervention was not able to make changes in the spatiotemporal gait parameters. On the other hand, maximal flexion of the knee and maximal abduction of the hip was asymmetrical pre and become symmetrical post NW intervention. **Conclusion:** We concluded that 11 weeks of NW training promoted similarities in gait parameters, and improved knee and hip angular parameters for PD subjects.

Keywords: pole walking; more affected side; symmetries; angles; spatiotemporal.

3.1 INTRODUCTION

The walking biomechanics in people with Parkinson's diseases (PD) is different compared to healthy adults. It has been observed the decrease in range of hip, knee, ankle, and trunk motion, as well as the reduction in arm swing, stride length, gait speed, the rhythmicity of gait and an increased double support time, stride to stride variability and left-right asymmetry (MORRIS et al., 2001a; FRAZZITTA et al., 2013; WILLIAMS et al., 2013; MARTINEZ et al., 2018).

The contralateral asymmetries in this population are unclear. Some authors showed that the motor dysfunction in PD is produced from an asymmetric dopamine uptake in the posterior putamen (DJALDETTI et al., 2006). Then, it was suggested that the less dopamine decrease is lateralized in substantia nigra. In addition, the greater neural loss may be in the contralateral hemisphere (DJALDETTI et al., 2006; LEE et al., 2015).

However, other studies suggested that the gait impairment may be associated with the multisystem degeneration, such as cholinergic pathway (CABELEIRA et al., 2018). Additionally, the greater gait asymmetry is associated to the chance of a person with PD develop freezing of gait (BOONSTRA et al., 2008; FRAZZITTA et al., 2013).

When comparing the movement of lower and upper limbs of PD subjects during walking, Morris et al. (2001a) demonstrated that in people with PD the tremor mainly reduced the upper and lower limbs asymmetry at higher walking speeds. Moreover, it has been suggested that there are differences in step length and support time (FRAZZITTA et al., 2013; LIN; WAGENAAR, 2018).

During gait cycle, the angular kinematic parameters, such as: shoulder and elbow movement, hip flexion and extension, pelvic rotation, knee flexion, plantar and dorsiflexion of ankle need to be coordinated to conserve energy. The preservation of the degrees of freedom of the segments demonstrates lower vibrations and lower impact forces during the gait as well as minor compensations during the task. Therefore, the symmetry during gait can assist in the lower energy expenditure (SAUNDERS et al., 1953; CAVAGNA et al., 1976; BIANCHI et al., 1998).

Aerobic exercises improve the functionality, mechanics and energetical parameters in people with PD (GOODWIN et al., 2008; SHU et al., 2014;

HUBBLE et al., 2018). In this context, Nordic Walking (NW) is an exercise that presented functional improvements in older and people with PD (CUGUSI et al., 2017; MONTEIRO et al., 2017; FRANZONI et al., 2018; GOMENUKA et al., 2019). The NW is characterized by the use of poles, that requires symmetrical and coordinated movements provided by arm participation to move the body forward (ARCILA et al., 2018). In addition, the range of upper limb motion is increased using poles (PELLEGRINI et al., 2017) changing the muscular synergies, particularly the spatial organization (BOCCIA et al., 2018) and the magnitude of activation (PELLEGRINI et al., 2015) of upper limb muscles in comparison to FW (BOCCIA et al., 2018).

Although of natural history of illness, the contralateral asymmetries are determinant in PD (MILLER et al., 1996, MARTINEZ et al., 2018, MORRIS et al., 2001b. However, the findings are controversial, for example, Delval and colleagues did not observe gait asymmetries (DELVAL et al., 2008), whereas Martinez et al. (2018) have seen that the swing time are markedly different between feet (MARTINEZ et al., 2018). The asymmetries are attributed to cardinal symptoms of PD seem to denote a natural functional dissimilarity between the limbs, particularly associated with propulsion and control tasks (SADEGHI et al., 2000). While the NW is considered as useful to functional mobility and independence for PD (MONTEIRO et al., 2017; FRANZONI et al., 2018), the potential improvement on the contralateral asymmetry after NW intervention remains unknown. Therefore, this study aimed to compare the gait symmetry of people with Parkinson's disease after 11 weeks NW training. Our hypothesis was that the differences between more affected and less affected side in the hip, knee, ankle, shoulder, elbow and spatiotemporal variables during gait, at pre-test period should be different (asymmetric). Additionally, at post test period, these differences should to decrease, resulting in a more symmetrical gait.

3.2 METHODS

3.2.1 Experimental design

This is a quasi-experimental study and was conducted in line with the protocol approved by the Ethics Committee of Research involving human beings from Universidade Federal do Rio Grande do Sul (UFRGS) (CAAE under the number: 69919017.3.0000.5347 and clinical trials ID: NCT03860649). All subjects gave their informed consent for inclusion before they participated in the study.

3.2.2 Participants

The sample selected was determined by intentional and non-probabilistic way. We included people with the diagnosis of idiopathic PD, 1 to 3 on the Hoehn & Yahr (H&Y) scale (MEHRHOLZ et al., 2016), and physically inactive at least one month. They should be in medical treatment, aged 50 to 80 years and with the ability to understand the verbal instructions to performing the tests. The participants should not have a history of Labyrinthitis, surgeries in lower limbs during the last year, making use of prostheses in the lower limbs. In addition, the participants who did the deep brain stimulation surgery, severe heart diseases or other associated neurological diseases, dementia and not having conditions of ambulation, which Montreal Cognitive Assessment (MoCA) at least 21 points were excluded (TUMAS et al., 2016). Subjects who performed on evaluation session and missed more than 75% of classes, were included in intention-to-treat analysis. In addition, only the individuals who walking independently and managed to walk without the aid on the treadmill were included.

Calculation of the sample size was carried out using the Gpower v.3.1 program and resulted in 11 participants. Values of maximal flexion of the knee and maximal abduction of the hip from the study of Ribeiro et al., (2018) were used for the calculation, with an α level of 5% and a power of 85%. A number of 14 subjects was estimated considering the possible sample losses and a good adhesion rate estimated at 70% (O'NEAL & BLAIR, 2001).

3.2.3 NW intervention

The training period had 11 weeks, with two weekly sessions (22 sessions in total). Before the training period, all participants were part of 2 weeks (4

sessions) of NW technique adaptation and 18 sessions of NW training. The volume was determined by the session time in minutes. In addition, there was a percentage of the distance covered in the six-minute walking test (6MWT), which was determined individually for each subject, from distance coefficient and predicted distance (Equation 3.1, 3.2 and 3.3) (ENRIGHT et al., 2003). In NW training, the subjects was divided in three groups, A1: those who walk at 50% of the 6MWT (coefficient less than .85), A2: those who walk at 70% of the 6MWT (coefficient between .86 and 1.2) and A3: those walking at 100% of the 6MWT (coefficient above 1.2) in the first session, and intensity was based on the subjective intensity of gait, that was comfortable, intermediate, maximal and jog. Comfortable velocity is that speed that person normally walks in the street. The intermediate velocity is the speed between the comfortable and the maximum, the maximum speed is the one that the person can walk as fast as possible without running, while the jog is the intensity in which the individuals will run for a short period of time.

$$performed\ distance\ /predicted\ distance$$

Equation 3.1

$$Man: predicted\ distance \\ (m) = 493 + (2.2\ xheight) - (.93\ xweight) - (5.3\ xage) + 17\ m$$

Equation 3.2

$$Woman: predicted\ distance(m) \\ = 493 + (2.2\ xheight) - (.93\ xweight) - (5.3\ xage)$$

Equation 3.3

The training periodization (Figure 3.1) was based on Gomeñuka et al. (2019), in figure 3.1 the number 1 represents, (comfortable), 2 (comfortable and intermediate), 2,5 (intermediate and fast), 3 (comfortable, intermediate and fast), 3,5 (intermediate and fast) and 4 (comfortable, intermediate, fast and jog) and the individual volume based on % of 6MWT. The NW training were conducted on the athletics track (400 meters) of the School of Physical Education, Physical Therapy and Dance (ESEFID) of the Universidade Federal do Rio Grande do Sul (UFRGS).

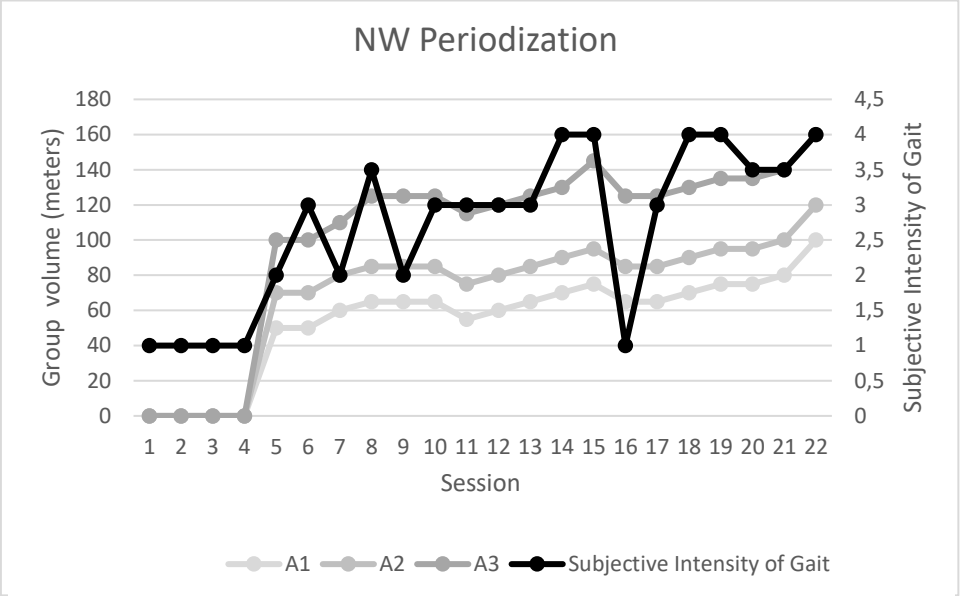

Figure 3.1 NW The graphs represent NW Periodization. In the axis of Subjective Intensity of Gait the number 1 represents, (comfortable), 2 (comfortable and intermediate), 2,5 (intermediate and fast), 3 (comfortable, intermediate and fast), 3,5 (intermediate and fast) and 4 (comfortable, intermediate, fast and jog) and on the axis of Group volume A1 are those who walk at 50% of the 6MWT (coefficient less than .85), A2: those who walk at 70% of the 6MWT (coefficient between .86 and 1.2) and A3: those walking at 100% of the 6MWT (coefficient above 1.2) in the fifth session.

3.2.4 Data collection

All procedures were carried out at the in the biodynamic sector of the Exercise Research Laboratory (LAPEX). Subjects attended three distinct moments to perform data collection. On the first day, previous evaluation of the individual was performed to verify whether it fits the eligibility criteria. After these initial procedures, the Unified Parkinson's Disease Rating Scale (UPDRS), H&Y scale and the side affected by PD were determined. Subsequently, after 10 minutes of rest, the individual was familiarized on the treadmill (INBRAMED, model ATL-Inbrasport, Porto Alegre, Brazil), for 15 minutes and Rating of perceived exertion (BORG Scale) (GOMENUKA et al., 2019).

The kinematic analysis was performed pre and post intervention of NW. The subjects walked in randomized walking speeds of .28 $m.s^{-1}$ and .83 $m.s^{-1}$ for three minutes and the kinematic data collection was performed on the last minute. The kinematic data collection was carried out by the three-dimensional motion analysis system Vicon (Vicon Motion Capture System-Oxford Instrument Group-USA, 1984), using 6 infrared cameras (100Hz, 3 cams Bonita with resolution of 1 MP, and 3 cams T10 with resolution of 1.3 MP). 35 reflective spherical markers

were placed on anatomic landmarks of interest according to the model Plug-in-Gait Full-Body. The three-dimensional reconstruction of the captured kinematic data was obtained automatically by the Vicon NEXUS® 1.8.5 software. The system captured a filming space of 4 meters wide x 6 meters long and 3.5 meters high.

3.2.5 Data analysis

The side more affected by PD was determined on the first day with motor tests presented in the UPDRS scale (RACITI et al., 2016). The kinematic analysis was performed using the Nexus software (GOMENUKA et al., 2019). The spatiotemporal variables were determined from the touch-down and take-off by ten strides in the gait cycle. The mean of ten strides were used to calculated angle and spatiotemporal outcomes. The main outcome was to compare in more affected and less affected sides, the ROM and the maximal flexion of hip, knee, ankle, shoulder and elbow (degree), and the ROM and the maximal abduction of hip and shoulder (degree), and flexion and extension maximal of Knee on first moment of contact phase (degree). The second outcome was to compare spatiotemporal variables in more affected and less affected size. The variables were stance time (s), relative stance time (%) and double stance time (s). Angles was determined by software VICON NEXUS® 1.8, that use Euler calculations, all lower and upper body angles are calculated in rotation order YXZ except for ankle Angles which are calculated in order YZX (available on Plug-in Gait Reference Guide). The data was exported from Vicon NEXUS® 1.8.5 software and processed in the LabVIEW software (National Instruments 8.5). The symmetry between the segments was considered when no statistical differences were observed in the parameters measured bilaterally (SADEGHI et al., 2000).

3.2.6 Statistical analysis

We used descriptive analysis to report the results (mean and confidence interval Wald 95%). Symmetry outcomes were analyzed in the intention-to-treat analysis. We used the Generalized Estimating Equations (GEE) to test the main effects, and Bonferroni post-hoc test was performed to identify the significant differences. The significance level adopted was $\alpha = .05$ for all tests. Effect size

(ES) was calculated and it is represented from the g de Hedges and was considered trivial (<.20), small (.20 - .49), moderate (.50 - .79), large (>.80) and too large (>1.30) it was calculated between pre and post of the affected and unaffected segments (ROSENTHAL, 1996; ESPIRITO SANTO & DANIEL, 2017). Statistical analysis was performed by a highly trained researcher who was blinded to the participants, using SPSS software (Statistical Package for Social Sciences, version 21.0).

3.3 RESULTS

A total of 14 participants with idiopathic PD were included in the study, two participants no finished the intervention. Individual characteristics of the sample is shown in the Table 3.1.

Table 3.1 Characteristics of the subjects.

Variable	Mean (Standard deviation)
Total subjects (male/female)	14 (7/7)
Gender (female/male)	7/7
Total affected segments (right/left)	14 (7/7)
Age (years)	66.85 (±9.68)
Disease duration (years)	7.28 (±5.45)
UPDRS (points)	12.21 (±6.07)
H & Y	1.50 (1-3)
MoCA	26.64 (2.17)
Lower limb lenght (m)	.89 (.05)
Body mass (kg)	64.50 (±23.46)
Height (m)	1.66 (±.86)

All results of the maximal values of joint flexion and abduction are represented in the Table 3.2. The results showed a significant difference for maximum knee flexion at speed of .28 $m.s^{-1}$. Time-condition interaction analysis ($p = .007$) showed that the improvement occurred only in the less affected limb [$p < .001$ (ES: .82)] when compared to the more affected limb (Figure 3.2A).

Table 3.2 Mean, confidence interval and statistical significance and effected size of Maximal angular of flexion and abduction more and less affected segments on .28 and .83 $m.s^{-1}$.

		Pre		Post						
		More affected	Less affected	More affected	Less affected	p-value				
	Speed ($m.s^{-1}$)	Mean (max;min)	Mean (max;min)	Mean (max;min)	Mean (max;min)	T	C	T*C	ES More affected	ES Less aaffected
Flexion										
Hip (degree)	.28	30.9 (25.2;36.5)	30.6 (26.1; 35.2)	28.5 (23.3; 33.7)	29.3 (25.2; 33.5)	.476	.855	.618	.21	.14
	.83	31.4 (26.3;36.4)	34.0 (29.52 ;38.5)	31.7 (26.5;37.0)	32.8 (29.0; 37.0)	.850	.135	.559	.03	.14
Knee (degree)	.28	49.9 (45.7;54.1)	42.3 (35.7; 49.0)	50.8 (46.2; 55.4)	52.3 (47.3; 57.3)	.012*	.236	.007*	.10	.82
	.83	54.5 (50.5; 58.5)	50.4 (44.4;56.4)	56.2 (50.9; 61.5)	59.3 (54.7;63.9)	.004*	.762	.069	.18	.80
Ankle (degree)	.28	12.3 (9.4; 15.2)	10.6 (8.5; 12.7)	10.0 (7.3; 12.6)	10.3 (8.4;12.3)	.325	.522	.313	.40	.07
	.83	9.3 (6.5; 12.2)	11.7 (8.8; 14.7)	9.5 (6.7; 12.3)	9.6 (7.4;11.9)	.433	.306	.316	.04	.39
Shoulder (degree)	.28	10.2 (5.0; 15.3)	7.5 (2.4; 12.6)	10.3 (6.1; 14.6)	7.5 (2.1;12.9)	.960	.219	.956	.02	.00
	.83	12.2 (7.3; 17.0)	8.3 (3.4; 14.0)	11.0 (5.7; 16.2)	8.9 (3.4;14.5)	.903	.163	.407	.12	.06
Elbow (degree)	.28	40.7 (36.5; 44.9)	41.9 (37.3; 46.5)	37.7 (30.2; 45.1)	43.8 (40.2;47.4)	.863	.089	.182	.24	.23
	.83	43.3 (39.1;47.4)	48.3 (44.0; 52.5)	41.3 (38.4; 44.3)	45.2 (42.6;47.4)	.197	.029*	.634	.26	.43
Abduction										
Hip (degree)	.28	1.1 (-1.9; 4.1)	7.6 (4.7;10.5)	4.00 (2.04; 5.96)	6.7 (4.7;8.6)	.329	.007*	.040*	.56	.19
	.83	2.9 (.3; 5.4)	8.7 (5.5;11.9)	4.8 (2.50; 7.02)	7.9 (5.3;10.4)	.542	.008*	.243	.38	.14
Shoulder (degree)	.28	14.0 (11.2; 16.7)	17.6 (14.4;20.7)	15.0 (10.51; 19.42)	17.5 (13.5;21.5)	.564	.213	.682	.13	.01
	.83	16.2 (13.1; 19.3)	18.5 (16.0; 20.9)	17.2 (13.93; 20.45)	17.7 (12.9;22.4)	.925	.548	.504	.15	.10

NOTE: ES : Effect size ; T: General effect of time ; C : General effect of condion ; T*C: Interation betwen time and condition *p : < .05.

In speed .83 $m.s^{-1}$, for maximal knee flexion the general effect of time was significant (p = .004) (ES: .18 in more affected and ES: .80 in the less affected side) (Figure 3.2B).

There was Time-Condition interaction in maximal hip abduction (figure 3.2C) at speed .28 $m.s^{-1}$ (p= .040). The maximal hip abduction was increased between PRE and POST conditions in both groups [p = .035 (ES = .56 more affected limb) and [p = .007 (ES: .19 less affected limb)] and the abduction of hip was different between the conditions independent of the time at the speed of .83 $m.s^{-1}$ (p = .008) (figure 3.2D).

We did not observe any significant differences for ankle and shoulder joints of individuals with mild PD (p>.05) for all conditions and interactions. Except for maximal elbow flexion at speed .83 $m.s^{-1}$ that showed difference between the conditions more affected and less affected independently of the time (p=.029), both groups decrease the elbow flexion on post time (Figure 3.2E).

The range of motion (ROM) of upper and lower limbs are represented in the Table 3.3. After NW intervention, the maximal knee flexion were increased for the both limb conditions [p = .017 (ES: .49 in more affected and ES: .67 in less affected side) at the speed .83 $m.s^{-1}$ (Figure 3.2F). In the speed .28 $m.s^{-1}$, there was no significative difference, however the effect size of the less affected side was ES:.67.

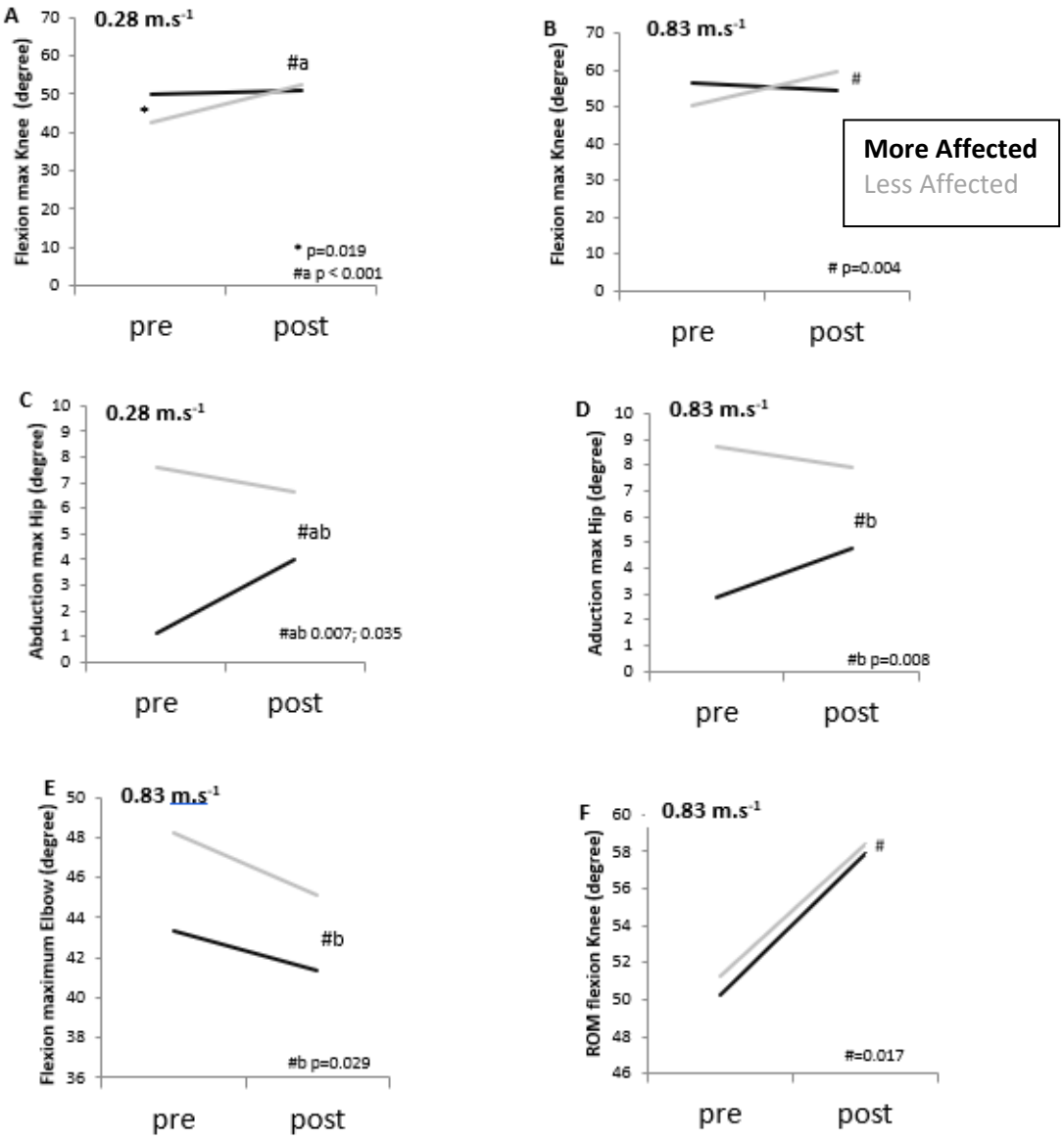

Figure 3.2 Variables for less affected (grey line) and more affected (black line) limbs, pre and post intervention at .28 m.s^{-1} and .83 m.s^{-1}.Difference between conditions on pre; **: Difference between conditions on post; #: Difference in the time; #a: Difference between pre and post in less affected side; #b: Difference between conditions independent of the time; #ab: Difference between pre and post in both groups**.**

Table 3.3 Mean, confidence interval and statistical significance and range of motion of more and less affected segments on .28 and .83 $m.s^{-1}$.

		Pre		Post						
		More affected	Less affected	More affected	Less affected	p-value				
	Speed ($m.s^{-1}$)	Mean (max;min)	Mean (max;min)	Mean (max;min)	Mean (max;min)	T	C	T*C	ES more affected	ES less affected
Sagital										
Hip (degree)	.28	33.1 (30.4; 35.7)	31.2 (28.4; 34.0)	33.0 (29.5; 36.5)	32.1 (28.7; 35.4)	.784	.283	.586	.01	.13
	.83	37.0 (32.4; 41.7)	40.0 (36.1;43.1)	39.2 (35.0; 43.3)	41.0 (37.9; 44.2)	.133	.207	.731	.24	.15
Knee (degree)	.28	46.7 (38.5; 55.0)	41.7 (34.9;48.6)	50.0 (44.2; 55.8)	50.6 (44.6; 56.5)	.072	.298	.089	.22	.67
	.83	50.2 (42.2; 58.2)	51.3 (45.2; 57.3)	57.8 (50.9; 64.8)	58.4 (53.6; 63.2)	.017*	.639	.870	.49	.67
Ankle (degree)	.28	19.8 (17.1; 22.6)	18.4 (15.8;21.1)	19.0 (16.9; 21.1)	20.3 (18.1; 22.4)	.604	.944	.147	.16	.34
	.83	25.5 (24.0 ;27.0)	24.8 (22.6;6.9)	25.8 (23.5; 28.4)	24.3 (21.3; 27.3)	.935	.255	.550	.08	.03
Shoulder (degree)	.28	15.2 (9.4;20.9)	9.5 (6.5;12.5)	14.0 (9.4; 18.6)	13.6 (8.4; 18.9)	.319	.206	.075	.11	.46
	.83	22.2 (15.6;28.8)	15.1 (11.0;19.2)	21.1 (14.7; 27.5)	18.1 (12.5; 23.7)	.697	.072	.258	.08	.30
Elbow (degree)	.28	7.6 (5.6;9.7)	6.5 (4.2;8.8)	6.6 (4.7; 8.5)	7.7 (4.5; 11.0)	.921	.993	.146	.25	.21
	.83	8.9 (6.3;11.4)	13.6 (8.8;18.5)	9.6 (6.6; 12.6)	10.3 (7.5; 13.1)	.464	.111	.078	.13	.39
Frontal										
Hip (degree)	.28	7.0 (5.7; 8.9)	7.6 (5.7;9.5)	7.7 (5.7; 9.7)	8.5 (6.9; 10.0)	.397	.217	.830	.18	.24
	.83	9.1 (7.7; 10.4)	9.8 (8.1; 11.5)	9.8 (7.2; 12.4)	11.0 (8.7; 13.3)	.448	.119	.617	.17	.28
Shoulder (degree)	.28	2.9 (1.8;4.1)	2.1 (1.4;2.9)	3.2 (1.7; 4.7)	3.00 (2.2; 3.7)	.086	.396	.315	.09	.54
	.83	4.1 (2.7;5.4)	4.0 (2.7;5.4)	4.6 (2.7; 6.4)	3.9 (2.7; 5.1)	.718	.670	.511	.18	.05

NOTE: ES : Effect size ;T: time; C: condition; T*C: Interaction time condition; max: maximum; min: minimum; *: p<.005.

The spatiotemporal variables are showed in the table 3.4. Subjects were similar with respect more and less affected size to the variable stance time when analyzed for time and condition, without interactions between the situations (p>.05). In addition, both sizes presented small effect size. When the relative stance time was measured, it was possible to observe decrease in the percentage in the speed .83 m.s^{-1}, significant differences in the general effect of time was showed (p = .009) (ES=1.01 and .72 in more affected and less affected side, respectively).

There are differences in general effect of time in the knee extension and flexion in the first phase of stance step in the .83 m.s^{-1} (p = .001 and .024 respectively) (figure 3.3A; 3.3B). There were no differences in the knee extension and flexion in the first phase of stance step in the .28 m.s^{-1}, however the effect size was moderate on the less affected side to extension and flexion (ES: .65 and .51 respectively).

The double stance (figure 3.3 C) presented significant differences between the conditions more affected and less affected segments (p=.013) only in .28m.s^{-1}. We did not observed difference to time, condition and interaction in .83m.s^{-1} (p > .05), and the ES was trivial and moderate to more affected and less affected segments, respectively.

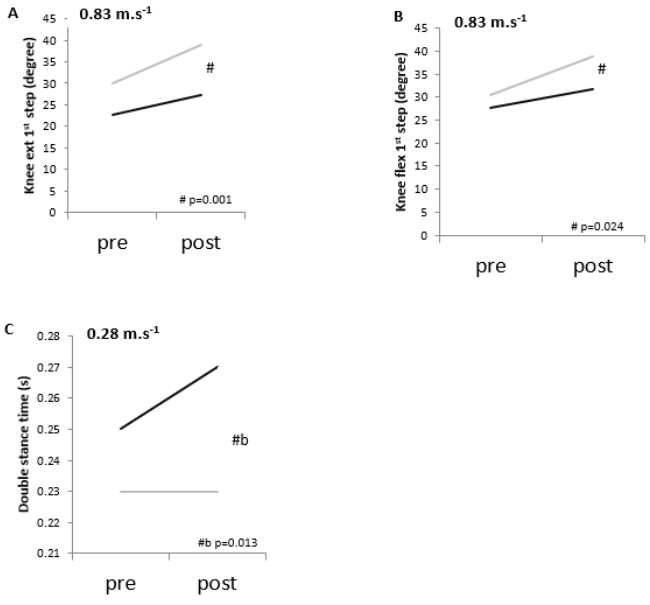

Figure 3.3 Knee range of motion in first moment of the step and spatiotemporal variables for less affected (grey line) and more affected (black line) segments pre and post intervention at .28 m.s-1 and .83 m.s-1. #: Difference in the time; #b: Difference between conditions independent of the time.

Table 3.4 Mean, confidence interval and statistical significance of spatiotemporal variables on .28 and .83 $m.s^{-1}$.

		Pre		Post						
		More affected	Less affected	More affected	Less affected	p-value				
	Speed [$m.s^{-1}$]	Mean [max;min]	Mean [max;min]	Mean [max;min]	Mean [max;min]	T	C	T*C	ES more affected	ES less affected
Stance Time [s]	.28	.91 (.82; 1.00)	.91 (.81; 1.00)	.96 (.86; 1.06)	.97 (.88; 1.06)	.217	.563	.239	.25	.37
	.83	.75 (.69; .81)	.76 (.68; .84)	.69 (.63; .76)	.71 (.64; .77)	.070	.369	.712	.46	.43
Relative Stance [%]	.27	.68 (.66; .69)	.67 (.65; .69)	.66 (.62; .71)	.67 (.64; .71)	.771	.562	.175	.29	.00
	.83	.66 (.62; .70)	.66 (.61; .72)	.59 (.57; .62)	.60 (.59; .62)	.009*	.470	.675	1.01	.72
Double stance [s]	.28	.25 (.21; .29)	.23 (.19; .26)	.28 (.22; .31)	.23 (.18; .28)	.684	.013*	.495	.23	.00
	.83	.18 (.14; .23)	.18 (.13; .23)	.20 (.06; .34)	.11 (.07; .14)	.552	.139	.209	.09	.78
Knee flex 1st [º]	.28	29.04 (19.82; 38.26)	25.75 (18.10; 33.4)	27.11 (15.66; 38.56)	35.29 (25.09; 45.49)	.124	.769	.105	.09	.51
	.83	27.72 (15.68; 39.76)	30.46 (20.93; 39.99)	31.78 (16.46; 47.10)	38.77 (25.71; 51.83)	.024*	.676	.523	.14	.35
Knee ext 1st [º]	.28	24.06 (14.89; 33.24)	21.54 (15.35; 27.73)	21.25 (10.94; 31.56)	31.44 (22.99; 39.88)	.113	.590	.051	.14	.65
	.83	22.65 (11.76; 33.53)	30.09 (21.43; 38.75)	27.29 (11.47; 43.11)	38.85 (26.97; 50.74)	.001*	.395	.519	.17	.41

NOTE: ES : Effect size T: time; C: condition; T*C: Interaction time condition; max: maximum; min: minimum; Knee flex 1st [Knee flexion in the first moment of step]; Knee ext 1st [Knee extension in the first moment of step]; *: p<.005

3.4 DISCUSSION

The main propose of this study was to compare the walking symmetry of people with Parkinson's disease after NW training. The main finding of this study were that before intervention our subjects with mild PD in general, no have differences between the more affected and less affected side of the segment. In addition, the gait parameters of the subjects were similar after the NW intervention. Our hypothesis was refuted because most movements of the walking of the people with PD are not asymmetric. On the other hand, the maximal flexion of the knee and maximal abduction of the hip were asymmetrical before the intervention. Our findings demonstrated that NW training was able to improve some of these parameters, become more symmetrical after the intervention.

In Parkinson´s disease, the basal ganglia dysfunction contributes to more significant gait disturbances and symptoms are directly associated with right or left cerebral hemisphere, mechanisms responsible for this left-right coordination are not fully understood (PLOTNIK et al., 2005; LEE et al., 2015). The study of Djaldett et al. (2006) suggested that the PD asymmetry can be explained for reduced number of neurons in one side of substantia nigra, however, the side of asymmetrical can be merely coincidental and in the early stage the degeneration is lower (DJALDETTI et al., 2006; MIRELMAN et al., 2019). In our study, the asymmetry between the sides was considered when the valued was less than 5% in the statistic test (SADEGHI et al., 2000). Probably, the general symmetry observed in the pre test seems to be explained due to mild stage (H&Y median: 1.5 points) of PD and phase of medication “ON” utilized in the present study (YOGEV et al., 2007; RIBEIRO et al., 2018). Furthermore, the disease duration is 7.3 ± 5.4 years and, at this stage of the disease the people with PD have similar likelihood of unilateral and bilateral motor impairments (SCHENKMAN et al., 2001). One important question raised by these findings is the importance of gait analysis for detecting the motor asymmetry as a screening evaluation (DJURIC-JOVICIC; BELIC, 2017; MEYER et al., 2019), given that H&Y and UPDRS scale, are not sensible to evaluate the gait asymmetry. The gait asymmetry is related to increase of freezing (PLOTNIK et al., 2005). It is important to highlight that our PD subjects did not experienced freezing of gait during walking evaluation, that reinforce the symmetry on baseline condition.

In our study, the maximum knee flexion and hip abduction at .28 $m.s^{-1}$ were asymmetric before the intervention. After intervention, both variables became symmetric. The literature shows that exercise can improve Parkinson´s gait performance (NI et al., 2018). In the study of Zhou et al. (2018) the authors observed that NW is able to increase knee power during gait, in more and less affected side. In the present study, we observed higher maximal and ROM of knee flexion in the less affected size, indicating that, may after NW intervention, the role of compensate the impaired movement were reduced in the less affected knee during the gait cycle.

In Luna et al. (2018) after treadmill training, PD subjects improve the angle of hip abduction of the dominant and non-dominant side. The higher angle of hip abduction could be explained by the higher pelvic rotation. However, no rotational movements were measured in this study (LUNA et al., 2018). Besides the improvement, the degrees were lower than healthy people that is 10 degrees (SAUNDERS et al., 1953).

The NW is an intervention where the upper and lower limbs are required, it is a rhythmic technique that stimulated the synergy of the muscle of upper limbs (DZIUBA et al., 2015). In this study, in general we did not observed differences in the parameters of upper limbs after NW intervention. Although the technique was controlled based on Arcila et al.(2018) one explanation for this result may be because the variability in the technique performance (NARDELLO et al., 2017). With this, NW was able to maintain the upper limbs parameters in people with PD.

In our study, the relative stance phase at .83 $m.s^{-1}$ was lower after NW and double contact time did not showed significant differences, however had a large effect size in .83$m.s^{-1}$ in less affected side, it is suggested that the lower relative stance phase may be attributed to the double support in the less affected size. Differently of the less affected side, in the more affected side the double support the effected size was small even with lower relative stance phase.

In this study was important to observe that less affected knee flexion and extension in the first phase of stride was significantly and moderately higher, it may represent that NW is an intervention that through of poles stimulates equal weight discharge between the lower segments, what allows more stimulus to more affected side and lower compensation in the less affected side. In this study NW improved knee ROM, flexion and extension in the first contact of the gait, in the energetic point of view it can helps to avoid reduce the energetic cost of walking (DIPAOLA et al., 2016). In

people with PD, it is important to maintain the quality of movements and conserve energy to daily functionality.

Limitations

This study has some limitations such: 1) no have a control group, 2) the control regarding to participants physical activities level on baseline (very active, active, inactive and sedentary), 3) the freezing was not evaluated, which could have aided to better detection of gait asymmetry, and 4) We evaluated the NW group without poles during the treadmill walking test. We suggest for further studies the gait asymmetry as inclusion criteria before NW intervention.

3.5 CONCLUSION

The hypothesis was not supported, our findings demonstrate that subjects with mild PD had symmetric gait before the intervention, except for hip and knee variables. NW improved these variables and the more affected and less affected side became symmetric. The improvement of the range of motion of lower limbs, such as knee and hip are important to improve the functionality of subjects with PD.

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CHAPTER 4

EFFECT OF GESTURAL SPECIFICITY PROMOTED BY NORDIC WALKING AND DANCE ON TRUNK AND PELVIS GIRDLE COORDINATION DURING WALKING IN PEOPLE WITH PARKINSON´S DISEASE

Abstract

Background: Although dance and Nordic walking promote muscle synergies altered, the effect of these interventions on walking biomechanics and coordination are unknown. Therefore, the aim of this study was to compare trunk coordination (primary outcome), mechanics (range of joint motion and spatiotemporal variables) during walking at different speeds and locomotor rehabilitation index after dance and Nordic walking (NW) interventions in individuals with Parkinson's disease (PD). **Methods:** This is a non-randomized controlled trial. Thirty-six participants with PD, were divided in three groups, dance (DG), Nordic walking (NWG) and control (CG), age between 50 to 80 years old and Hoehn and Yard 1 to 3, and the interventions were periodized and controlled. The gait and coordination parameters were determined by three-dimensional gait analysis before and after 22 sessions of interventions. **Results:** The general results observed by the Generalized Estimating Equations with Bonferroni post-hoc (α= .05) and effect sizes show that the trunk and pelvis coordination was enhanced just in NWG, particularly in the initial and final phases of contact period, while it remains unchanged in the DG. The rotation of trunk and pelvis also were maintained in both groups and the spatiotemporal parameters remain unaltered in both groups. Mostly, our results showed differences at .28m.s^{-1} and fast speeds. **Conclusion:** Our findings demonstrate that the biomechanics of complex trunk-pelvis was improved in both interventions. Nevertheless, the NW physical training was able to change the coordinative pattern in people with PD.

Keywords: biomechanics, coordination, speed, gait, neurodegenerative disease.

4.1 INTRODUCTION

The human walking is characterized by repetitive movements of limbs an trunk resulting in a relatively low energy expenditure (SAIBENE & MINETTI, 2003). Some movement patterns of pelvis and lower limbs are determinants of the gait, denoting in an effective and energetically efficient mode of locomotion (SAUNDERS et al., 1953). Besides adequate range of trunk and lower limb motions, the coordination between the segments and girdles is an important aspect of functionality. During walking, the axial coordination between trunk and pelvis plays a role on the body stability during locomotion reducing the risk of falls in individuals with PD (VAN EMMERIK, HAMILL & MCDERMOTT, 2005).

The trunk and pelvis coordination are impaired in older than young individuals. Van Emmerik, Hamill and Mcdermott (2005) observed that young people rotate the at transverse plane most predominant than trunk, and the intergirdle coordination is out of phase. Conversely, in older individuals, the trunk rotation is most predominant than pelvis girdle and the intergirdle coordination is in-phase (VAN EMMERIK, HAMILL & MCDERMOTT, 2005).

In neurological disease, such as Parkinson Disease (VAN EMMERIK et al., 1999) the gait speed and range of limb motion are reduced accompanied by an increased anterior flexion of trunk, greater rigidity and lower pelvis and trunk rotation at transverse plane. Also, the intergirdle coordination is more in-phase than age-matched controls (VAN EMMERIK et al., 1999).

Van Emmerik et al. (1999) showed that in subjects with early diagnostic of PD in OFF period of medication, the continuous relative phase (CRP) between trunk and pelvis was lower than in healthy matched control subjects, reducing also the variability of CRP suggesting a lower resilience/flexibility on the coordinative system during gait in this population (VAN EMMERIK et al., 1999). The CRP variable is the angular variation between two segments or girdles and represents coordination. Varying values denoting an out of phase coordination whereas constant values denoting an in-phase coordination (VAN EMMERIK et al., 1999; LAMB & STÖCKL, 2014; PRINS et al., 2019). The variability of CRP is, in turn, the capacity of the system to adapt to different stimulus representing a sort of resilience or flexibility of the coordinative system (VAN EMMERIK, HAMILL & MCDERMOTT, 2005).

The coordination of trunk and pelvis girdles can affect the functionality, impacting the gait speed, stride length, and the risk of falls, and, consequently, decreasing the independence in this population (PETERSON & HORAK, 2014; MONTEIRO et al., 2017a). Van Emmerik et al. (1999) suggested that, can be relevant to evaluate the coordination of trunk and pelvis of PD after exercise interventions in order to improve the CRP. Recently, one parameter based on self-selected walking speed and lower limb length is the Locomotor Rehabilitation Index (LRI), one simple and useful method to evaluate the rehabilitation level of the intervention informing how much the mechanics and energetics is far from the optimal conditions (PEYRÉ-TARTARUGA & MONTEIRO, 2016; PEYRÉ-TARTARUGA & COERTJENS, 2018).

It has been extensively discussed in the last years the benefits of exercise in terms of motor and non-motor symptoms in individuals with PD (SHU et al., 2014; WU et al., 2016; MAK et al., 2017). Dance and Nordic Walking are activities that can improve gait characteristics in people with PD, promoting social contact to their practitioners (SHU et al., 2014; MONTEIRO et al., 2017b).

The dance interventions in people with PD have analyzed predominantly non-motor symptoms and functional parameters. And, the most common modality of dance found is on Tango (SHU el al., 2014; MCNEELY et al., 2015; DE NATALE et al., 2017; DOS SANTOS et al., 2018). In Brazil, the Forró and Samba are very popular and common modalities of dance characterized by a intense rhythm (TILLMANN et al., 2017). The study of Tillmann et al. (2017) applied samba in individuals with PD, without analysis, however, on walking biomechanics. Currently, one unique study was found that evaluated the gait in individuals with PD after dance intervention, analysing spatiotemporal variables (SOWALSK et al., 2017).

From a neurological point of view, ballroom dancing has potential to improve axial rotation coordination of trunk and pelvis in people with PD due to the auditory stimulus coming from the music, changes of directions and transversal movements promotiong additional benefits to the motor neurons, improving balance, coordination, rhythm, synchrony and spatial sense (FONSECA et al., 2014; SHARP; HEWITT, 2014; SHANAHAN et al., 2015). In addition, dance is an acyclic activity that encourage postural extension, body turning, balance and changes of directions, with high potential to PD walking (HULBERT et al., 2017). The study of Hulbert et al. (2017) showed that after dance classes, the analysis of dance turning was more “en-bloc” in people with PD.

Not only dance, but also NW is an intervention that shows potential to improve the gait in people with PD. This intervention uses poles during walking, and the practitioner need to propel the poles against the ground and demands contralateral coordination of upper and lower limbs (MONTEIRO et al., 2017b; GOMENUKA et al., 2019). This is a rhythm and synchrony activity (NARDELLO et al., 2017). The correct technique is characterized by the subject keep looking forward, with erect trunk, small anterior inclination, slight elbow flexion, hands semi-open and poles diagonally (NARDELLO et al., 2017). The NW has potential to improve trunk stability, coordination of segments and spatiotemporal variables of walking in people with PD (GOUGEON, ZHOU & NANTEL, 2017; WARLOP et al., 2017).

In this context, the first aim of this study was to compare the intergirdle coordination (trunk and pelvis) during walking at different speeds in individuals with PD after dance and NW interventions. The second aim of this study was to compare ROM sagittal, frontal and transverse of trunk and pelvis during walking. The third aim was to compare spatiotemporal, self-selected walking speed (SSWS) and LRI walking of subjects with PD after dance and NW interventions. In addition, all variables of both groups were compared with control group.

Our first hypothesis is that coordination of trunk and pelvis girdle rotations, ROM transverse of trunk and pelvis should be higher after interventions when compared with control group and higher in dance group than Nordic walking group. Our second hypothesis is that ROM sagittal and frontal of trunk and pelvis during walking analysis should be higher in the interventions when compared with control group and higher in Nordic walking than dance group. And our third hypothesis is that spatiotemporal parameters, SSWS and LRI walking should be higher in the interventions when compared with control group and higher in Nordic walking group than dance group. In addition, we hypothesized that in SSWS and fast speeds the subjects will be more coordinated of axial trunk and pelvis rotations during walking analysis.

4.2 METHODS

4.2.1 Experimental design

This is a non-randomized controlled study. The protocol was approved by the Ethics Committee of Research involving human beings from Universidade Federal do

Rio Grande do Sul (UFRGS) (CAAE under the number: 69919017.3.000.5347 and clinical trials ID: NCT03860649). All subjects gave their informed consent for inclusion before they participated in the study (Supplement material 4.1). The structure of CONSORT check list was followed (Supplement material 4.2).

4.2.2 Participants

We recruited an intentional and non-probabilistic sample. The people with PD were 1 to 3 from the Hoehn & Yahr (H&Y) scale (MEHRHOLZ et al., 2016), and physically inactive at least for one month (Supplement material 4.3). They should be in medical treatment, with the regular use of Parkinson´s disease control medications, aged between 50 to 80 years and with the ability to understand the verbal instructions for performing the tests, with Montreal Cognitive Assessment (MoCA) attaining at least 21 points (TUMAS et al., 2016). We excluded people who showed labyrinthitis history, surgeries during the last year, making use of prostheses in the lower limbs, people with deep brain stimulation surgery, severe heart diseases, other associated neurological diseases, dementia or not having conditions of ambulation. Individuals who lacked any of the assessments were excluded (MONTEIRO et al., 2017b; FRANZONI et al., 2018). Subjects that did not meet the requirements were excluded and who performed the evaluation and were adherent in more than 75% of classes, was included in intention-to-treat analysis. In addition, only the individuals who walking independently and managed to walk without the support of the hands on the treadmill were included.

The subjects were separated in Nordic walking (NWG) and dance group (DG) by preference. The control group (CG) was composed by people who not participated of any interventions, they were evaluated before and after the interventions and they were invited to participate of the activities in the next semester. The study was disclosed by extension groups that work with PD people at Universidade Federal do Rio Grande do Sul (UFRGS) and by internet and through posters, movies, social medias (@PPT Parkinson UFRGS) (Supplementary material 4.4).

4.2.3 Subjects allocation

The sample size was determined based on Castagna et al., (2016), Gougeon and Nantel (2017) and Hulbert et al. (2017). The sample calculation was performed based on the mean and the standard deviation of ROM trunk and pelvis at dance and NW participants. The calculation was performed using G-Power software (version 3.0),

which used a power of .95 (significance level of .05 and correlation coefficient of .5). Based on the standard deviations and the differences between the means, the calculation performed evidenced the need for an "n" of 27 individuals for the variable ROM trunk horizontal, with this it is necessary 9 individuals in each group. Considering the possible sample losses and a good adhesion rate estimated at 70% (O'NEAL & BLAIR, 2001), the estimated n was 12 people for each group (Supplement material 4.5).

The distance performed in 6MWT was used to allocate the subjects in the interventions. An independent evaluator allocated the individual according to the distance performed in the 6MWT.

4.2.4 Data Collection

Subjects attended three distinct visits to perform data collection and 11 weeks to attend the interventions. The assessments were conducted in the biodynamic sector of the Exercise Research Laboratory from UFRGS. All the data collection occurred on the morning, between 8 and 11 a.m., in ON phase at Parkinson´s disease medication. On the first day, previous evaluation of the participant was performed to verify whether it fits the eligibility criteria and all procedures performed during the research were explained. After these initial procedures, the Unified Parkinson's Disease Rating Scale (UPDRS) (Supplement material 4.6), H&Y, 6MWT were performed to control the group that subjects was allocated. The 6MWT was performed following the guidelines of the American Thoracic Society (2002). Subsequently, after 10 minutes of rest, the individual was familiarized on the treadmill (INBRAMED, model ATL-Inbrasport, Porto Alegre, Brazil) and they were informed of the safety mechanism present on the equipment. The subjects walked on the treadmill at different speeds (with a gradual increase or decrease of .5 $km.h^{-1}$) to determine SSWS (MONTEIRO et al., 2017b), also fast speed, higher than SSWS was determined (it was considered fast speed the one they could walk without holding their hands on the treadmill).

For measurement of axial coordination of trunk and pelvis rotation, ROM and spatiotemporal variables during gait, the kinematic analysis was performed. For this, in the second day, for three-dimensional (3D) reconstruction, there was measured body mass (kg), height (cm), length of the lower limbs (mm), distance between the femoral condyles (mm), distance between the malleolus (mm), distance between the epicondyles (mm), distance from the tuber of the escafoid bone to the pisiform bone

(mm). The subjects walked in .28 m. s^{-1}, .83 m. s^{-1}, SSWS and in fast speed upper SSWS, the velocities were randomized. They rested for three minutes or until heart rate measured less than 100 bpm. They are walking for three minutes at each speed and the kinematic data collection was performed on the last minute. In the third day, after 11 weeks of interventions the same procedure was performed (Figure 4.1).

The kinematic data collection was carried out by the three-dimensional motion analysis system VICON NEXUS® (Vicon Motion Capture System-Oxford Instrument Group-USA, 1984), using 3 cams Bonita with resolution of 1 MP, and 3 cams T10 with resolution of 1 MP, with frequency of Sampling of 100 Hz. The system captured a filming space of 4 meters wide x 6 meters long and 3.5 meters high. The cameras recorded the kinematics of 35 reflective spherical markers were placed on anatomic landmarks of interest according to the model Plug-in-Gait Full-Body. In Figure 4.2 A represents all the marques used to reconstruct 3D gait analysis and Figure 4.2 B represents trunk and pelvis segments used in data collection.

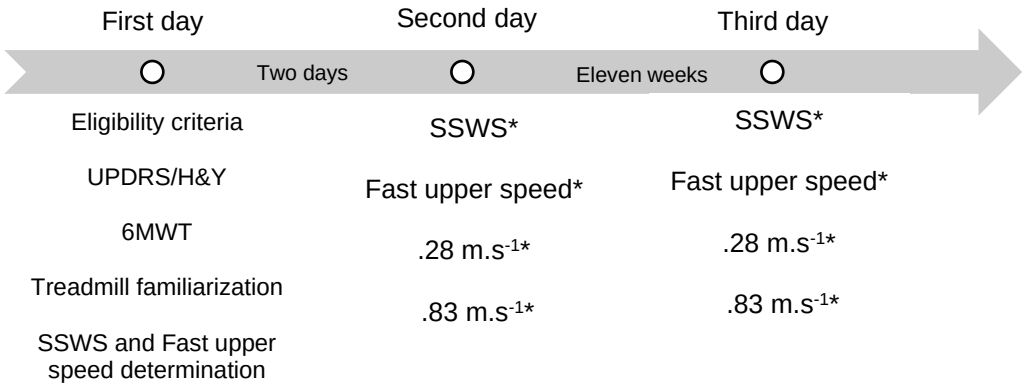

Figure 4.1 Study experimental design.

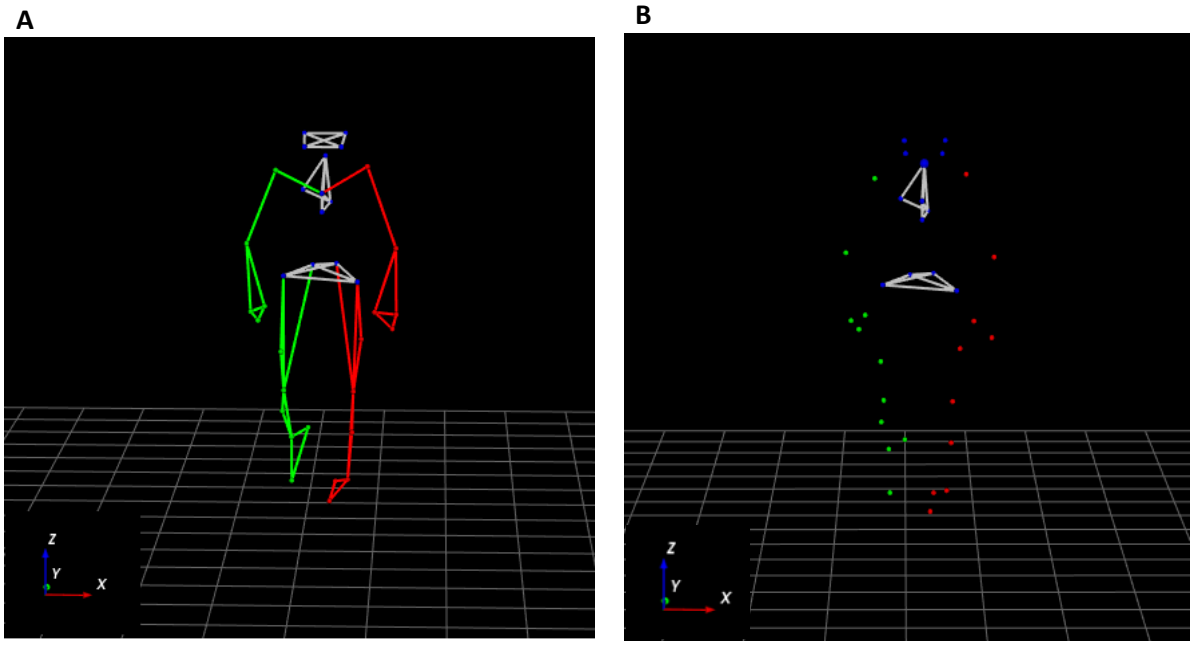

Figure 4.2 A: Reconstruction of 3D Plug-in-Gait Full-Body **B**: Representation of trunk and pelvis

4.2.5 Interventions

Dance: The dance program consists of dance classes inspired in Forró rhythm and Samba rhythm. The dance sessions were at 9 a.m., twice a week, lasting 60 minutes, for 11 weeks, totaling 22 sessions (4 familiarization, 9 lessons inspired in Forró rhythm and 9 lessons inspired in the Samba rhythm). The familiarization sessions were to subjects learn the basic steps of the Forró and Samba rhythm. The 22 dance sessions were divided into four stages described in table 4.1. And the training was controlled by intensities and volume (Supplementary material 4.7).

Table 4.1 Parts of dance class structure.

Class Parts	Time	Objetive
Part 1	15 minutes	Joint warming and sensitization of the body through the touch, with the support of chairs.
Part 2	10 minutes	Balance and rhythm with the support of the bar.
Part 3	10 minutes	Exercises in front of the mirror with shifts in the room, inspired by the genres Forró and Samba and exploration of the movements in the rhythm of music.
Part 4	25 minutes	Rhythmic works that stimulate displacement, motor coordination, rhythm, and creativity. Final relaxation.

NOTE: Adapte from NOGUEIRA, DOS SANTOS, GIMENES (2018).

The training volume was determined by the total session time and the 6MWT. Differently than in the NW, in the dance was measured the average of the 6MWT of the participants and from this, was determined how many steps on average all the students danced by class. The intensity of the classes was measured according to the beats per minute (BPMs) of the songs. The songs had different intensities: comfortable (76 a 108 bpm), intermediate (108 a 120 bpm), fast (120 a 168 bpm) and maximum (168 a 200 bpm). In the figure which are represented by 1 (comfortable), 2 (comfortable and intermediate), 2,5 (intermediate and fast), 3 (comfortable, intermediate and fast), 3,5 (comfortable and fast) and 4 (comfortable, intermediate, fast and maximum).

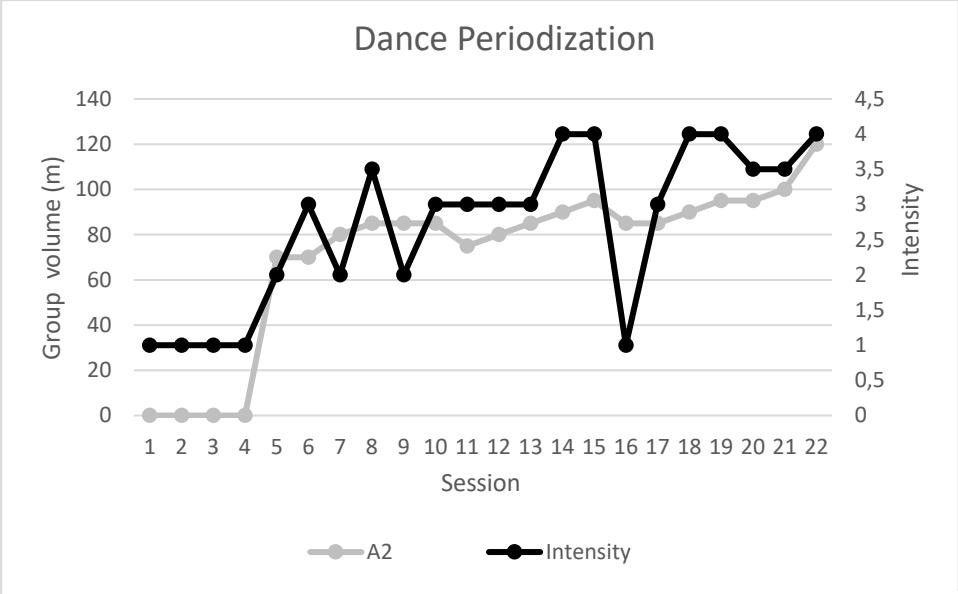

Figure 4.3 The graphs represent dance Periodization. In the axis of Subjective Intensity of Gait the number 1 represents, (comfortable), 2 (comfortable and intermediate), 2,5 (intermediate and fast), 3 (comfortable, intermediate and fast), 3,5 (intermediate and fast) and 4 (comfortable, intermediate, fast and maximum) and on the axis of Group volume A2: those who walk at 70% of the 6MWT (coefficient between .86 and 1.2).

Although different interventions, both were performed in group, in the same time and were periodized, the particularities of each intervention were respected. Therefore, in NW the training volume was defined by the total time of the session and the intensity was based on the person subjective perception of the gait. That was comfortable, intermediate, maximum and trot, an individual distance was determined per participant

according to 6MWT. While in dance, the volume was defined by the total session time that is the same between the interventions. In addition, the overall average of the distance did in the the class was calculated on 6MWT and the intensity was based in the different bpms of the songs. Both interventions had the loads controlled by the subjective perception of BORG scale (FOSTER et al., 2001).

NW: The volunteers trained in the period of 11 weeks, twice a week, totaling 22 sessions (4 familiarization and 18 training) at 9 a.m., in ON phase of medication. The sessions lasted 60 minutes. In the familiarization sessions the objective was the learning of the Nordic Walking Technique (ARCILA et al., 2018; GOMENUKA et al., 2019) and the training were controlled by intensities and volume (Supplementary material 4.8). The structure of the NW class is in table 4.2.

Table 4.2 Parts of NW class structure

Class Parts	**Time**	**Objetive**
Part 1	5 to 10 minutes	Joint warming
Parte 2	40 to 50 minutes	Walk with the distance and speed that will be determined in the periodization.
Part 3	5 to 10 minutes	Stretching of trunk, upper and lower limbs.

Training volume was determined by total session time and in addition, there was a percentage of the distance covered in the 6MWT, which was determined individually for each subject, from distance coefficient and predicted distance (Equation 4.1, 4.2 and 4.3) (ENRIGHT et al., 2003). In NW training the subjects was divided in three groups, A1: those who walk at 50% of the 6MWT (coefficient less than .85), A2: those who walk at 70% of the 6MWT (coefficient between .86 and 1.2) and A3: those walking at 100% of the 6MWT (coefficient above 1.2) in the first session.

$$performed\ distance\ /predicted\ distance$$

Equation 4.1

$$Man: predicted\ distance\ (m) = 493 + (2.2\ xheight) - (.93\ xweight) - (5.3\ xage) + 17\ m$$

Equation 4.2

$$Woman: predicted\ distance\ (m) = 493 + (2.2\ xheight) - (.93\ xweight) - (5.3\ xage)$$

Equation 4.3

The intensity was determined based on the person subjective perception of gait. That was comfortable, intermediate, maximum and jog. Comfortable speed is that speed that person normally walks in the street. The intermediate speed is the speed between the moderate and the maximum, the maximum speed is the one that the person can walk as fast as possible without running, while the jog is the intensity in which the individuals will run for a short period of time. In figure 4.4 is represented NW periodization sessions, intensity represented by 1 (comfortable), 2 (comfortable and intermediate), 2,5 (intermediate and fast), 3 (comfortable, intermediate and fast), 3,5 (comfortable and fast) and 4 (comfortable, intermediate, fast and jog) and the individual volume based on % of 6MWT.

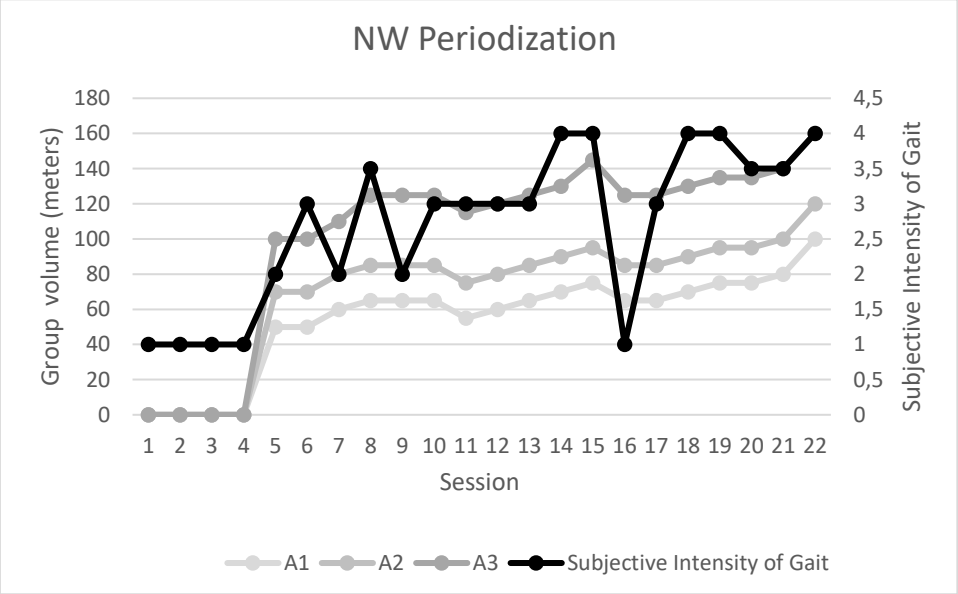

Figure 4.4 The graphs represent NW Periodization. In the axis of Subjective Intensity of Gait the number 1 represents, (comfortable), 2 (comfortable and intermediate), 2,5 (intermediate and fast), 3 (comfortable, intermediate and fast), 3,5 (intermediate and fast) and 4 (comfortable, intermediate, fast and jog) and on the axis of Group volume A1 are those who walk at 50% of the 6MWT (coefficient less than .85), A2: those who walk at 70% of the 6MWT (coefficient between .86 and 1.2) and A3: those walking at 100% of the 6MWT (coefficient above 1.2) in the fifth session.

4.2.6 Data analysis

The ROM angles of trunk and pelvis was determined by software VICON NEXUS® 1.8, that use Euler calculations (as Euler angles are calculated, each rotation causes the axis for the subsequent rotation to be shifted. X' indicates an axis which has been acted upon and shifted by one previous rotation, X'' indicates a rotation axis

which has been acted upon and shifted by two previous rotations). All lower and upper body angles are calculated in rotation order YXZ except for ankle Angles which are calculated in order YZX (available on Plug-in Gait Reference Guide).

For the calculation of the continuous relative phase angle was necessary four steps: 1) transform the amplitude of the data around zero; 2) calculation of the Hilbert equation to transform a real number to number Complex; 3) Perform the division of the complex number by the actual number; and 4) calculate the arc tangent for each segment. The CRP of the trunk and pelvic is given by subtracting one arch tangent by the other, the result will be in degrees (LAMB & STÖCKL, 2014). The CRP was calculated on gait cycle (stride) (VAN EMMERIK et al., 1999) and contact phase of the gait, it was divided into four functional periods that were defined as from 0-20% of contact (loading response), 20-50% contact (mid- contact), 50-80% contact (terminal contact), and 80-100% contact (push-off), respectively (CORNWALL, JAIN & HAGEL, 2019).

White phase difference angle was calculated by the equation $360°(tpelvis - ttrunk)/stridetime$ (DA ROSA, 2017). The variability of the CRP was determined by the equation $standarddeviation/\ average * 100$, and it was calculated to CRP stride and CRP contact (VAN EMMERIK et al., 1999). The spatiotemporal variables was determined by $speed = stridelenght * stridefrequency$, the stance phase time was determined by touch off minus touch down. The LRI was determined by $\frac{VAS}{OWS} * 100$ (PEYRÉ-TARTARUGA; MONTEIRO, 2016), OWS is consider the optimal walking speed, OWS was calculated by OWS: $\sqrt{0{,}25\ .\ g\ .\ l}$, *g* is the gravity and *l* is the length of the lower limb, that was obtained by measuring the greater trochanter of the femur to the ground in the orthostatic position).

All the calculus was made by a mathematical routine built in the Labview software (National Instruments 8.5) (Supplement material 4.9). Before to processing the data, it was applied the 3-order, low-pass Butterworth digital filter and the cut off frequency was defined by residual analysis.

4.2.7 Statistical analysis

The data is showed in descriptive measures, using means, standard deviations for continuous measurements and median to categorical measurements. The Shapiro Wilk was applied to check the normality of the sample, ANOVA one way was used in

continuous parametric variables and Kruskal Wallis was used to continuous non-parametric and categorical variables to calculate the baseline groups differences. The outcomes were analyzed using the generalized estimates equations (GEE), with the comparison between the groups (DG, NWG and CG) between the moments (pre and post training). Intention-to-treat analysis was made. The SSWS and the Fast speed was considered co-variables. The Bonferroni post-hoc test was used to identify the differences between effects and interactions. The effect sizes (ES) was calculated from post test between dance and control group and between NW and control group, for CRP stride, CRP stride variability, CRP contact, CRP contact 0-20; 20-50; 50-80, 80-100%, CRP contact variability and CRP contact variability 0-20;20-50;50-80;80-100%, ROM sagittal, frontal and transverse trunk and pelvis and spatiotemporal variables from interventions between control group. It is represented from the g de Hedges and was considered trivial (<.20), small (.20 - .49), moderate (.50 - .79), large (>.80) and too large (>1.30) (ROSENTHAL, 1996; ESPIRITO SANTO & DANIEL, 2017), and the alpha is equal to .05. For statistical data treatment, the SPSS (Statistical Package for the Social Sciences), version 21.0 was used.

4.3 RESULTS

Although this study started with 36 participants (dance=15, NW=15 and control=6). Thus, 28 participants finished the interventions and completed all assessments, 8 participants did no completed the study. However, baseline data was used to intention to treat (Figure 4.5). Moreover, some data has been lost during data analysis and the sample size number of Phase difference and CRP variability varied and the exact number are showed in the Figures 4.10 and 4.11 On DG the adherence was 86% and NWG the adherence was 88%. The groups were homogeneous and baseline characteristics of the sample are presented in table 4.3. The SWSS and fast speed were considered covariables during statistical analysis, and during GEE analysis covariables fixed SWSS on .81 $m.s^{-1}$ and fast speed on 1.17 $m.s^{-1}$.

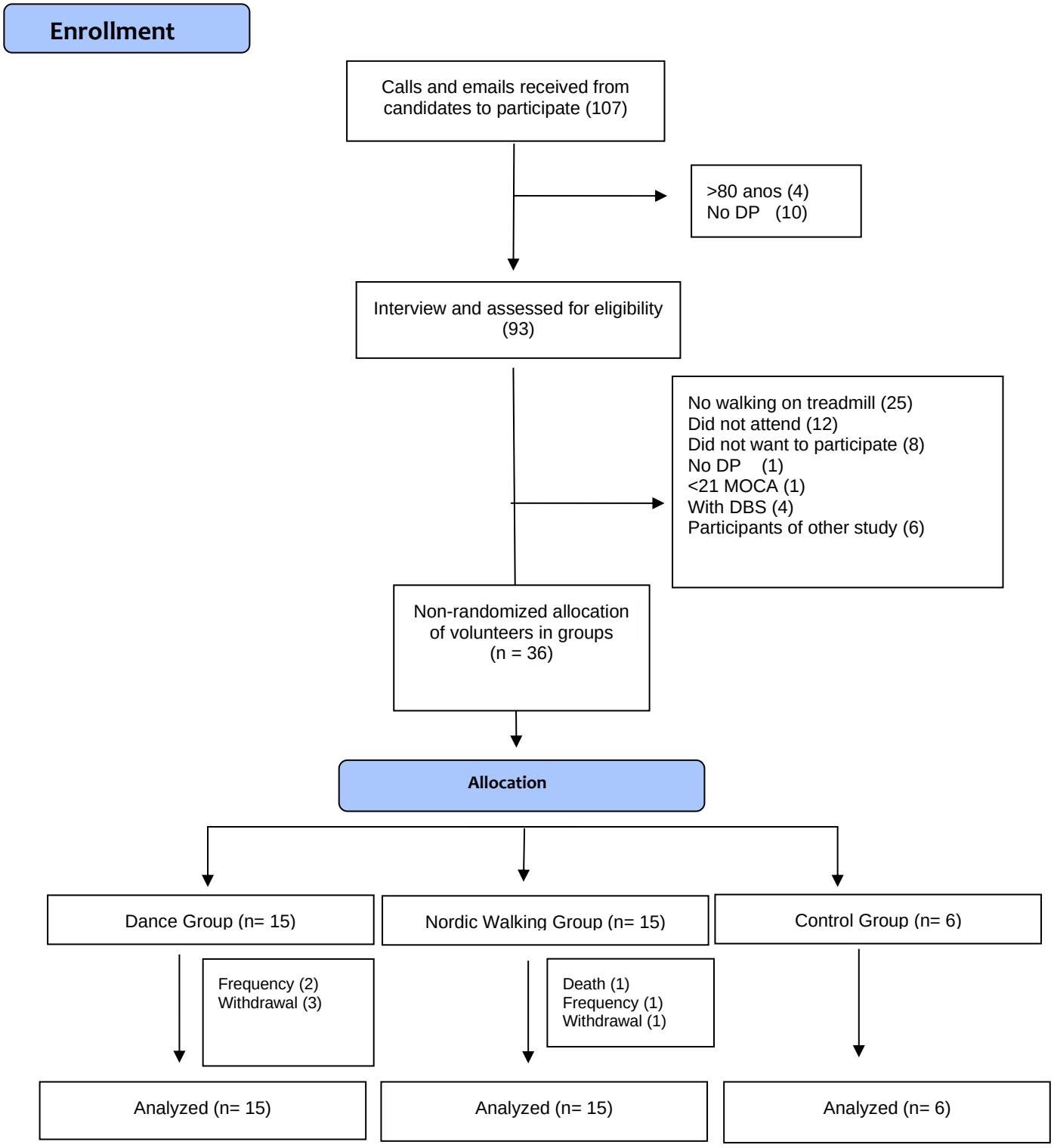

Figure 4.5 Flow Diagram of the study allocated participants.

Table 4.3 Mean, standard-deviation and statistical significance of Baseline characteristics of the Dance (DG), Nordic Walking (NWG) and Control (CG) groups.

	DG (n=15)	**NWG (n=15)**	**CG (n=6)**	***p value***
Age (years)	65.87(6.50;71.23)	66.53(61.32;71.75)	7.40(59.00;81.80)	.561
Body mass (kg)	7.13(64.62;75.65)	78.73(69.78;87.69)	63.20(55.89;7.51)	.070
Height (m)	1.65(1.60;1.70)	1.66(1.62;1.71)	1.60(1.54;1.67)	.634
Gender(female/male)	10/5	7/8	5/1	.262
Lower limb lenght (m)	.90 (.87;.90)	.89 (.86;.92)	.88 (.85;.90)	.756
Disease duration (years)	6.93(2;15)	7.47(2;18)	6.60(2;15)	.859
UPDRS (points)	12.67(9.69;15.64)	12.27(9.02;15.51)	8.80 (4.93;12.67)	.382
H&Y (points)	2 (1;3)	2 (1;3)	1 (1;3)	.239
MoCA (points)	24 (21;28)	27 (21;29)	25 (23;28)	.107
6MWT predicted (m)	457.13(423.62;49.64)	438.80(41.43;467.17)	426.20(35.17;502.23)	.501
6MWT measured (m)	485.93(449.04;522.83)	472.40(419.73;525.07)	482.40(376.06;588.74)	.797

Coordination variables

In general, CRP stride did not show significance differences between the groups and time (p>.05). On .28 $m.s^{-1}$ the CRP stride did not demonstrated significance difference between the time and groups [p=.460 (ES: .43; .35 DG and NWG, respectively)]. The mean of DG at pre was [.008° (CI 95%: -.012;.029)] at post was [.012° (CI 95%: -.012;.037)] (Figure 4.6 A;B). In NWG the mean at pre was [-.002° (CI 95%: -.006; .001)], at post was [.069° (CI 95%: -.053;.192)] (Figure 4.6 C;D). In CG the mean at pre was [.001° (CI 95%: -.002;.003)], at post was [-.002° (CI 95%: -.004; -.001)] (Figure 4.6 E;F).

The results of CRP stride in SSWS did not demonstrate significance difference between the time and groups [p=.617 (ES: .001; .28 DG and NWG, respectively)]. The mean of DG at pre was [-.004° (CI 95%: -.012;.004)] at post was [-.001° (-.007;.007)] (Figure 4.7 A;B). In NWG the mean at pre was [-.002° (CI 95%: -.014; .008)], at post was [.004° (CI 95%: -.002;.012)] (Figure 4.7 C;D). In control group the mean at pre was [.001 (CI 95%: -.004;.006)], at post was [-.001° (CI 95%: -.007; -.006)] (Figure 4.7 E;F).

The results of CRP stride in .83 $m.s^{-1}$ did not express significance difference between the time and groups [p=.429 (ES: .67; .11 dance and NW, respectively)]. The mean of DG at pre was [-.008° (CI 95%: -.020;.005)] at post was [-.002° (-.007;.003)] (Figure 4.8 A;B). In NWG the mean at pre was [-.003° (CI 95%: -.010; .004)], at post was [.003° (CI 95%: -.006;.001)] (Figure 4.8 C;D). In control group the mean at pre

was [-.010 (CI 95%: -.032;.013)], at post was [-.055° (CI 95%: -.146; .035)] (Figure 4.8 E;F).

The results of CRP stride in fast speed did not express significance difference between the time and groups [p=.637 (ES: .01; .25 dance and NW, respectively)]. The mean of DG at pre was [-.009° (CI 95%: -.033;.014)] at post was [-.001° (-.029;.027)] (Figure 4.9 A;B). In NWG the mean at pre was [-.004° (CI 95%: -.025; .016)], at post was [.079° (CI 95%: -.064;.223)] (Figure 4.9 C;D). In control group the mean at pre was [-.020 (CI 95%: -.048;.007)], at post was [-.003° (CI 95%: -.017; .010)] (Figure 4.9 E;F).

The CRP contact did not show difference in .28m.s^{-1}, SSWS, .83m.s^{1} and fast speed, however showed small to moderate effect size to both interventions [p>.05 (ES:.14 to .74)] (Table 4.4). The results showed interaction between time and group on CRP 0-20% of contact in .28 m. s^{-1} (p:.001), however Bonferroni post hoc no presented significant differences between the groups on pre and post time and showed small effect size [p>.005 (ES:.34; .30 dance and NWG)], respectively). The Time-group interaction analysis showed a significant difference in CRP mean 80-100% contact in .28 m.s^{-1} with large and too large effect size [p:.026 (ES:1.42 and .84 dance and NW, respectively)]. Bonferroni post hoc showed that NWG increase CRP mean 80-100% of contact pre to post test (p:.040), and NW had a higher CRP mean 80-100% of contact than control group on post test (p:.021). The other variables did not have time-group interaction or time significative differences and the effect size was small. The CRP mean 80-100% of SSWS and Phase difference on fast speed are different between the groups, independently of the time (p<.05). Phase difference also did not showed differences between time and groups and in general the effected size was between small and moderate in both groups [p>.05 (ES:.17 to .80)] (Table 4.4). The individual values of phase difference in .28 m.s^{1}, SSWS, .83m.s^{-1} and fast speed are represented on figure 4.10.

Table 4.4 Mean, confidence interval and statistical significance of coordinate variables in angles of contact, parts of contact and phase difference pre and post test in dance, Nordic walking and control group at different speeds.

		Dance Group (n = 15)		Nordic Walking Group (n = 15)		Control Group (n = 6)				
S	Variable	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Group**	**Time**	**Group*Time**
		Mean (CI 95%)	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**			
.28 m.s^{-1}	CRPcontact	- .25(-.42;-.07)	-.15(-.54;-.22)	-.35(-.55;-.16)	-.43(0-.65;-.20)	-.21(-.42;-.01)	-.26(-.38;-.13)	.313	.912	.750
	CRP0-20%	.58(.23; 1.44)	.22(.10;.50)	.12(.05;.26)	.50(.27;.95)	.36 (.18; .71)	.32(.27;.38)	.465	.765	.001
	CRP20-50%	-.46(-.96;.03)	-.42(-1.28;.43)	-.61(-1.02;-.21)	-.74(-1.04;-.43)	-.45(-1.14;.24)	-.36(-.69;-.04)	.493	.995	.815
	CRP50-80%	-.47(-.78; -.16)	-.18(-.87;-.49)	-.61(-.91;-.32)	-.89(-1.42;.35)	-.31(-.62;-.01)	-.54(-.68;-.40)	.196	.611	.377
	CRP80-100%	.75(.28; 1.99)	.57(.28;1.16)	.26(.13;.51)*	.69(.44;1.09)*$^{@}$	.60(.19;1.84)	.19(.19;.19)$^{@}$	.214	.623	.026
	PhaDiff	31.01(17.37;55.35)	27.04(12.89;56.73)	29.95(14.51;61.83)	35.61(23.12;54.85)	14.09(4.63;42.90)	54.79(32.14;93.41)	.856	.184	.212
SSWS	CRPcontact	-.62(-.84;-.41)	-.60(-.96;-.24)	-.58(-.90;-.26)	-.82(-1.23;-.42)	-.72(-1.15;-.29)	-.41(-.70;-.12)	.695	.804	.247
	CRP0-20%	-.15(-.56;.25)	-.06(-.86;.74)	.52(.04;1.01)	- .04(-.59;.50)	.27(-.01;.57)	.67(-.04;1.38)	.103	.913	.196
	CRP20-50%	-1.12(-1.46;-.77)	-1.06(-1.89;-.23)	-.72(-1.05;-.39)	- 1.24(-1.82;-.65)	-.87 (-1.44;-.29)	- .38(-.91;.14)	.279	.968	.067
	CRP50-80%	-.98(-1.51;-.45)	-1.02(-1.42;-.62)	-1.24(-2.06;-.43)	-1.45(-2.44;-.47)	-1.54(-2.38;-.70)	- 1.13(-1.88;-.37)	.308	.840	.719
	CRP80-100%	.36(.17;.73)	.66(.33;1.32)	.67(.39;1.16)	.63(.24;1.59)	.02(.01;.03)$^{+ab}$	.01(.01;.02)$^{+ab}$	.001	.800	.177
	PhaDiff	45.40(17.74;116.20)	47.75(22.16;102.90)	5.14(34.54;72,78)	6.18(42.26;85.71)	59.41(34.19;103.23)	57.23(2.12;162.76)	.832	.836	.930
.83 m.s^{-1}	CRPcontact	- .46(-.74;-.18)	-.52(-.98;-.06)	-.81(-1.06;-.55)	-.76(-1.15;-.38)	-.59(-.89;-.29)	- .65(-.92;-.37)	.311	.840	.920
	CRP0-20%	.48(-.01;.98)	-.18(-.64;.28)	.29(-.34;.93)	.40 (-.15;.95)	.53(-.54;1.62)	.26(-.55;1.08)	.631	.304	.266
	CRP20-50%	-.60(-1.23;.03)	-.92(-1.75;-.09)	-.56(-1.05;-.07)	- .89 (-1.54;-.24)	-.51(-1.08;.04)	- .51(-.83;-.20)	.624	.355	.769
	CRP50-80%	-1.05(-1.43;-.67)	-.75(-1.50;-.01)	-1.81(-2.48;-1,15)	-1.60 (-2.43;-.76)	-1.40(-2.16;-.64)	- 1.31(-1.78;-.84)	.075	.402	.933
	CRP80-100%	-.32(-.86;.21)	.07(-.34;.49)	-.79(-1,49;-.09)	-.51 (-1.17;.15)	-.62(-1.68;.43)	-.77(-1.76;.21)	.072	.422	.509
	PhaDiff	21.18(-4.69;47.06)	23.81(-16.11;63.74)	5.95(-37.86;49.76)	55.49(25.03;85.96)	13.30(-29.66;56.27)	23.44(-13.01; 59.89)	.868	.100	.246
FAST	CRPcontact	-.81(-1.23;-.39)	-.71(-1.29;-.13)	-.98(-1.32;-.65)	- 1.13(-1.75;-.52)	-1.13(-1.60;-.65)	-.64(-.93;-.35)	.592	.271	.184
	CRP0-20%	.96(.19;1.72)	.01(-1.07;1.10)	.70(.11;1.29)	.71(-.30;1.74)	.89(-.48;2.28)	.96(.44;1.48)	.641	.423	.303
	CRP20-50%	-1.04(-2.16;.06)	-1.04(2.24;.15)	-1.04(-1.74;-.34)	-1.30(-2.52;-.08)	-.93(-1.65;-.21)	-.39(-1.01;.22)	.397	.731	.515
	CRP50-80%	-1.87(-2.62;-1.13)	-1.21(-2.12;-.29)	-2.11(-2.77;-1.44)	- 2.38(-3.37;-1.39)	-2.45(-3.28;-1.62)	-1.78(-2.43;-1.13)	.253	.102	.108
	CRP80-100%	-.62(-1.19;.06)	-.23(-1.13;.66)	-.91(-1.54;- .27)	-.86(-1.76;.03)	-1.46(-2.32;- .59)	-.89(-1.42;-.37)	.125	.206	.783
	PhaDiff	27.15(-25.29;79;59)$^{+}$	27.16(-34.32;88.64)$^{+}$	7.84(33.21;108.46)	65.35(15.80;114.91)	138.54(109.25;167.83)$^{+}$	49.98(-5.00;124.96)$^{+}$	.015	.094	.243

NOTE: S: Speed; CRPcontact: CRP angle at all contact; CRP0-20%: Angle at contact 0-20%; CRP20-50%: Angle at contact 20-50%: CRP50-80%: Angle at contact 50-80%; CRP80-100%: Angle at contact 80-100% PhaDiff: Phase difference.*: Difference pre and post independent of the group @: Difference between groups in post time +:Difference between groups independent time a:Dance group b:NW group

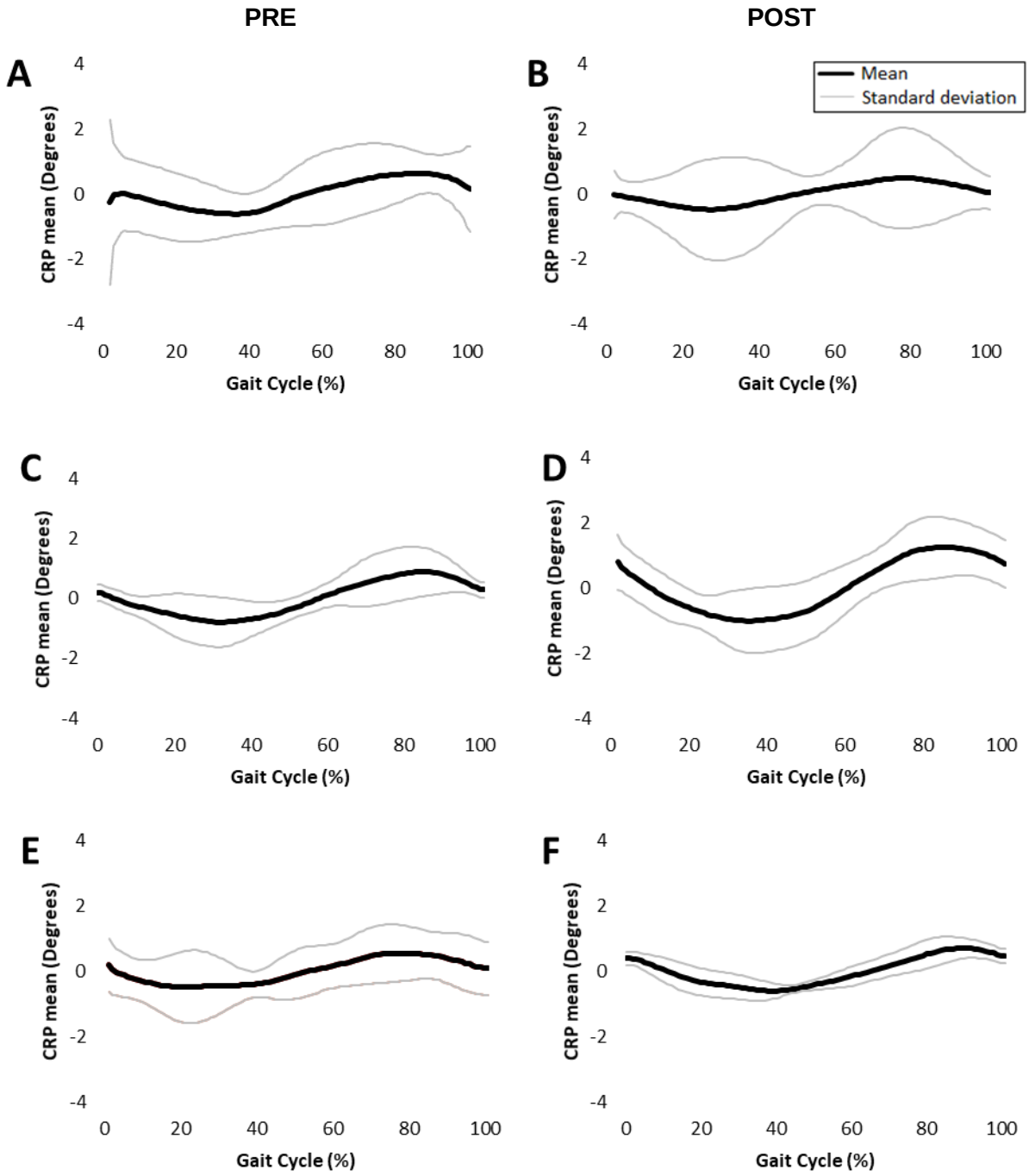

Figure 4.6 CRP mean in degrees on gait cycle in coordination of Trunk and Pelvis rotation in .28m.s-1 speed. **A**: Dance group pre **B**: Dance group post **C**: Nordic Walking group pre **D**: Nordic Walking group post **E**: Control group pre **F**: Control group post. Black lines represent CRP mean and green lines represent standard deviation.

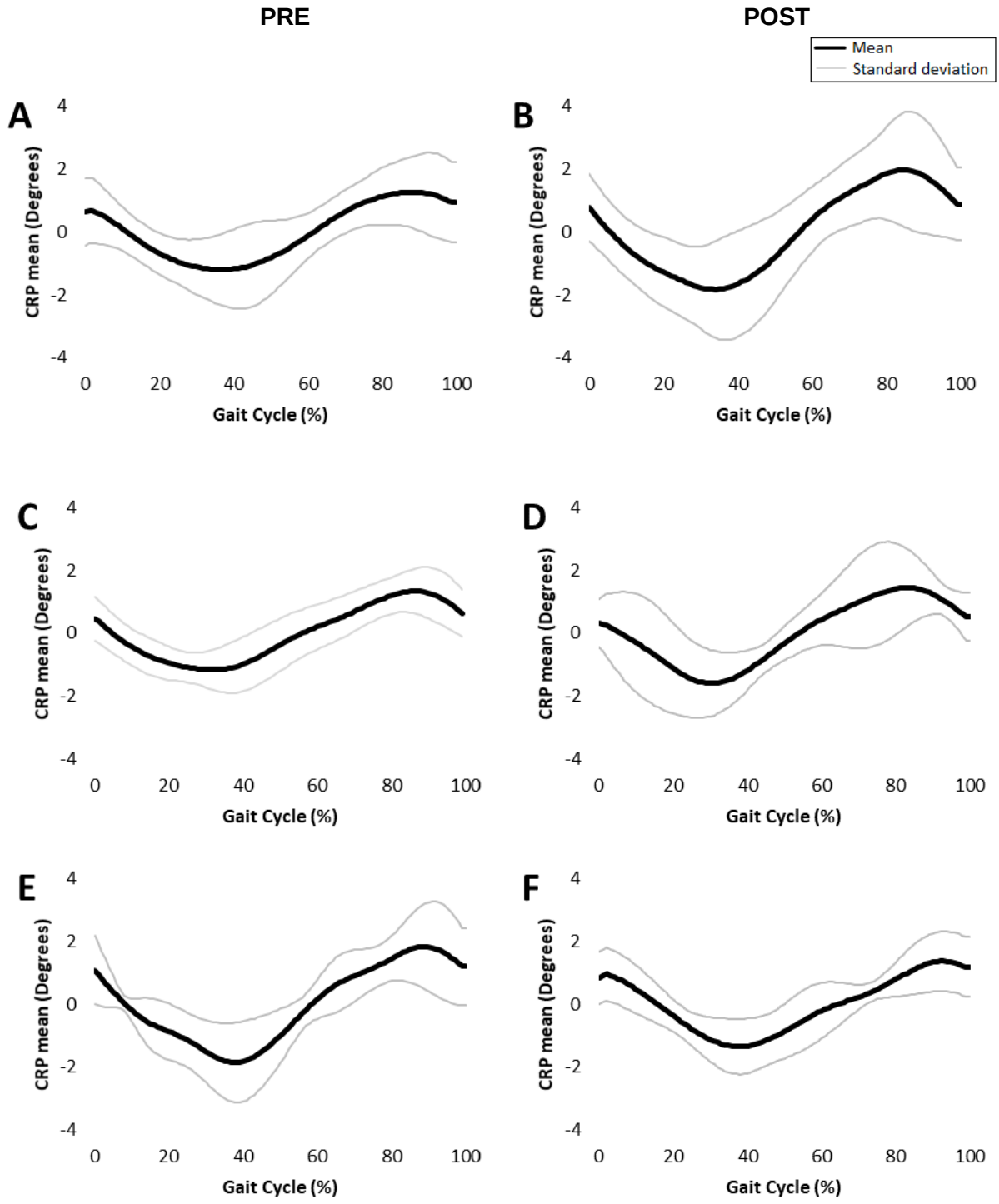

Figure 4.7 CRP mean in degrees on gait cycle in coordination of Trunk and Pelvis rotation in SWSS. **A**: Dance group pre **B**: Dance group post **C**: Nordic Walking group pre **D**: Nordic Walking group post **E**: Control group pre **F**: Control group post. Black lines represent CRP mean and green lines represent standard deviation.

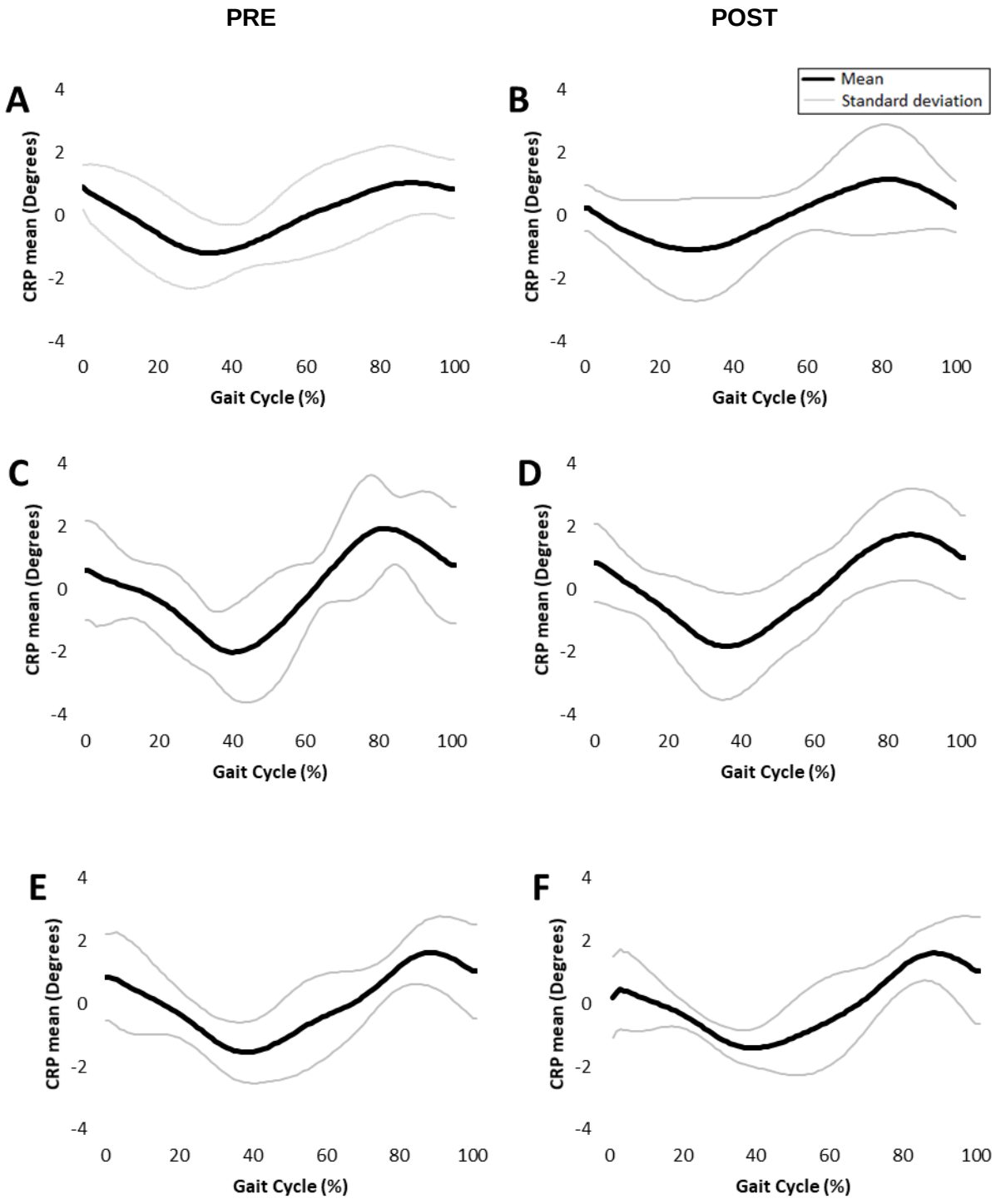

Figure 4.8 CRP mean in degrees on gait cycle in coordination of Trunk and Pelvis rotation in .83 $m.s^{-1}$ speed. **A**: Dance group pre **B**: Dance group post **C**: Nordic Walking group pre **D**: Nordic Walking group post **E**: Control group pre **F**: Control group post. Black lines represent CRP mean and green lines represent standard deviation.

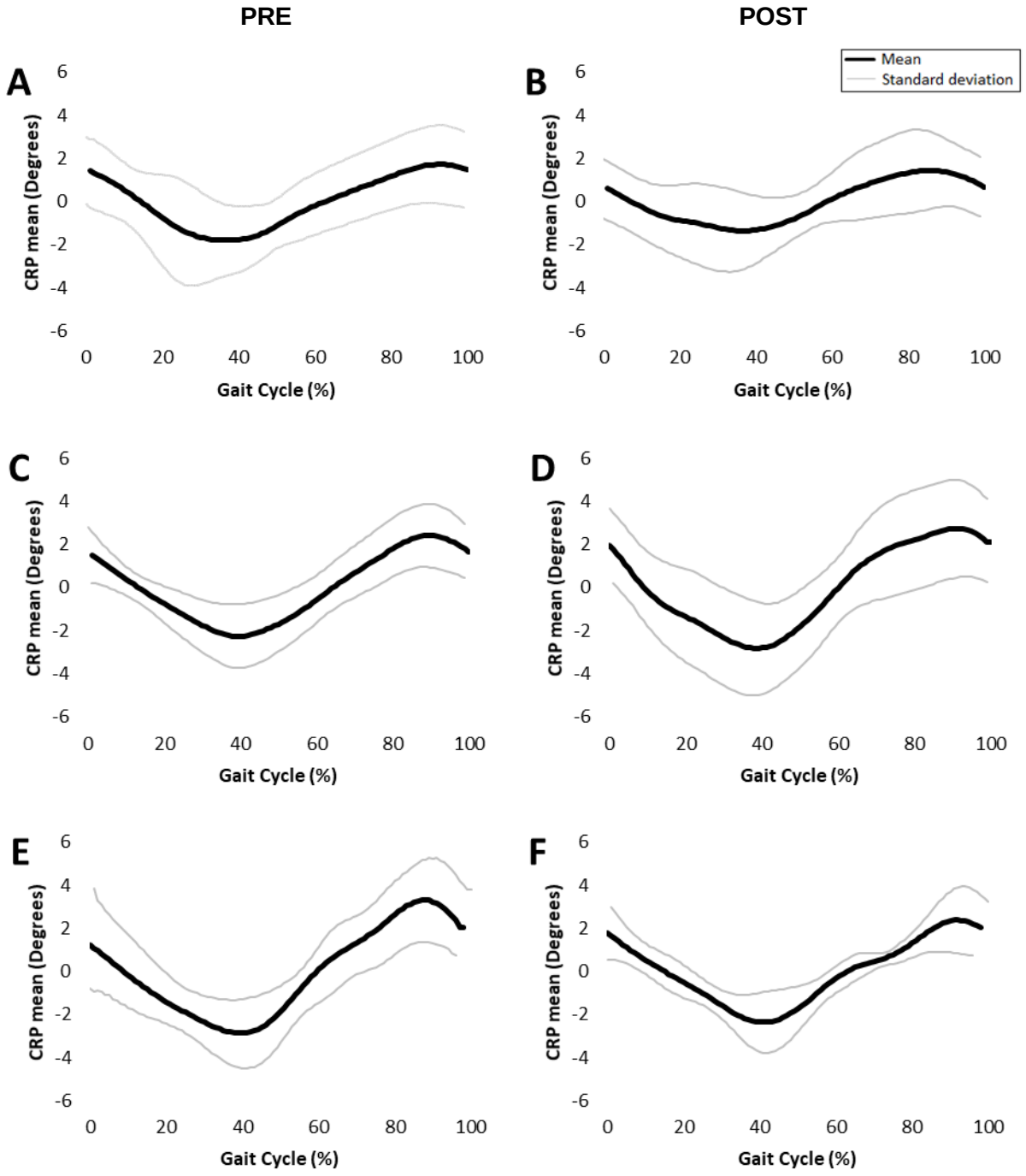

Figure 4.12 CRP mean in degrees on gait cycle in coordination of Trunk and Pelvis rotation in FAST speed. A: Dance group pre **B**: Dance group post **C**: Nordic Walking group pre **D**: Nordic Walking group post **E**: Control group pre **F**: Control group post. Black lines represent CRP mean and green lines represent standard deviation.

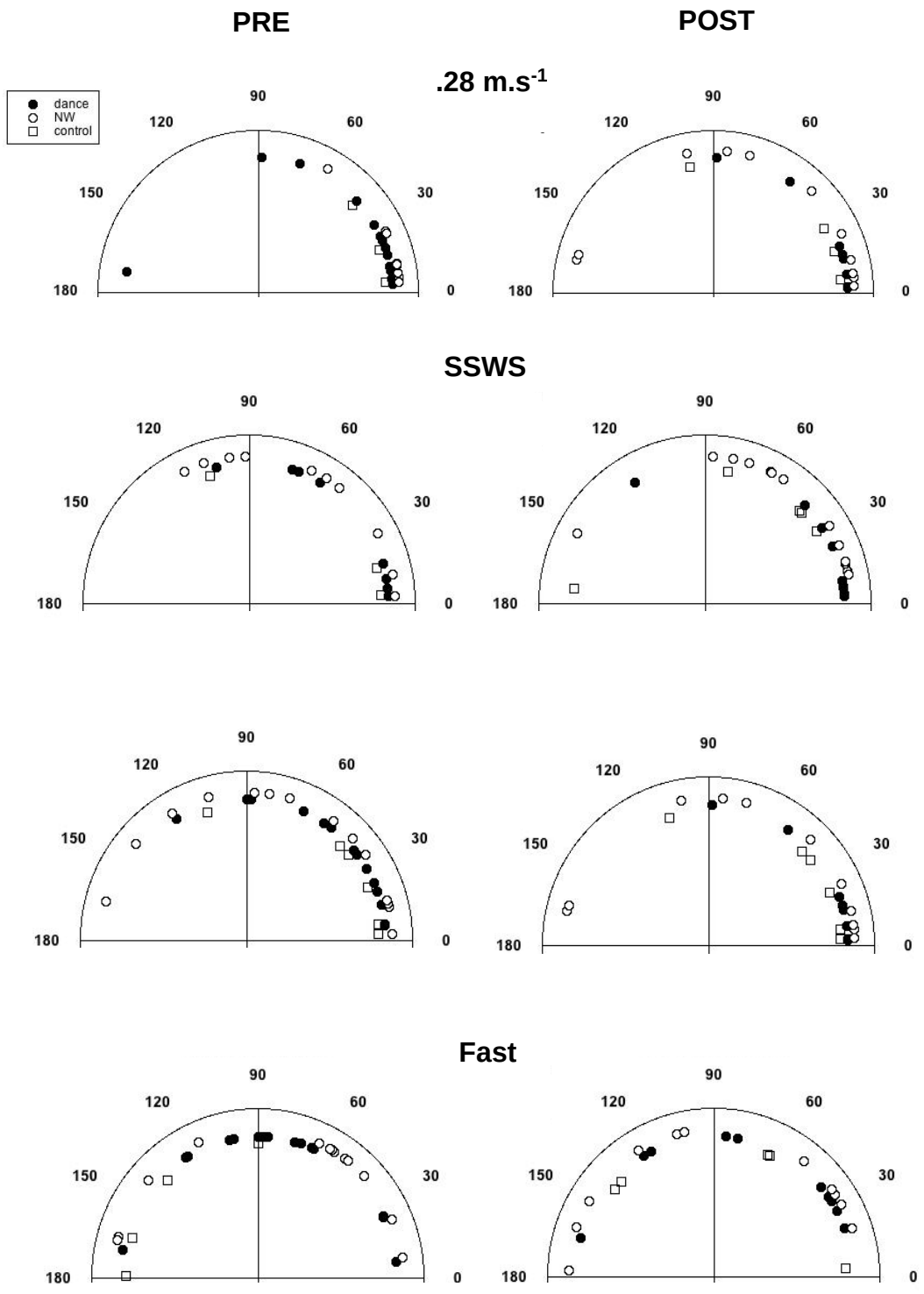

Figure 4.10 Individuals angles values of phase difference in dance, NW and control group pre and post test in different speeds. Values near zero degrees represent in-phase coordination and near 180 degrees represents antiphase coordination.

The results variability of CRP stride in .28 $m.s^{-1}$ did not show significance difference between the time and groups (p=.774), however the effect size was large in DG and moderate in NWG (ES:1.01; .35 dance and NW, respectively). The mean of DG at pre was [.551° (CI 95%: .312;.791)] at post was [.543° (.348; .737)]. In NWG the mean at pre was [.420° (CI 95%: .232; .608)], at post was [.567° (CI 95%: .258;.875)]. In control group the mean at pre was [.213° (CI 95%: -.125;.551)] and at post was [.264° (CI 95%:.204; .325)] (Figure 4.11 A).

The variability of CRP stride in SSWS did not expressed significance difference between the time and groups and the effect size was small [p:.882 (ES>.01; .28 dance and NWG, respectively)]. The mean of DG at pre was [.457° (CI 95%: .355;.559)] at post was [.488° (.384;.592)]. In NWG the mean at pre was [.505° (CI 95%: .419; .591)], at post was [.594° (CI 95%: .407;.780)]. In control group the mean at pre was [.507° (CI 95%: .367;.647)], at post was [.572° (CI 95%: .384; .760)] Figure 4.11 B).

The results of variability of CRP stride in .83 $m.s^{-1}$ did not demonstrate significance difference between the time and groups (p=.521). The mean of DG at pre was [.548° (CI 95%: .284;.812)] at post was [.536° (.356;.717)]. In NWG the mean at pre was [.634° (CI 95%: .440; .828)], at post was [.621° (CI 95%: .394;.848)]. In control group the mean at pre was [.360° (CI 95%: -.240;.480)], at post was [.485° (CI 95%: .324; .645)] Figure 4.11 C).

The variability of CRP stride showed time-group interaction on fast speed (p=.002). The covariable speed did not influence the result (p=.772), and NWG showed moderate effect size (ES: .01; .80 dance and NW, respectively)]. In NWG, the variability of CRP stride was lower pre test [.565° (CI 95%: .370; .862)] than post test [1.094° (CI 95%:.713; 1.679)] (p=.011), and higher between NW and control group on post test (p=.007) and DG (p=.025).The mean of DG and CG were maintain in the effect of time. The mean of DG at pre was [.694° (CI 95%: .423;1.139)] and at post was [.527° (.316;.881)], and in CG the mean at pre was [.862° (CI 95%: .293; 2.532)], and at post was [.425° (CI 95%: .337; .537)] (Figure 4.11 D).

Time-group interaction analysis showed variability of CRP contact on fast speed [p=.038 ES: .36; 1.09 dance and NW, respectively)] and covariable did not influence in the result (p=.676) (Table 4.5). The variable was higher post than pre test on NWG (p=.027) and higher between NW and control group on post test (p=.009) and higher between NW than dance on post test (p=.025). In addition, time-group interaction showed significative differences in variability of CRP 0-20% on fast speed [p<.001

(ES:.76; 1.50 dance and NW, respectively)] and covariable did not influenced in the result (p=.633) variability of CRP 0-20% was higher post than pre test on NWG (p<.001), and higher between NW and control group on post test (p<.001) and higher between NW than dance on post test (p=.003). The variability of CRP 20-50%, CRP 50-80% and CRP 80-100% did not show time-group interaction or time significative differences (p>.05). Nevertheless, moderates, large and too large effects sizes were showed in .28m.s^{-1} and in fast speed (ES: .50-1.50).

The variability of CRP contact, CRP 0-20%, CRP 20-50%, CRP 50-80% and CRP 80-100% are different between the groups (p<.05) in .28m.s^{-1}. In SWSS the differences between the groups(p<.05) happened on variability of CRP 0-20% (p<.05) and on fast speed on CRP contact, CRP 20-50%, CRP 50-80% and CRP 80-100% (p<.05), and the time remained the same.

On the other hand, some variables presented large ES between intervention and control group. To variability of CRP 20-50 and 50-80 on .28m.s^{-1} the DG showed large effect size between control group on pos test (ES:.88 CI 95%: -.37; 2.13 and ES: .97 CI 95%: -.32;1.37).

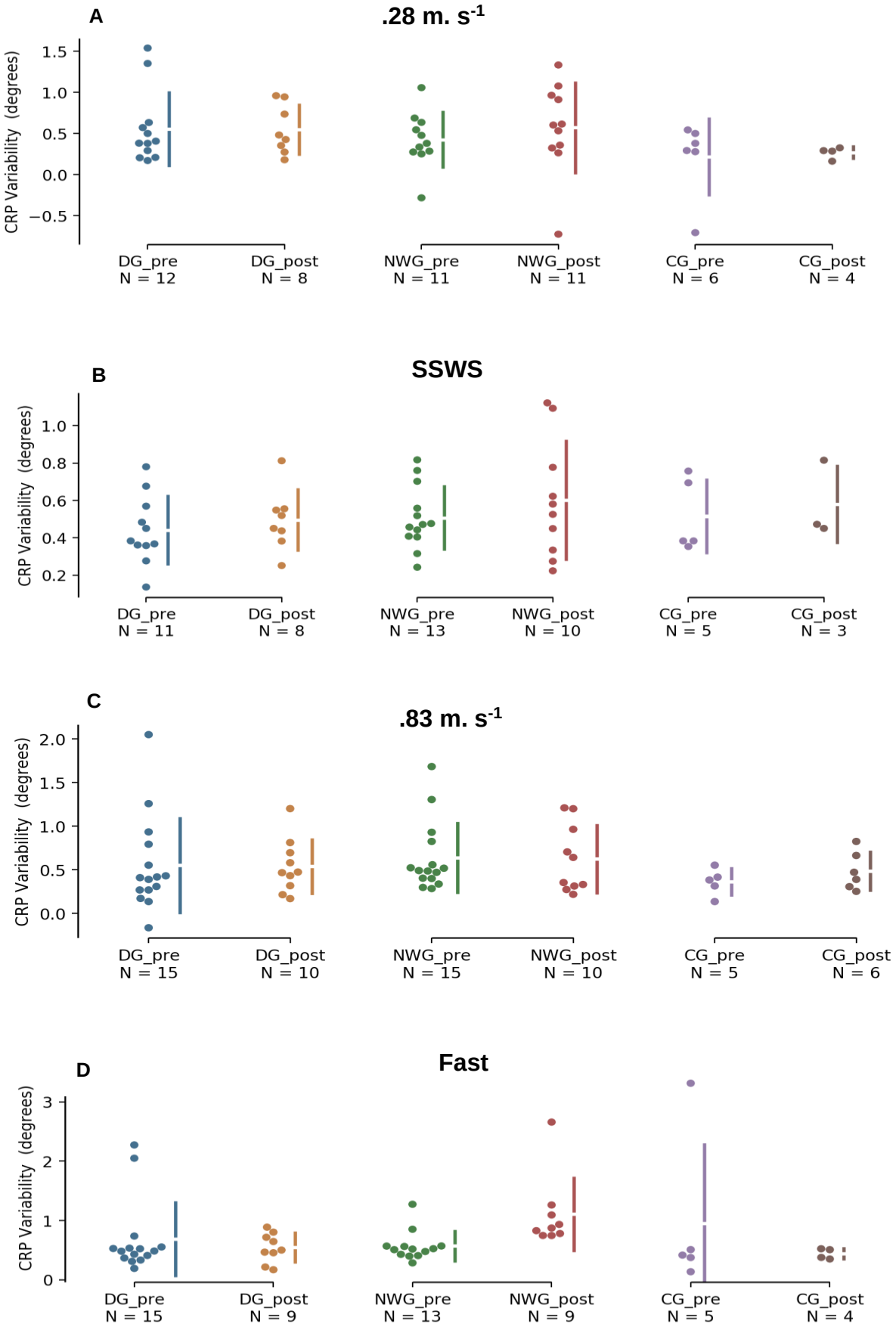

Figure 4.11 Individuals angles values of CRP variability in dance, NW and control group pre and post test in different speeds. Based on Ho et al.(2019). Built on https://www.estimationstats.com

Table 4.5 Mean, confidence interval and statistical significance of variability coordinate variables in angles of contact and parts of contact in pre and post test in dance, Nordic walking and control group at different speeds.

		Dance Group (n = 15)		Nordic Walking Group (n = 15)		Control Group (n = 6)				
S	Variable	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Group**	**Time**	**Group*Time**
		Mean (CI 95%)	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**			
.28 m.s^{-1}	CRPsdcontact	.67 (.27; 1.06)	.53 (.33; .74)	.40 (.23; .57)$^{+}$	.75 (.34; 1.15)$^{+}$	.20 (-.10; .52)$^{+}$	.25 (.20; .29)$^{+}$	.006	.332	.160
	CRPsd0-20%	.85(.44; 1.26)	.64 (.38; .90)	.46 (.24; .67)	.65 (.30; 1.00)	.24 (-.10; .58)$^{+ab}$	.27 (.18; .36)$^{+ab}$	.002	.973	.336
	CRPsd20-50%	.63 (.13; 1.12)	.58 (.35; .80)	.43 (.24; .63)	1.00 (.39; 1.60)	.28 (-.05; .61)	.23 (.20; .26)	.020	.258	.123
	CRPsd50-80%	.63 (.18; 1.09)	.46 (.28; .65)	.36 (.22; .50)	.83 (.19; 1.47)	.20 (-.06; .46)	.23 (.21; .24)	.017	.382	.236
	CRPsd80-100%	.61 (.29; .94)	.47 (.24; .71)	.36 (.20; .52)$^{+}$	.43 (.07; .80)$^{+}$	.09(-.22; .42)$^{+}$	.28 (.17; .39)$^{+}$	.012	.535	.097
SSWS	CRPsdcontact	.46 (.34; .58)	.46 (.36; .56)	.53 (.42; .63)	.63 (.44; .82)	.51 (.30; .71)	.60 (.42; .78)	.224	.322	.655
	CRPsd0-20%	.55 (.39; .71)	.52 (.40; .63)	.65 (.51; .79)	.75 (.49; 1.02)	.57 (.32; .82)	.96 (.69; 1.22)	.032	.118	.110
	CRPsd20-50%	.42 (.29; .54)	.51 (.37; .65)	.49 (.35; .63)	.66 (.43; .89)	.52 (.26; .78)	.60 (.43; .78)	.356	.192	.859
	CRPsd50-80%	.45 (.30; .59)	.40 (.27; .54)	.50 (.40; .60)	.63 (.43; .84)	.50 (.30; .70)	.45 (.28; .62)	.159	.863	.444
	CRPsd80-100%	.46 (.35; .58)	.42 (.25; .60)	.50 (.41; .60)	.48 (.23; .73)	.43 (.26; .61)	. 47 (.26; .69)	.847	.902	.867
.83 m.s^{-1}	CRPsdcontact	.50 (.29; .70)	.56 (.38; .75)	.67 (.44; .89)	.81 (.30; 1.32)	.32 (.20; .44)	.65 (.39; 0;92)	.412	.054	.381
	CRPsd0-20%	.52 (.31; .74)	.58 (.38; .78)	.80 (.53; 1.06)	.72 (.40; 1.04)	.33 (.19; .46)	.47 (-.22; 1.18)	.148	.771	.717
	CRPsd20-50%	.45 (.26; .65)	.61 (.34; .88)	.63 (.44; .82)	.91 (.25; 1.56)	.35 (.20; .50)	.57 (.38; .76)	.282	.064	.929
	CRPsd50-80%	.48 (.26; .69)	.56 (.36; .75)	.67 (.37; .96)	.93 (.15; 1.72)	.25 (.17; .34)	.74 (.16; 1.32)	.538	.069	.410
	CRPsd80-100%	.56 (.22; .91)	.49 (.23; .74)	.61 (.38; .84)	.58 (.35; .82)	.36 (.16; .55)	.81 (-.01; 1.64)	.877	.431	.485
FAST	CRPsdcontact	.62 (.26; .99)	.50 (.21; .79)	.79 (.43; 1.16)*	1.35 (.68; 2.03)*$^{@ac}$	.54 (.19; .89)	.38 (.28; .47)	.039	.393	.038
	CRPsd0-20%	.64 (.22; 1.06)	.61 (.35; .86)	.39(-.04; .83)*	1.23 (.80; 1.66)*$^{@ac}$	.55 (.28; .83)	.40 (.28; .51)	0;092	.034	.001
	CRPsd20-50%	.53 (.14; .92)	.48 (.19; .77)	.79 (.37; 1.20)$^{+}$	1.52 (.63; 2.40)$^{+}$	.44 (.19; .68)$^{+}$	.36 (.26; .45)$^{+}$	.027	.171	.144
	CRPsd50-80%	.62 (.38; 1.01)	.45 (.24; .83)	1.04 (.51; 2.08)	1.43 (.62; 3.32)	.49 (.25; .98)	.30 (.25; .36)	.003	.320	.126
	CRPsd80-100%	.75 (.35; 1.14)	.47 (.02; .91)	.83 (.36; 1.29)	1.09 (.65; 1.53)	.75 (-.04; 1.54)	.53 (.30; .76)	.230	.544	.052

NOTE: S: Speed**;** CRPsdcontact: CRP variability of angle at all contact;CRP0-20%: variability of angle at contact 0-20%; CRP20-50%: Variability of angle at contact 20-50%: CRP50-80%: variability of angle at contact 50-80%; CRP80-100%: variability of angle at contact 80-100%. *:Difference pre and post independent of the group @:Difference between groups in post time +:Difference between groups independent time a:Dance group b:NW group c:control group.

Angular variables

In general, the ROM angular variables of trunk in sagittal, frontal and transverse no presented significant differences between the groups and time (p>.05) (Table 4.6). Nevertheless, some variables exposed moderate and large effect size on .28 m. s^{-1}, was possible to observe that although dance and NWG showed similar means of control group the effect size was moderated of ROM trunk in the sagittal (ES: .75 CI 95%: -.46; 1.97), frontal (ES:.65 CI 95%: -.55; 1.86) and transverse (ES: .61 CI 95%: -.59; 1.81) NWG also showed moderate effect size on ROM trunk in the sagittal (ES: .71 CI 95%: -.47; 1.88), small in frontal (ES:.18 CI 95%: -.97; 1.33) and large in transverse (ES: 1.09 CI 95%: -.12; 2.30). Moreover, on SSWS DG also present moderate effect size of ROM trunk in the sagittal (ES: .82 CI 95%: -.55; 2.19), frontal (ES:.80 CI 95%: -.57; 2.17) and transverse (ES: .60 CI 95%: -.75; 1.95).

The ROM angular variables of pelvis (Table 4.7) showed time-group interaction in pelvis frontal at SSWS [p:.027 (ES:.30; .74, dance and NW, respectively)], and the covariable did not influence in the result (p=.411). Time-group interaction analysis showed that ROM pelvis frontal increase on NWG compared with control group at post (p=.033). Pelvis sagittal and pelvis transverse on .28 m. s^{-1} and fast speed, respectively are differences between the groups without time effects (p<.05). On .28m.s^{-1} both groups, dance (ES: .74 CI 95%: -.47; 1.96 and NW ES: .86 CI 95%: -.32; 2.05) showed on pelvis transverse moderate effect size compared with control group.

Spatiotemporal variables

The spatiotemporal variables are represented in table 4.8. In general, the results did not show significance differences (p>.05). On fast speed the stance time decrease in post time all groups (p<.05). Nevertheless, on .28m.s^{-1}, the effect size of stance time was largely longer (ES: .91 CI 95%: -.35;2.16) and the effect size of stride frequency was largely higher (ES: 1.59 CI 95%: .23;2.95) in the DG with respect to control group. The effect size of stride length was higher in the NWG compared to control group (ES: 1.53 CI 95%: .26; 2.80).

The SSWS significantly increased from pre [.78 m.s^{-1} (CI 95%: .70-.86)] to post, [.82 m.s^{-1} (CI 95%: .75-.90) (p<.007). The values of SSWS for DG were at pre=.73 m.s^{-1} (CI 95%: .65-.82) and at post=.75 m.s^{-1} (CI 95%: .64-.86), for NWG at pre=.75 m.s^{-1} (CI 95%: .66-.85) and at post= .77 m.s^{-1} (CI 95%: .63-.91), and for control group at

pre=.85 $m.s^{-1}$ (CI 95%: .70-1.00) and post=.90 $m.s^{-1}$ (CI 95%: .77-1.02). The fast speed did not show difference between the time and group (p=.303), The mean of DG pre=1.12$m.s^{-1}$ (CI 95%: .99;1.24) and post=1.11 $m.s^{-1}$ (CI 95%: .95;1.26), in NWG pre=1.17 $m.s^{-1}$ (CI 95%: 1.06;1.28) and post= 1.23 $m.s^{-1}$ (CI 95%:1.14;1.32) and in control group pre=1.22 $m.s^{-1}$ (CI 95%: 1.02;1.41) and post:1.27$m.s^{-1}$ (CI 95%: 1.15;1.39).

In general effect of time, all groups increase the LRI (p=.004). The mean of DG in pre:49.6% (CI 95%: 43.7; 55.4) post=51.1% (CI 95%: 43.6-58.7) in NWG pre= 5.9% (CI 95%: 43.7;58.0) and post= 56.5% (CI 95%:5.2-62.7) and the control group (Pre:38.3%, CI 95%: 47.7-68.9; Post: 61.3%, CI 95%: 52.5; 7.26).

Table 4.6 Mean, confidence interval and statistical significance angles of trunk in sagittal, frontal and transverse plane, in pre and post test in dance, Nordic walking and control group at different speeds.

	Dance Group (n = 15)		Nordic Walking Group (n = 15)		Control Group (n = 6)				
Speed ($m.s^{-1}$)	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Group**	**Time**	**Group*Time**
	Mean (CI 95%)	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**			
				Trunk (Sagittal)					
.28 $m.s^{-1}$	2.1(1.6;2.7)	2.4(1.9;3.0)	2.5(2.2;2.9)$^{+}$	2.9(2.1;4.0)$^{+}$	1.8(1.3;2.4)$^{+}$	1.7(1.2;2.2)$^{+}$	.021	.402	.451
.83 $m.s^{-1}$	2.1(1.7;2.8)	2.4(1.6;3.4)	2.4(1.9;3.0)	2.1(1.5;2.8)	1.6(.9;2.6)	2.4(1.5;3.7)	.732	.406	.417
SSWS	1.8(1.4;2.6)	2.4(1.6;3.6)	2.3(1.8;3.0)	1.9(1.5;2.4)	1.7(.9;3.0)	1.2(1.0;1.5)	.070	.370	.212
FAST	2.0(1.6;2.5)	2.5(1.8;3.5)	2.2(1.5;3.3)	2.1(1.2;2.8)	1.5(.9;2.6)	2.1(1.1;3.8)	.517	.238	.428
				Trunk (Frontal)					
.28 $m.s^{-1}$	2.7(2.1;3.9)	3.2(2.4;4.3)	2.7(2.1;3.5)	2.4(1.9;3.0)	1.9(1.6;2.3)	2.2(1.7;2.8)	.070	.517	.278
.83 $m.s^{-1}$	3.2(2.2;4.9)	3.7(2.4;5.7)	2.7(2.1;3.4)	2.0(1.6;2.6)	1.7(1.5;1.9)	2.0(1.5;2.6)	.001	.967	.075
SSWS	3.0(2.1;4.3)$^{+}$	3.2(2.4;4.4)$^{+}$	2.4(1.7;3.3)	2.2(1.8;2.7)	1.8(1.3;2.4)$^{+}$	1.9(1.3;2.6)$^{+}$	.003	.839	.807
FAST	3.0(2.0;4.5)	3.3(2.0;5.4)	3.1(2.1;4.6)	2.3(1.6;3.2)	2.2(1.4;3.4)	2.2(1.4;3.6)	.349	.487	.109
				Trunk (Transverse)					
.28 $m.s^{-1}$	7.6(6.5;8.8)	8.0(6.2;1.4)	9.8(7.6;12.7)	1.6(8.7;12.9)	8.5(6.8;1.5)	6.3(5.2;7.6)	.021	.412	.095
.83 $m.s^{-1}$	7.2(6.0;8.6)	8.0(6.4;1.1)	9.2(7.4;11.4)	9.4(7.1;12.4)	7.7(7.4;8.0)	7.3(5.4;1.0)	.266	.670	.741
SSWS	8.2(6.7;9.9)	7.9(6.4;9.8)	8.3(6.3;1.7)	8.5(6.6;11.0)	7.8(6.4;9.6)	6.3(4.8;8.4)	.404	.390	.389
FAST	7.0(5.4;9.1)	7.5(5.7;9.9)	7.9(6.2;1.1)	6.6(4.9;8.8)	6.5(4.5;9.4)	6.2(4.6;8.3)	.645	.409	.441

NOTE: +:Difference between groups independent time.

Table 4.7 Mean, confidence interval and statistical significance angles of pelvis in sagittal, frontal and transverse plane, in pre and post test in dance, Nordic walking and control group at different speeds.

	Dance Group (n = 15)		Nordic Walking Group (n = 15)		Control Group (n = 6)				
Speed ($m.s^{-1}$)	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Group**	**Time**	**Group*Time**
	Mean (CI 95%)	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**			
Pelvis (sagital)									
.28 $m.s^{-1}$	2.3(1.8;3.1)	1.9(1.6;2.3)	2.7(2.2;3.3)$^{+}$	3.2(2.4;4.2)$^{+}$	2.4(1.7;3.3)$^{+}$	1.8(1.4;2.2)$^{+}$	.018	.319	.124
.83 $m.s^{-1}$	2.5(1.6;3.9)	1.9(1.5;2.3)	3.1(1.8;5.3)	2.5(1.7;3.7)	2.1(.8;5.4)	2.3(1.5;3.7)	.443	.582	.791
SSWS	3.5(2.2;5.3)	2.1(1.6;2.7)	2.6(1.9;3.6)	2.0(1.3;3.1)	2.2(.9;2.2)	3.3(2.0;5.4)	.732	.557	.330
FAST	2.9(1.8;4.9)	2.3(1.3;3.8)	2.3(1.5;3.5)	2.4(1.5;3.8)	2.7(1.2;6.4)	1.7(1.1;2.9)	.775	.154	.175
Pelvis (frontal)									
.28 $m.s^{-1}$	3.8(2.9;5.1)	2.8(2.0;4.0)	2.7(1.2;3.7)	4.0(2.8;5.5)	3.6(2.2;5.8)	3.5(2.6;4.7)	.917	.879	.144
.83 $m.s^{-1}$	3.4(2.5;4.8)	2.8(1.9;4.1)	4.0(2.9;5.6)	4.8(3.2;7.2)	3.3(2.3;4.7)	3.0(2.1;4.2)	.063	.743	.636
SSWS	3.2(2.0;5.1)	2.7(1.5;4.9)	4.1(2.8;5.9)	4.7(3.0;7.2)$^{@}$	4.8(2.6;9.0)	2.0(1.7;2.4)$^{@}$	.050	.078	.027
FAST	5.1(3.4;7.5)	4.3(2.3;7.9)	4.1(2.7;6.4)	5.9(4.0;8.9)	4.5(1.8;1.9)	4.2(2.4;7.4)	.849	.772	.319
Pelvis (Transverso)									
.28 $m.s^{-1}$	6.4(5.3;7.6)	6.6(5.5;7.9)	7.6(6.2;9.3)	8.3(6.5;1.7)	6.9(5.3;9.0)	5.0(3.6;7.0)	.156	.478	.092
.83 $m.s^{-1}$	4.8(3.9;6.0)	4.4(3.2;5.9)	6.8(4.4;1.5)	7.3(5.2;1.2)	5.2(3.6;7.5)	4.5(3.0;6.8)	.077	.632	.778
SSWS	4.7(2.9;7.5)	5.3(3.3;8.4)	6.5(4.1;1.1)	5.7(3.8;8.4)	5.3(3.3;8.6)	4.8(2.2;1.5)	.649	.786	.456
FAST	5.3(3.3;7.4)	5.3(3.0;7.6)	7.8(5.5;1.1)	7.4(4.3;1.6)	9.2(6.5;11.9)	7.7(4.0;11.4)	.028	.394	.587

NOTE: +:Difference between groups independent time, @:Difference between groups in post time.

Table 4.8 Mean, confidence interval and statistical significance angles of spatiotemporal variable in pre and post test in dance, Nordic walking and control group at different speeds.

	Dance Group (n = 15)		Nordic Walking Group (n = 15)		Control Group (n = 6)				
Speed (m.s-1)	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Group**	**Time**	**Group*Time**
	Mean (CI 95%)	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**	**Mean (CI 95%)**			
Stride lenght (m)									
.28 m.s-1	.34(.29;.39)	.31(.20;.43)	.37(.33;.41)	.41(.36;.45)	.39(.36;.4)	.29(.35;.16)	.183	.880	.082
SWSS	.84(.78;.91)	.85(.79;.92)	.89(.84;.96)	.89(.84;.95)	.85(.78;.92)	.80(.72;.89)	.117	.566	.702
.83 m.s-1	.91(.87;.94)	.91(.85;.96)	.95(.88;1.01)	.97(.89;1.05)	.89(.85;.92)	.95(.86;1.03)	.384	.174	.539
FAST	1.14(1.07;1.22)	1.15(1.07;1.24)	1.21(1.13;1.29)	1.19(1.11;1.28)	1.19(1.11;1.28)	1.14(1.08;1.21)	.407	.346	.380
Stride Frequency (Hz)									
.28 m.s-1	.72(.61;.83)	.53(.34;.73)	.77(.70;.85)	.70(.63;.78)	.73(.66;.79)	.77(.70;.83)	.120	.105	.054
SWSS	.91(.86;.98)	.91(.85;.97)	.86(.80;.92)	.87(.81;.93)	.88(.81;.95)	.91(.83;.99)	.408	.452	.418
.83 m.s-1	.92(.88;.95)	.92(.86;.99)	.89(.83;.95)	.87(.80;.94)	.90(.87;.92)	.88(.81;.95)	.419	.557	.779
FAST	1.02(.96;1.09)	1.02(.94;1.10)	.97(.91;1.04)	.99(.92;1.07)	.97(.90;1.04)	1.03(.97;1.08)	.519	.134	.211
Stance time (s)									
.28 m.s-1	.85(.77;.93)	.94(.87;1.01)	.90(.79;1.01)	.97(.87;1.07)	.90(.80;1.00)	.84(.75;.93)	.594	.222	.078
SWSS	.70(.64;.75)	.73(.67;.79)	.76(.69;.82)	.71(.65;.77)	.72(.66;.78)	.70(.66;.74)	.749	.456	.126
.83 m.s-1	.69(.65;.73)	.65(.60;.70)	.75(.69;.82)	.70(.64;.76)	.70(.66;.73)	.70(.64;.77)	.271	.189	.315
FAST	.60(.56;.64)*	.59(.53;.64)*	.63(.59;.68)*	.59(.55;.63)*	.64(.59;.69)*	.59(.57;.61)*	.591	.004	.459

NOTE: *:Difference pre and post independent of the group.

4.4 DISCUSSION

The main purpose of this study was to compare the axial coordination trunk and pelvis rotation, trunk and pelvis ROM (sagittal, frontal and transverse), spatiotemporal, and LRI at different speeds, after dance and NW interventions during PD walking. The main finding of this study were that, in whole gait cycle, the axial coordination trunk and pelvis rotation did not show differences between time and group. However, coordination differences were more sensitive when analyzed in functional periods of gait, showing improvements in NWG post test compared with control group at the beginning and end of contact period. Additionally, variability of CRP stride and contact also was higher in fast speed. In addition, based on effect size, both interventions improved ROM trunk and pelvis in people with PD. While, in general, spatiotemporal variables remained unchanged after the interventions. Our results showed mainly differences in .28m.s^{-1} and fast speeds.

Our hypothesis was partially confirmed because NWG improved the axial coordination of trunk and pelvis rotation compared to control group. Conversely, the gait coordination remains unaltered between DG and NWG. We expected improvement in DG compared to NWG. In addition, in general, ROM sagittal, frontal and transverse of trunk and pelvis did not expressed differences between time and group factors. Nevertheless, the effect size showed improvements in interventions groups compared with control group. The pelvis frontal rotation significantly increased in the NWG with respect to control group at the SSWS condition. Moreover, while the SSWS increased in all groups, the LRI was improved only for the NWG. Also, the coordination was not altered in SSWS condition, changing at .28 m.s^{-1} and fast speed conditions.

The effect size is a descriptive measurement and can be used to complement the statistical analysis and it has been used in gait analysis studies (SCHWENK et al., 2014; SPECIALI et al., 2014; PSARAKIS et al., 2018). In this study, the groups have different number of participants and relatively low sample number, therefore, g of Hedges was used (LINDENAU & GUIMARÃES, 2012; ESPÍRITO-SANTO & DANIEL, 2017). In our study, the effect size was calculated in order to complement the statistical analysis.

Mostly, the intergirdle (trunk and pelvis) coordination occurs during daily life activities, such as, turning to pick up or reaching an object, turning in bed and mainly

during walking. In people with PD the axial rotation coordination is impaired, promoting postural instability and consequently propensities to falls (VAUGOYEAU et al., 2006). Van Emmerik et al. (1999) found that CRP of rotation of trunk and pelvis was lower in people with PD at early stage than elderly control group. As a result, they suggest physical interventions in the attempt to improve trunk and pelvis rotation coordination in people with PD. In our study, we evaluated CRP of trunk pelvis rotation in people with PD after dance and NW intervention.

Our results did not show differences after interventions when CRP mean of trunk and pelvis rotation were evaluated in all gait cycle, independently of speed. All gait cycle has different moments, balance and contact. Perry (2005) showed that in contact phase, pelvis has the higher rotation moment, and with this, CRP trunk and pelvis rotation may be more sensitive when measured based in contact walking phase. Another studies measure CRP in different gait phase functional and the variable was sensible (YODER, PETRELLA & SILVERMAN, 2015; CORNWALL, JAIN & HAGEL, 2019).

Thus, our results showed differences in mean and variability of CRP trunk and pelvis mainly in 0-20 and 80-100% of contact phase in .28m.s^{-1} and fast speed, highlighting NWG. These stages of contact phase are important because involves touch-down and touch-off, that is, the moment of potential and kinetic change energies, higher trunk pelvis rotation coordination in this phase, helping to maintain and to improve the inverted pendulum in people with PD and avoid an further increase in the metabolic cost of walking (CAVAGNA, THYS & ZAMBONI, 1976; DIPAOLA et al., 2016).

The variability of CRP trunk and pelvis rotation in stride and contact was measured (Figure 4.10 and Table 4.6) showing a higher variability in CRP stride, CRP contact and CRP 0-20% of contact in NWG on fast speed, considered as a positive result. People with PD have more in-phase movements than people without PD, and the axial movements are more limited. Our results suggested that the people with PD were walking more anti-phase after NW intervention. Thereby, variability indicates the capacity of the system to adapt a different stimulus. Therefore, higher variability may indicate movement pattern change and more capacity to adapt a different stimulus during gait in people with PD (VAN EMMERIK et al., 1999; VAN EMMERIK, HAMILL & MCDERMOTT, 2005). Fast speed is more challenging compared with others, with this, our results propose that after NW intervention, the participants had greater CRP

variability of trunk and pelvis rotation or more capacity to adapt to gait stimulus during fast speeds, what may decrease risk of falls and improve functional daily life. To complete, no difference was found in phase difference, perhaps due to the fact that subjects pattern were so variable, it is possible to observe in figure 4.10 that on .28m.s^{-1} the subjects trend to be more in-phase, or more next to zero, and in fast speed is possible to observe higher tendency to anti-phase, in concordance with CRP results.

Our hypothesis was refuted and the mainly modification of variables coordination did not occur in SSWS, occurring at .28m.s^{-1} and at fast speed. Our results are in line with Van Emmerik et al. (1999) that observed, increase in CRP of trunk and pelvis rotation with increasing speeds. In the present study, the fast speed was more homogeneous than SSWS in all three groups. The biomechanical differences occurred at .28 m.s^{-1} which we highlight the importance for evaluating at controlled speeds (VAN EMMERIK et al., 1999), because even with a small variation, it was possible to observe improvements after NW.

Based on the principles of changes of directions, transversal movements of head and trunk and turning (FONSECA et al., 2014; SHARP; HEWITT, 2014; SHANAHAN et al., 2015) we hypothesized that after dance classes people with PD could improve trunk and pelvis coordination during walking. Nevertheless, our results showed that in people with PD in important phases of the walking NWG was able to change the biomechanics trunk and pelvis coordination during walking. It can be explained by the fact that NW require propulsive force through the poles in the ground associated to high upper body movement that is synchronic with trunk and lower limbs during all walking movement (BOCCIA et al., 2018). Additionaly, in Zoffoli et al. (2017) they suggest that in adults, during walking with poles, the stride length can be higher and consequently the external oblique can be more active and increase trunk rotation. NW is a cycle activity that requires poles in diagonal with propulsive force and higher ROM of upper limbs the external oblique may be more activated during the task, these may explain some improved in NWG on biomechanics trunk and pelvis coordination during walking.

Although dance intervention provides auditory stimulus, rhythm, synchrony, coordination, spatial sense and transversal movements (FONSECA et al., 2014) the PD subjects were not able to infer these benefits for the moment of the walk. As a result, the improvement of NWG may be because of motor learning (MAWASE et al., 2017). The literature showed that in addition to learning a movement it is necessary to

train, because the training of a task influence the excitability of the motor cortex. Thus, even the dance intervention providing greater movement in the transverse plane, it is not enough to improve axial coordination during walking. In this way, NW is a sagittal task and the daily walking also is a task mainly in a sagittal plane, which allows that the participant use-dependent memory and the skills acquired in the intervention training could be applied during the walking task (MAWASE et al., 2017).

Therefore, this suggest more evaluations of trunk and pelvis comportment in people with PD after dances classes during turning the specific movement that participants did in class (HULBERT et al., 2017). Additionally, after dance intervention no statistic significance was found in coordination variable. Nevertheless, some moderated and higher effect size was found compared with control group, despite no statistic significance, based on effect size dance intervention was able to modify some variables coordination. Dance is an acyclic intervention and the general movements are in transverse plane, and consequently, the gains were not able to be transmitted to a sagittal task, such as walking.

Therefore, despite some improvement of trunk and pelvis coordination, in general, this variable was maintaining in the groups, however moderated and large effect size was show in both groups compared with control group in transverse plane. However, our subjects in general, showed higher degrees of freedom on trunk than pelvis, what corroborate with Van Emmerik, Hammil and McDermott (2005) that showed higher ROM trunk than pelvis in elderly people, our participants can be consider aging based on the age characterizes. Additionally, higher pelvis frontal movement, that is, tilt pelvic, was found in NWG compared with control group. The maintenance of tilt pelvic during walking is one of the determinants of gait with 5 degrees average (SAUNDERS et al., 1953). The interventions were important to maintain this variable and avoid higher energy cost during gait.

All groups improved stance time, SSWS and LRI in general time effect. The interventions were able to improve these variables. Nevertheless, control group also improved it may be because our study did not control quantitatively what activities these people did during this time. In addition, improve this variable are a positive result, because lower stance time is related with more walking stability and lower falls risk, besides that, speed is considering the sixth vital signal. To complete, LRI is an variable related with SSWS, and the closer of 100% more pendular and less energy cost of walking is expended (OWING & GRABINER, 2004; FRITZ & LUSARDI, 2009; PEYRÉ-

TARTARUGA & MONTEIRO, 2016). Finally, the improvement and maintain of axial trunk and pelvis coordination associated with mobility and spatiotemporal variables are important to higher independence of people with PD.

Limitations

This study has some limitations such: 1) no have the same number of sample in control group compared to interventions; 2) the control regarding to participants physical activities level on baseline (very active, active, inactive and sedentary); 3) the control regarding of physical activity in the participants of control group during the 11 weeks; and 4) The volunteers with PD of the present study were classified with mild-to-moderate PD.

We suggest future studies to evaluated trunk and pelvis coordination in people with PD with a specific movement of dance, and analyses of effects of dance and nordic walking in biomechanics of complex trunk-pelvis of subjects with severe PD.

4.5 CONCLUSION

Our findings demonstrate that the intergirdle (trunk and pelvis) biomechanics was improved in both interventions. Nevertheless, the NW physical training was able to change the coordinative pattern in people with PD. These finding are important to PD independency and can contribute to exercise programs applied to individuals with PD.

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SUPPLEMENT MATERIAL 4.1

TÍTULO DA PESQUISA: EFEITOS DE DIFERENTES TERAPIAS FÍSICAS E DA DANÇA NOS PARÂMETROS CLÍNICO-FUNCIONAIS, NA QUALIDADE ECOGRÁFICA MUSCULAR, NO MECÂNISMO PENDULAR DA MARCHA E NÍVEIS SÉRICOS DE BDNF EM PESSOAS COM DOENÇA DE PARKINSON COM CAMPTOCORMIA OU SÍNDROME DE PISA.

Pesquisador Responsável: PROFº DRº. LEONARDO ALEXANDRE PEYRÉ TARTARUGA

NOME DO PARTICIPANTE:_____

Você está sendo convidado a participar de uma pesquisa cujo objetivo é analisar os efeitos de diferentes terapias físicas (Jogging aquático, Fisioterapia neurofuncional – exercícios para pacientes neurológicos - e Caminhada nórdica) e de Dança e comparar com exercícios domiciliares não supervisionados nos parâmetros clínico-funcionais (avaliações que medem o quanto você é independente para suas atividades do dia a dia), equilíbrio postural (capacidade de ficar em pé sem desequilibrar), na qualidade ecográfica muscular (avaliação da espessura muscular da coxa, para avaliar a força dos músculos dessa região), no mecanismo pendular da caminhada (como você caminha) e em níveis séricos de BDNF (avaliação da presença de uma substância indicadora de função dos neurônios) em pessoas com doença de Parkinson com camptocormia (desvio postural onde ocorre uma inclinação do corpo para frente) ou Síndrome de Pisa (desvio postural onde ocorre uma inclinação lateral do corpo).

Caso você aceite participar da pesquisa, irá participar de um grupo de atividades de caminhada nórdica, de dança, de fisioterapia (onde aprenderá exercícios de alongamentos e de força muscular) ou de jogging aquático. Os grupos serão compostos por 20 participantes e serão divididos pelos pesquisadores, através de um sorteio. As aulas terão a duração de 30 a 60 minutos, de uma a duas vezes por semana, de seis meses a 1 ano. Esta pesquisa será realizada no Laboratório de Pesquisa do Exercício (LAPEX), na Escola de Educação Física, Fisioterapia e Dança e no Hospital de Clínicas de Porto Alegre (HCPA).

Além de praticar as atividades físicas de 1 a duas vezes por semana, por seis meses a um ano, deverá participar das seguintes avaliações: responder a questionários; avaliar seu peso e estatura; participar de testes de caminhada na esteira, em diferentes velocidades e inclinações, e em corredor demarcado de 15 metros em participar de testes de flexibilidade e força (que avaliam a capacidade do músculo de se alongar e de vencer uma resistência imposta pelo avaliador); participar de testes de postura (permanecer em pé sem desequilibrar de forma mais reta possível); coleta sanguínea (será coletada uma amostra de sangue da veia do seu braço, para verificar a presença de uma substância indicadora de função dos neurônios); testes de ecografia muscular (permanecer deitado, enquanto é posicionada uma sonda na sua musculatura).

Os questionários aplicados serão a escala motora UPDRS III (que avalia o quanto a Doença de Parkinson está afetando o seu dia a dia), a escala deHoehn & Yahr (que avalia o quanto a Doença de Parkinson está progredindo), o questionário PDQ-39 (que avalia como você considera que está a sua qualidade de vida), o teste TUG (que avalia o quanto você se movimenta de um lado para o outro, onde você levantará de uma cadeira, caminhará três metros e dará a volta em um obstáculo e

sentará novamente. Durante este teste, o tempo será cronometrado) e a análise cinemática da caminhada (você irá caminhar na esteira ergométrica por dois minutos em diferentes velocidades e, enquanto caminha, será filmado; serão colocados marcadores esféricos nos braços, pernas e tronco).

As avaliações serão realizadas antes, durante e após o período de participação na prática das atividades. Você terá que visitar o Laboratório três vezes (uma hora e meia de duração cada visita), a cada 4 meses, para realizar essas avaliações.

O estudo apresenta um risco considerado mínimo pelo constrangimento eventual que você possa ter ao responder as perguntas dos questionários e algum desconforto na participação nas avaliações. Também é reconhecido um risco considerado mínimo na execução dos movimentos de dança, durante os testes de caminhada e de jogging, assim como, na realização de alguns testes para testar sua postura ou evolução da sua doença. Dentre estes, estão possíveis perdas no equilíbrio, que serão amenizadas pela supervisão constante dos professores, monitores e avaliadores durante toda a avaliação e atividades em grupo. Em relação à coleta de sangue os riscos são mínimos, podendo ocorrer um desconforto no momento da perfuração da agulha, podendo haver um pequeno hematoma no local. Durante as coletas, terá a presença de um médico do LAPEX/UFRGS, para acompanhamento dos testes, caso seja necessário. Caso você se sinta constrangido ou desconfortável em alguma das etapa dos procedimentos de coleta de dados, poderá abandonar a pesquisa em qualquer momento.

O benefício direto do estudo está relacionado à possibilidade de você aprimorar seu equilíbrio, postura e qualidade na caminhada, melhorando a sua qualidade de vida e sua aptidão física visto que as intervenções realizadas podem ser métodos complementares na sua reabilitação.

O presente documento é baseado no item IV das Diretrizes e Normas Regulamentadoras para a pesquisa em saúde, do Conselho Nacional de Saúde (Resolução 466/12), e será assinado em duas vias, de igual teor, ficando uma via em seu poder ou de seu representante legal e outra com o pesquisador responsável. Os seus dados serão sempre tratados com confidencialmente, você não será identificado(a) por nome, e os resultados deste estudo serão usados para fins científicos.

Sua participação no estudo é voluntária, de forma que, caso você decida não participar, você não terá nenhum comprometimento por esta decisão. Você não terá custo e nem receberá por participar. Se necessário, os gastos referentes ao transporte poderão ser ressarcidos conforme combinação com o pesquisador responsável pela pesquisa. Sua participação não é obrigatória e, a qualquer momento, poderá desistir e retirar seu consentimento.

Caso você tenha dúvidas, poderá entrar em contato com o pesquisador responsável Prof. Dr. Leonardo Alexandre Peyré-Tartaruga, pelo telefone (51) 984063793 ou (51) 3308-5817 (Escola de Educação Física, Fisioterapia e Dança – Rua Felizardo, 750, Jardim Botânico – POA/RS); ou com os pesquisadores Profª. Drª. Flávia Gomes Martinez, Profa. Dra. Aline Haas, Prof. Dr. Luciano Palmeiro Rodrigues pelo telefone (51) 3308-5817 (Laboratório de Pesquisa do Exercício, da Escola de Educação Física, Fisioterapia e Dança, UFRGS); ou Comitê de Ética em Pesquisa da UFRGS (Av. Paulo Gama, 110 - Sala 317 – POA/RS) pelo telefone (51) 3308-3738; ou com o Comitê de Ética em Pesquisa do Hospital de Clínicas de Porto Alegre (HCPA), pelo telefone (51) 33597640, ou no 2º andar do HCPA, sala 2227, de segunda à sexta, das 8h às 17h.

Declaração do paciente

Eu,_____, fui informado dos objetivos da pesquisa acima de maneira clara, tendo tempo para ler e pensar sobre a informação contida no termo de consentimento antes de participar do estudo. Recebi informação a respeito dos procedimentos de avaliação realizados e esclareci minhas dúvidas. O pesquisador responsável pela pesquisa certificou-me também de que todos os dados coletados serão mantidos em anonimato e de que a minha privacidade será mantida. Também sei que caso existam gastos adicionais, estes serão absorvidos pelo orçamento da pesquisa. Caso tiver novas perguntas sobre este estudo, poderei entrar em contato com o pesquisador responsável pelo projeto, nos telefones e endereço informados acima, para qualquer pergunta sobre meus direitos como participante. Declaro que recebi cópia do presente Termo de Consentimento.

_____

Data: / / Assinatura do Participante

_____

Assinatura do Pesquisador Responsável

SUPPLEMENT MATERIAL 4.3

CONSORT CHECKLIST

Although this is a non-randomized control study the structure was based on CONSORT check list. The sections of randomized study was not filled.

CONSORT CHECKLIST

Table. CONSORT 2010 Checklist of Information to Include When Reporting a Randomized Trial[a]

Section and Topic	Item No.	Checklist Item	Reported on Page No.
Title and abstract			
	1a	Identification as a randomized trial in the title	-
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	97
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	98;99;100
	2b	Specific objectives or hypotheses	100
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	101
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	-
Participants	4a	Eligibility criteria for participants	101
	4b	Settings and locations where the data were collected	102
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	104
Outcomes	6a	Completely defined prespecified primary and secondary outcome measures, including how and when they were assessed	103
	6b	Any changes to trial outcomes after the trial commenced, with reasons	-
Sample size	7a	How sample size was determined	102
	7b	When applicable, explanation of any interim analyses and stopping guidelines	-
Randomization Sequence generation	8a	Method used to generate the random allocation sequence	-
	8b	Type of randomization; details of any restriction (such as blocking and block size)	-
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	-
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	-
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	-
	11b	If relevant, description of the similarity of interventions	106
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	109
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	109
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analyzed for the primary outcome	111
	13b	For each group, losses and exclusions after randomization, together with reasons	111
Recruitment	14a	Dates defining the periods of recruitment and follow-up	-
	14b	Why the trial ended or was stopped	-
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	112
Numbers analyzed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	114
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	113;120;121
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	-
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing prespecified from exploratory	113;120;121
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	-
Comment			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	133
Generalizability	21	Generalizability (external validity, applicability) of the trial findings	133
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	133
Other information			
Registration	23	Registration number and name of trial registry	79
Protocol	24	Where the full trial protocol can be accessed, if available	79
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	133

[a]We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomized trials, noninferiority and equivalence trials, nonpharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up-to-date references relevant to this checklist, see http://www.consort-statement.org.

SUPPLEMENT MATERIAL 4.3

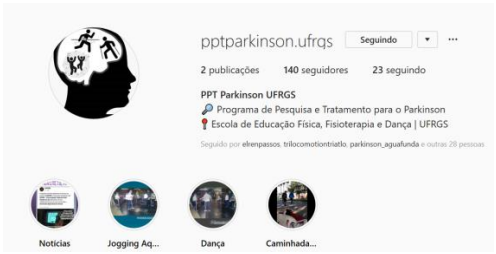
ESTADIAMENTO SINTOMAS	
Estágio 0	Sem sinais da doença
Estágio 1	Doença unilateral
Estágio 1,5	Acometimento unilateral e axial
Estágio 2	Acometimento bilateral, sem prejuízo do equilíbrio
Estágio 2,5	Leve acometimento bilateral, recuperação no teste de equilíbrio (“*pull test*”)
Estágio 3	Acometimento leve a moderado; alguma instabilidade postural; independente fisicamente.
Estágio 4	Acometimento severo; ainda capaz de caminhar ou permanecer em pé sem auxílio.
Estágio 5	Usando cadeira de rodas ou acamado exceto se auxiliado.

SUPPLEMENT MATERIAL 4.4

Scientific divulgation

Facebook:

Instagram:



Poster:

Jornal

BEM-ESTAR

NO RITMO DA SAÚDE

Neusa e Elder dão um show na pista

FOTOS TADEU VILANI

Cláudio baila com a profe Rebeca

"FICAR TRAVADO EM CASA SÓ PIORA"

Na pesquisa, a professora Rebeca Donida conta que um dos principais objetivos é que os alunos foquem na música que está tocando. Assim, não prestam atenção nos tremores ou nas demais reações da doença. O chamado freezing, por exemplo, é um dos sintomas do Parkinson. Os pacientes "congelam", e então caem para trás, ou vão para frente.

– Quando acontece o freezing, dizemos para eles pensarem em uma música para sair do congelamento. Se ficam pensando em caminhar e sair do lugar, não dá certo – diz a professora.

Distração

Rebeca relata que, ao ingressarem na atividade, os pacientes contam que vivem cansados, são desequilibrados, caem com certa frequência e não têm muita vontade de sair de casa, sintomas que costumam melhorar com as aulas.

Neusa Ramos de Souza, 84 anos, está no projeto desde o início deste ano.

– Gosto muito de vir, porque me distraio e nos divertimos. Moro sozinha e fico muito em casa – aponta.

Benefícios

O benefício da dança para o corpo e para o condicionamento é importante para Elder Rocha, 47 anos, há dois anos nas aulas.

– Ajuda na flexibilidade, também. Ficar travado em casa só piora. Isso até se torna uma competição saudável, porque vemos os colegas fazendo bem, e também quero fazer o melhor – diz Elder.

Ao final da aula, Rebeca diz um mantra, repetido pelos alunos, em coro: "Cada vez que a gente vem aqui, ou que vá fazer algo na nossa vida, que se doe o máximo. No mínimo, no mínimo, o máximo!".

PARA PARTICIPAR

/// O projeto é semestral. Inscrições para a próxima turma abrirão somente em fevereiro de 2019.

/// Informações podem ser solicitadas pelo e-mail dancaparkinsonesefid@gmail.com

Pacientes com Parkinson têm aulas gratuitas de dança na UFRGS para melhorar a flexibilidade, a força e o equilíbrio.

MARIA EUGENIA BOFILL
maria.bofill@diariogaucho.com.br

No som tocava Eu Só Quero um Xodó, de Dominguinhos, e na sala 7 do Campus Olímpico da Universidade Federal do Rio Grande do Sul (UFRGS), cinco casais dançavam um forró. Além da identificação com a música e o gosto pela dança, os alunos, com idades entre 47 e 84 anos, tinham outras semelhanças: todos têm Parkison (*distúrbio do sistema nervoso central que afeta o movimento, muitas vezes incluindo tremores*). E todas as segundas e quartas-feiras frequentam as aulas da professora Rebeca Donida, 26 anos, com o objetivo de lidarem melhor com a doença.

As aulas fazem parte do Programa de Treinamento para Parkinson, uma parceria da UFRGS com o SUS. Os pacientes têm aulas gratuitas duas vezes por semana, num total de 24 encontros, onde trabalham, principalmente, a flexibilidade, a força e o equilíbrio por meio da dança – há também as opções de *jogging aquático (corrida e caminhada na piscina)* e a caminhada nórdica (*tipo de caminhada com bastões*). Após completar as aulas, os pacientes podem seguir no grupo de extensão, onde há só as aulas, sem a pesquisa.

Vergonha

Os encontros têm início com um alongamento. Depois, na barra, são feitos exercícios de equilíbrio, de transferência de peso e de mobilidade. Só então os alunos estão prontos para dançar.

Dispostos em frente ao espelho, seguem as orientações da professora Rebeca. Inicialmente, dançam sozinhos, depois, em pares.

– No dia a dia, a gente nota como a dança é boa para eles. Percebemos que as pessoas chegavam depressivas. Devido ao Parkinson, elas tinham vergonha de saírem de casa, achavam que iriam derrubar as coisas ou cair. Mas, quando encontram colegas iguais, sentem-se parte de um todo – afirma Rebeca.

Superação

Cláudio Fakredin, 76 anos, teve o Parkinson diagnosticado há cerca de três anos. Na época, perdeu a flexibilidade e não conseguia mais montar no cavalo sozinho. O aposentado, que mostra ser um grande bailarino, está há cerca de oito meses na dança. No primeiro semestre, passou pela pesquisa, e agora está na extensão.

– Fez uma diferença muito grande na minha vida. Superei todos os resultados, em flexibilidade e alongamento. Agora, já monto no cavalo sozinho – conta.

Os participantes fazem encontros fora das aulas, trocam dicas sobre o tratamento e conversam diariamente no grupo do WhatsApp que criaram.

– Temos uma relação de família aqui. Isso é muito importante para a gente – afirma Cláudio.

Apelidado de Maridão, Waldir Palma, 74 anos, não tem Parkinson, mas é o par da aposentada Dora Palma, 71 anos, na dança.

– Ele vinha me buscar e ficava esperando no carro. Então, começou a participar também. Estou há dois anos em tratamento e o médico não aumentou as doses. A dança é importante para mim. Já sou alegre, e, aqui, fico ainda mais – relata.

EM-ESTAR

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...da a lidar com o Parkinso

...oferece, na Capital, aulas que melhoram a flexibilidade, a força e o equilíbrio de pa

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"FICAR TRAVADO EM CASA SÓ PIORA"

Na pesquisa, Rebeca conta que um dos principais objetivos é que os alunos foquem na música que está tocando, assim não prestam atenção em tremores e reações da doença. O chamado freezing, por exemplo, é um dos sintomas. Os pacientes "congelam", e então caem para trás, ou vão para frente.

– Quando acontece o freezing, dizemos para eles pensarem em uma música para sair do congelamento. Se ficam pensando em caminhar e sair do lugar, não dá certo – diz a professora.

Segundo Rebeca, ao ingressarem na atividade, os pacientes relatam que vivem cansados, são desequilibrados, caem com frequência e não têm vontade de sair de casa, sintomas que costumam melhorar após as aulas.

Neusa Ramos de Souza, 84 anos, está no projeto desde o início deste ano.

– Gosto muito de vir, porque me distraio e nos divertimos. Moro sozinha e fico muito em casa – aponta.

O benefício da dança para o corpo e para o condicionamento é importante para Elder Rocha, 47 anos, há dois anos nas aulas.

– Ajuda na flexibilidade, também. Ficar travado em casa só piora. Isso até se torna uma competição saudável, porque vemos os colegas fazendo bem, e também quero fazer o melhor, quero estar como ele – diz Elder.

No fim da aula, Rebeca e os alunos repetem um mantra: "Cada vez que a gente vem aqui, ou que vá fazer algo na nossa vida, que se doe o máximo. No mínimo, o máximo!".

SUPPLEMENT MATERIAL 4.5

Sample size determined using data from Castagna et al. 2016.
ROM Pelvis Parkinson disease group versus control group in SSWS.

F tests -	ANOVA: Repeated measures, within-between interaction		
Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	.64
	α err prob	=	.05
	Power (1-β err prob)	=	.80
	Number of groups	=	3
	Number of measurements	=	2
	Corr among rep measures	=	.5
	Nonsphericity correction ε	=	1
Output:	Noncentrality parameter λ	=	19.6608000
	Critical F	=	4.2564947
	Numerator df	=	2.0000000
	Denominator df	=	9.0000000
	Total sample size	=	12
	Actual power	=	.9225262

Sample size determined by Gougeon and Nantel 2017.
ROM trunk horizontal Parkinson disease group with versus without poles of NW.

F tests -	ANOVA: Repeated measures, within-between interaction		
Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	.43
	α err prob	=	.05
	Power (1-β err prob)	=	.95
	Number of groups	=	3
	Number of measurements	=	2
	Corr among rep measures	=	.5
	Nonsphericity correction ε	=	1
Output:	Noncentrality parameter λ	=	19.9692000
	Critical F	=	3.4028261
	Numerator df	=	2.0000000
	Denominator df	=	24.0000000
	Total sample size	=	27
	Actual power	=	.9710979

Sample size determined by Hulbert et al. 2017.
ROM pelvis during turning after dance classes Parkinson disease versus control

F tests -	ANOVA: Repeated measures, within-between interaction		
Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	1,62
	α err prob	=	.05
	Power (1-β err prob)	=	.95
	Number of groups	=	3
	Number of measurements	=	2
	Corr among rep measures	=	.5
	Nonsphericity correction ε	=	1
Output:	Noncentrality parameter λ	=	36.0000000
	Critical F	=	5.1432528
	Numerator df	=	2.0000000
	Denominator df	=	6.0000000
	Total sample size	=	9
	Actual power	=	.9853857

ROM trunk during turning after dance classes Parkinson disease versus control

F tests - ANOVA: Repeated measures, within-between interaction

Analysis:	A priori: Compute required sample size	
Input:	Effect size f	= 5.38
	α err prob	= .05
	Power (1-β err prob)	= .95
	Number of groups	= 3
	Number of measurements	= 2
	Corr among rep measures	= .5
	Nonsphericity correction ε	= 1
Output:	Noncentrality parameter λ	= 694.6656
	Critical F	= 9.5520945
	Numerator df	= 2.0000000
	Denominator df	= 3.0000000
	Total sample size	= 6
	Actual power	= 1.0000000

SUPPLEMENT MATERIAL 4.6

ESCALA UNIFICADA DE AVALIAÇÃO PARA DOENÇA DE PARKINSON

Nome: _____ Data do dia: _____
Observações:

Escala UPDRS (Parte III): Exame Motor
18. Fala
. Normal.
1. Leve perda da expressão, dicção e/ou volume.
2. Monótona, inarticulada mas compreensível; moderadamente prejudicada.
3. Marcadamente prejudicada, difícil de compreender.
4. Ininteligível.

19. Expressão Facial
. Normal.
1. Mínima hipomímia, podendo ser “face de pôquer”.
2. Leve mas definida diminuição anormal da expressão facial.
3. Moderada hipomímia; lábios separados algumas vezes.
4. Facies em máscara ou fixa com severa ou completa perda da expressão facial; lábios separados mais de .5 cm.

2. Tremor de repouso
. Ausente.
1. Leve e raramente presente.
2. Leve em amplitude e persistente. Ou moderado na amplitude, mas somente intermitentemente presente.
3. Moderada amplitude e presente a maior parte do tempo.
4. Marcada amplitude e presente a maior parte do tempo.
Face, lábios e queixo:
Mão direita:
Mão esquerda:
Pé direito:
Pé esquerdo:

21. Tremor postural e de ação das mãos
. Ausente.
1. Leve, presente com a ação.
2. Moderado em amplitude, presente com a ação.
3. Moderado em amplitude, postural e de ação.
4. Marcado em amplitude, interferindo com a alimentação.
Direita:
Esquerda:

22. Rigidez *[movimento passivo das articulações maiores com o paciente relaxado em posição sentada, ignore a roda denteada]*
. Ausente
1. Leve ou detectável só quando ativado por outros movimentos.
2. Leve a moderada.
3. Marcada, mas total extensão de movimentos obtida facilmente.
4. Severa, total extensão de movimentos obtida com dificuldade.
Pescoço:
Superior direita:

Superior esquerda:
Inferior direita:
Inferior esquerda:

23. "Finger Taps" *[paciente bate o polegar com o dedo indicador em rápida sucessão com a maior amplitude possível, cada mão separadamente]*
. Normal
1. Um tanto quanto lento e/ ou reduzido na amplitude.
2. Moderadamente prejudicado. Cansaço definido e inicial. Pode apresentar pausas ocasionais durante o movimento.
3. Prejuízo severo. Freqüente hesitação ao iniciar o movimento ou pausas no movimento continuado.
4. Dificilmente pode executar a tarefa.
Direita:
Esquerda:

24. Movimentos manuais *[Paciente abre e fecha as mãos sucessivamente e rapidamente com a maior amplitude possível, cada mão separadamente]*
. Normal
1. Levemente lento e/ ou reduzido na amplitude.
2. Moderadamente prejudicado. Cansaço nítido e inicial. Pode ter pausas ocasionais no movimento.
3. Prejuízo severo. Frequente hesitação ao iniciar movimentos ou pausas no movimento continuado.
4. Dificilmente pode executar a tarefa.
Direita:
Esquerda:

25. Movimentos rápidos alternantes das mãos *[movimentos de pronação-supinação das mãos, verticalmente ou horizontalmente, com a maior amplitude possível, cada mão separadamente]*
. Normal
1. Levemente lento e/ ou reduzido na amplitude.
2. Moderadamente prejudicado. Cansaço nítido e inicial. Pode ter pausas ocasionais no movimento.
3. Prejuízo severo. Frequente hesitação ao iniciar movimentos ou pausas no movimento continuado.
4. Dificilmente pode executar a tarefa.
Direita:
Esquerda:

26. Agilidade das pernas *[paciente bate sucessivamente e rapidamente o calcanhar no chão, erguendo totalmente a perna. Amplitude deve ser aproximadamente de 8 cm].*
. Normal.
1. Levemente lento e/ ou reduzido na amplitude.
2. Moderadamente prejudicado. Cansaço nítido e inicial. Pode ter pausas ocasionais no movimento.
3. Prejuízo severo. Frequente hesitação ao iniciar movimentos ou pausas no movimento continuado.
4. Dificilmente pode executar a tarefa.
Direita:
Esquerda:

27. Ao levantar-se da cadeira *[paciente tentando levantar de uma cadeira de metal ou madeira reta com os braços mantidos cruzados]*
. Normal
1. Lento; ou pode necessitar mais que uma tentativa.
2. Impulsiona-se com os braços da cadeira.
3. Tende a cair para trás e pode ter que tentar mais que uma vez, mas pode levantar sem auxílio.
4. Sem capacidade de levantar sem auxílio.

28. Postura
. Normalmente ereto.
1. Não fica totalmente ereto, postura levemente inclinada, poderia ser normal para pessoas mais idosas.
2. Coloca-se moderadamente inclinado, definidamente anormal; pode estar ligeiramente inclinado para um lado.
3. Postura severamente inclinada com cifose; pode estar moderadamente inclinado para um lado.

4. Marcada flexão com extrema anormalidade de postura.

29. Marcha
. Normal
1. Caminha lentamente, pode ter marcha arrastada com passos curtos, mas sem festinação (acelerando os passos) ou propulsão.
2. Caminha com dificuldade, mas requer pouca ou nenhuma assistência; pode ter alguma festinação, passos curtos ou propulsão.
3. Severo distúrbio da marcha, necessitando auxílio.
4. Não pode caminhar, mesmo com auxílio.

3. Estabilidade Postural *[Resposta ao súbito deslocamento posterior produzido por puxada nos ombros enquanto o paciente está de pé com os olhos abertos e os pés ligeiramente separados. Paciente é preparado, podendo ser repetido algumas vezes a manobra]*
. Normal
1. Retropulsão, mas volta à posição original sem auxílio.
2. Ausência de resposta postural, podendo cair se não for amparado pelo examinador.
3. Muito instável, tende a perder o equilíbrio espontaneamente.
4. Não consegue parar sem auxílio.

31. Bradicinesia e hipocinesias corporais *[Combinando lentificação, hesitação, diminuição do balanço dos braços, pequena amplitude, e pobreza dos movimentos em geral]*
. Sem.
1. Mínima lentificação, dando ao movimento um caráter “deliberado”; poderia ser normal para algumas pessoas. Possivelmente amplitude reduzida.
2. Leve grau de lentificação e pobreza dos movimentos que é definitivamente anormal. Alternativamente, alguma redução da amplitude.
3. Moderada lentificação, pobreza ou diminuição da amplitude dos movimentos.
4. Marcada lentificação, pobreza ou diminuição da amplitude dos

SUPPLEMENT MATERIAL 4.7

Supplementary Material – TIDieR Items
Dance Intervention

* The focus of TIDieR is on reporting details of the intervention elements (and where relevant, comparison elements) of a study. Other elements and methodological features of studies are covered by other reporting statements and checklists and have not been duplicated as part of the TIDieR checklist. When a **randomised trial** is being reported, the TIDieR checklist should be used in conjunction with the CONSORT statement (see www.consort-statement.org) as an extension of **Item 5 of the CONSORT 2010 Statement.** When a **clinical trialprotocol** is being reported, the TIDieR checklist should be used in conjunction with the SPIRIT statement as an extension of **Item 11 of the SPIRIT 2013 Statement** (see www.spirit-statement.org). For alternate study designs, TIDieR can be used in conjunction with the appropriate checklist for that study design (see www.equator-network.org).

	BRIEF NAME	
1	Provide the name or a phrase that describes the intervention.	Dance Intervention
	WHY	
2	Describe any rationale, theory, or goal of the elements essential to the intervention.	The dance is a group activity, that stimulates the physiological, social, affective and cognitive aspects. It is an activity, capable of promoting physical and mental well- being.
	WHAT	
3	Materials: Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. Provide information on where the materials can be accessed (e.g. online appendix, URL).	Soundbox, cellular, auxiliary cable, ribbons crepes, ballet bars and chairs.
4	Procedures: Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities.	The dance program consisted of 4 adaptation classes, 9 lessons inspired by the Forró rhythm, and 9 by the Samba rhythm.The classes were divided in four parts: heating in chairs, standing activities with the help of the bar, activities of displacement in front of the mirror and double activities (table 1; 2).
	WHO PROVIDED	
5	For each category of intervention provider (e.g. psychologist, nursing assistant), describe their expertise, background and any specific training given.	The evaluators and teachers of the program were undergraduate, master and doctoral students of the Universidade Federal do Rio Grande do Sul, of the courses of Dance, Physical Education and Physiotherapy.A training was conducted, given by students, so that the evaluations were carried out in a standardized way.

	HOW	
6	Describe the modes of delivery (e.g. face-to-face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group.	The instructions of the dance classes were given initially in a group, by the teacher, always of the classes.During the activities, the teacher provided additional instructions and feedback for some students, face-to-face.
	WHERE	
7	Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features.	The classes took place in a classroom of the Universidade Federal do Rio Grande do Sul. The room has a mirror, 2 ballet bars, chairs, fans and air conditioning.The floor was lined with linoleum, suitable for activity.
	WHEN and HOW MUCH	
8	Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose.	The volunteers trained in the period of 11 weeks, twice a week, totaling 22 sessions (4 familiarization and 18 dance class) at 9 a.m., the peak of the medication was respected. The sessions lasted 60 minutes. The classes were divided into 4 parts, each 10 to 15 minutes and the class were controlled by intensities (different bpms) and volume.
	TAILORING	
9	If the intervention was planned to be personalised, titrated or adapted, then describe what, why, when, and how.	There was no individual personalization for the intervention, because it was a group class.
	MODIFICATIONS	
10	If the intervention was modified during the course of the study, describe the changes (what, why, when, and how).	There were no modifications in the intervention, the model had already been tested in previous semesters and was adapted for the present study.
	HOW WELL	
11	Planned: If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them.	The subjects should have a minimum of 75% attendance in classes, or they could not be part of the evaluation group. All sample losses were described. To stimulate the frequency, warnings were made in all classes about the importance of the presence of the subjects, for the research. Moreover, the group stimulus and affective bonds proved to be effective in maintaining the group's frequency.
12	Actual: If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned.	The exclusion criteria in case of frequency below 75% of the classes were maintained during the entire intervention

Table 1. Adaptation class descriptions

Session	Objective	Dance Class
S1	Socialization and stimulate rhythmic movements	Name presentation, rhythmic movements sit on the chair, Unloading of weight with the help of the bar; displacements in the forró rhythm
S2	Socialization and stimulate double rhythmic movements	Playful activity with balloon in Forró rhythm; Double activities: Walk sideways in a straight line on the ground, pass an obstacle in Forró rhythm.
S3	Socialization and stimulate rhythmic movements	Rhythmic movements sit on the chair, Unloading of weight with the help of the bar; Task in quadrants (moving arms, moving legs, shaking head) in Forró rhythm; displacements in the forró rhythm
S4	Socialization; stimulate rhythmic movements and rotation movements	Rhythmic movements sit on the chair, Unloading of weight with the help of the bar; Sequence of body weight changes: Touching the right and left foot on the front 2x of each; Touch one foot from behind, perform lower limb abduction; If possible turn. In Forró and Samba rhythmics.

Table 2. Class descriptions

Session	General volume= 60´ General intensity: Different bpms	Group volume (%) of 6MWT	BORG
S5	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: comfortable 15´ Part four: Intermediary 10´ Final relaxation	A2 = 70	B_1:Easy B_2:Difficult
S6	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: Intermediary/ fast 15´ Part four: Intermediary 10´ Final relaxation	A2 = 70	B_1: Easy B_2:Moderate
S7	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: comfortable 15´ Part four: Intermediary 10´ Final relaxation	A2 = 80	B_1: Easy B_2: Easy
S8	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: comfortable/ fast 15´ Part four: comfortable/ fast 10´ Final relaxation	A2 = 85	B_1:1 Easy B_2: Easy
S9	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: comfortable/ intermediary 15´ Part four: comfortable/ intermediary 10´ Final relaxation	A2 = 85	B_1: Easy B_2:Moderate
S10	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: intermediary / fast 15´ Part four: intermediary 10´ Final relaxation	A2 = 85	B_1: Easy B_2: Easy
S11	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: intermediary / fast 15´ Part four: intermediary 10´ Final relaxation	A2 = 75	B_1:Easy B_2: Easy

S12	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: intermediary / fast 15´ Part four: intermediary 10´ Final relaxation	A2 = 80	B_1: Easy B_2: Easy
S13	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: intermediary / fast 15´ Part four: intermediary 10´ Final relaxation	A2 = 85	B_1: Easy B_2: Easy
S14	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: comfortable/intermediary 15´ Part four: fast/ maximum 10´ Final relaxation	A2 = 90	B_1: Easy B_2: Easy
S15	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: comfortable/intermediary 15´ Part four: fast/ maximum 10´ Final relaxation	A2 = 95	B_1: Easy B_2: Easy
S16	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: comfortable 15´ Part four: comfortable 10´ Final relaxation	A2 = 85	B_1: Easy B_2: Easy
S17	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: Intermediary/ fast 15´ Part four: Intermediary 10´ Final relaxation	A2 = 85	B_1: Easy B_2:Moderate
S18	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: comfortable/ intermediary 15´ Part four: intermediary /maximum 10´ Final relaxation	A2 = 90	B_1: Easy B_2:Moderate
S19	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: comfortable/ intermediary 15´ Part four: intermediary /maximum 10´ Final relaxation	A2 = 95	B_1: Easy B_2: Easy
S20	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: comfortable/ fast 15´ Part four: comfortable/ fast 10´ Final relaxation	A2 = 95	B_1: Easy B_2: Easy
S21	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: comfortable/ fast 15´ Part four: comfortable/ fast 10´ Final relaxation	A2 = 100	B_1: Easy B_2: Easy
S22	15´ Part one: comfortable 10´ Part two: comfortable 10´Part three: comfortable/ intermediary 15´ Part four: fast/ maximum 10´ Final relaxation	A2 = 110	B_1: Easy B_2:Moderate

Figure 1 Class Part 1

Figure 2 Class Part1

Figure 3 Class Part 3

Figure 4 Class Part 3

Figure 5 Class Part 4

SUPPLEMENT MATERIAL 4.8

TIDieR Items

* The focus of TIDieR is on reporting details of the intervention elements (and where relevant, comparison elements) of a study. Other elements and methodological features of studies are covered by other reporting statements and checklists and have not been duplicated as part of the TIDieR checklist. When a **randomised trial** is being reported, the TIDieR checklist should be used in conjunction with the CONSORT statement (see www.consort-statement.org) as an extension of **Item 5 of the CONSORT 2010 Statement.** When a **clinical trialprotocol** is being reported, the TIDieR checklist should be used in conjunction with the SPIRIT statement as an extension of **Item 11 of the SPIRIT 2013 Statement** (see www.spirit-statement.org). For alternate study designs, TIDieR can be used in conjunction with the appropriate checklist for that study design (see www.equator-network.org).

	BRIEF NAME	
1	Provide the name or a phrase that describes the intervention.	Nordic Walking intervention
	WHY	
2	Describe any rationale, theory, or goal of the elements essential to the intervention.	The Nordic walking (NW) is a technique advocate for the development of physical fitness and quality of life due to additional benefits. The biomechanical and physiological alterations in walking using poles gives support to our hypothesis that after NW will be difference between the axial coordination
	WHAT	
3	Materials: Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. Provide information on where the materials can be accessed (e.g. online appendix, URL).	Usual Nordic walking poles were used.
4	Procedures: Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities.	The NW program consisted of 4 adaptation classes, 18 classes organized in different intensities and volume (table 1, 2).
	WHO PROVIDED	
5	For each category of intervention provider (e.g. psychologist, nursing assistant), describe their expertise, background and any specific training given.	Professionals of physical education taught classes two times per week, at Mondays and Wednesdays to one group training Nordic walking.
	HOW	
6	Describe the modes of delivery (e.g. face-to-face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group.	The intervention is primarily provided by the primary investigator, a professional of Physical Education with 5 years of clinical experience, trained in providing the intervention throughout the development phase and in pilot testing of the intervention. Alternates designated to take over in case the primary investigator is unable to complete one or more intervention sessions will be professionals of Physical Education and Physiotherapists trained and approved by the

		primary investigator. Training was focus on uniform correction of exercise form, progression and regression of exercises and standard face-to- face adherence reminders.
	WHERE	
7	Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features.	The NW class are provided at athletics track and gymnasium.
	WHEN and HOW MUCH	
8	Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose.	The volunteers trained in the period of 11 weeks, twice a week, totaling 22 sessions (4 familiarization and 18 training) at 9 a.m., the peak of the medication was respected. The sessions lasted 60 minutes. In the familiarization sessions the objective was the learning of the Nordic Walking technique and the training were controlled by intensities (different speeds) and volume (session time) (Figure 1, 2, 3, 4, 5, 6; table 3)
	TAILORING	
9	If the intervention was planned to be personalised, titrated or adapted, then describe what, why, when, and how.	For all intervention Phases the intensity and volume was individualized, respecting the principles of physical training (individuality, adaptation, progression, specificity, continuity).
	MODIFICATIONS	
10	If the intervention was modified during the course of the study, describe the changes (what, why, when, and how).	No modifications happen in the intervention during the study period.
	HOW WELL	
11	Planned: If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them.	The subjects should have a minimum of 75% attendance in classes, or they could not be part of the evaluation group. All sample losses were described. To stimulate the frequency, warnings were made in all classes about the importance of the presence of the subjects, for the research. Moreover, the group stimulus and affective bonds proved to be effective in maintaining the group's frequency.
12	Actual: If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned.	The exclusion criteria in case of frequency below 75% of the classes were maintained during the entire intervention

* We strongly recommend using this checklist in conjunction with the TIDieR guide (see *BMJ* 2014;348:g1687) which contains an explanation and elaboration for each item.

Table 1. Adaptation class descriptions

Session	Objective	Nordic walking
S1	Posture, strengthening of abdomen and balance (winch) + Correction of gait patterns: position of feet, knees and ankles flexion/extension (Squeeze the lemon / kneading grapes).	Posture + Dragging the sticks + Correction of gait patterns: position of feet, knees and ankles flexion/extension (Squeeze the lemon / kneading grapes).
S2	Dissociation of pelvic and scapular girdles (Gingado carioca, samba step) + Coordination of arms and legs (hiking in the forest).	S1 + Trunk rotation and arm swinging + amplitude and arms and legs swinging, with altering limbs.
S3	Range and motion and gait speed (Ayrton Senna)	S1+S2 + Pressure of sticks on the ground (load) + ↑ stride length + Open and closing hands on sticks
S4	Complete technique of Nordic walking (fashion week parade)	Technique of Nordic walking walk in comfortable speed

Table 2. Class periodization and BORG scale descriptions

Session	General volume= 60´ General intensity: Different speeds	Individual volume (%) of 6MWT	BORG
S5	5´ heating 44´= 20´comfortable / 24´ intermediary 11´stretching	A1 = 50 A2 = 70 A3 = 110	B_1: Easy B_2:Moderate
S6	5´ heating 45´= 20´ comfortable / 10´ intermediary / 15´ fast 10´ stretching	A1 = 50 A2 = 70 A3 = 110	B_1: Easy B_2:Moderate
S7	10´ heating 40´= 20´ comfortable 20´ intermediary 10´ stretching	A1 = 60 A2 = 80 A3 = 120	B_1: Easy B_2: Easy
S8	5´ heating 45´= 25´ comfortable/ / 20´ fast 10´ stretching	A1 = 65 A2 = 85 A3 = 125	B_1: Easy B_2:Moderate
S9	5´ heating 44´= 20´comfortable / 24´ intermediary 11´stretching	A1 = 65 A2 = 85 A3 = 125	B_1: Easy B_2:Moderate
S10	5´ heating 45´ 20´ comfortable / 20´ intermediary / 5´ fast 10´ stretching	A1 = 65 A2 = 85 A3 = 125	B_1: Easy B_2: Easy
S11	5´ heating 45´ 20´ comfortable / 10´ intermediary / 15´ fast 10´ stretching	A1 = 55 A2 = 75 A3 = 115	B_1: Easy B_2:Moderate
S12	5´ heating 45´ 20´ comfortable / 10´ intermediary / 15´ fast 10´ stretching	A1 = 60 A2 = 80 A3 = 120	B_1: Easy B_2:Moderate
S13	5´ heating	A1 = 65 A2 = 85	B_1: Easy B_2: Easy

	45´ 20´ comfortable / 10´ intermediary / 15´ fast 10´ stretching	A3 = 125	
S14	10´ heating 41´= 25´ comfortable/ 10´ intermediary / 3´ fast / 3´ jog 10´ stretching	A1 = 70 A2 = 90 A3 = 130	B_1: Easy B_2:Moderate
S15	10´ heating 41´= 25´ comfortable/ 10´ intermediary / 3´ fast / 3´ jog 10´ stretching	A1 = 75 A2 = 95 A3 = 145	B_1: Easy B_2: Easy
S16	10´ heating 40´= 40´ comfortable 10´ stretching	A1 = 65 A2 = 85 A3 = 125	B_1: Easy B_2:Moderate
S17	5´ heating 45´ 20´ comfortable / 10´ intermediary / 15´ fast 10´ stretching	A1 = 65 A2 = 85 A3 = 125	B_1: Easy B_2:Moderate
S18	10´ heating 41´= 25´ comfortable/ 10´ intermediary / 3´ fast / 3´ jog 10´ stretching	A1 = 70 A2 = 90 A3 = 130	B_1: Easy B_2:Moderate
S19	10´ heating 41´= 25´ comfortable/ 10´ intermediary / 3´ fast / 3´ jog 10´ stretching	A1 = 75 A2 = 95 A3 = 135	B_1: Easy B_2: Easy
S20	10´ heating 40´= 20´ comfortable / 20´ fast 10´ stretching	A1 = 75 A2 = 95 A3 = 135	B_1: Easy B_2:Moderate
S21	10´ heating 40´= 20´ comfortable / 20´ fast 10´ stretching	A1 = 80 A2 = 100 A3 = 140	B_1: Easy B_2:Moderate
S22	10´ heating 41´= 25´ comfortable/ 10´ intermediary / 3´ fast / 3´ jog 10´ stretching	A1 = 90 A2 = 110 A3 = 150	B_1: Easy B_2:Moderate

Figure 1 Heating

Figure 2 Heating

Figure 3 Heating

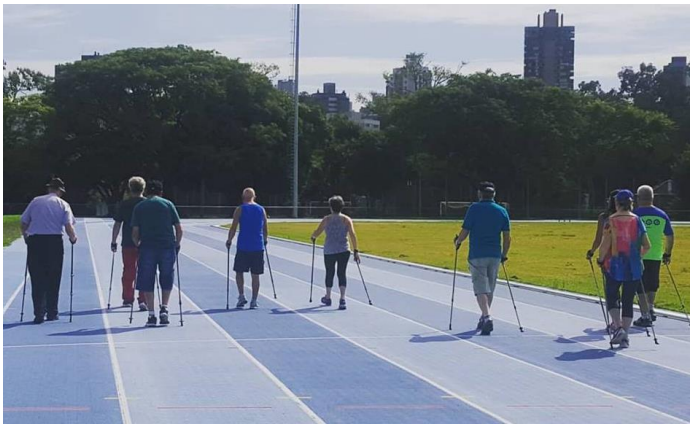
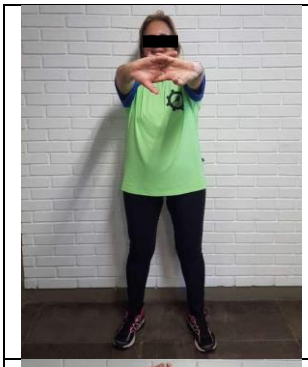
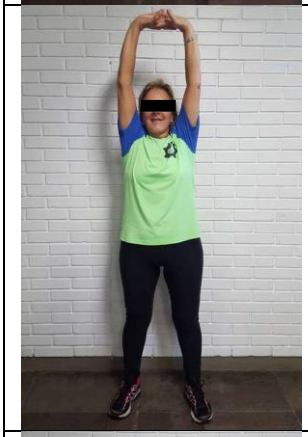
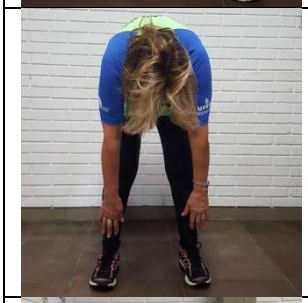
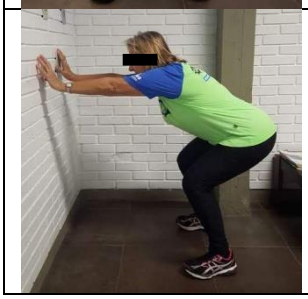


Figure 4 NW Class

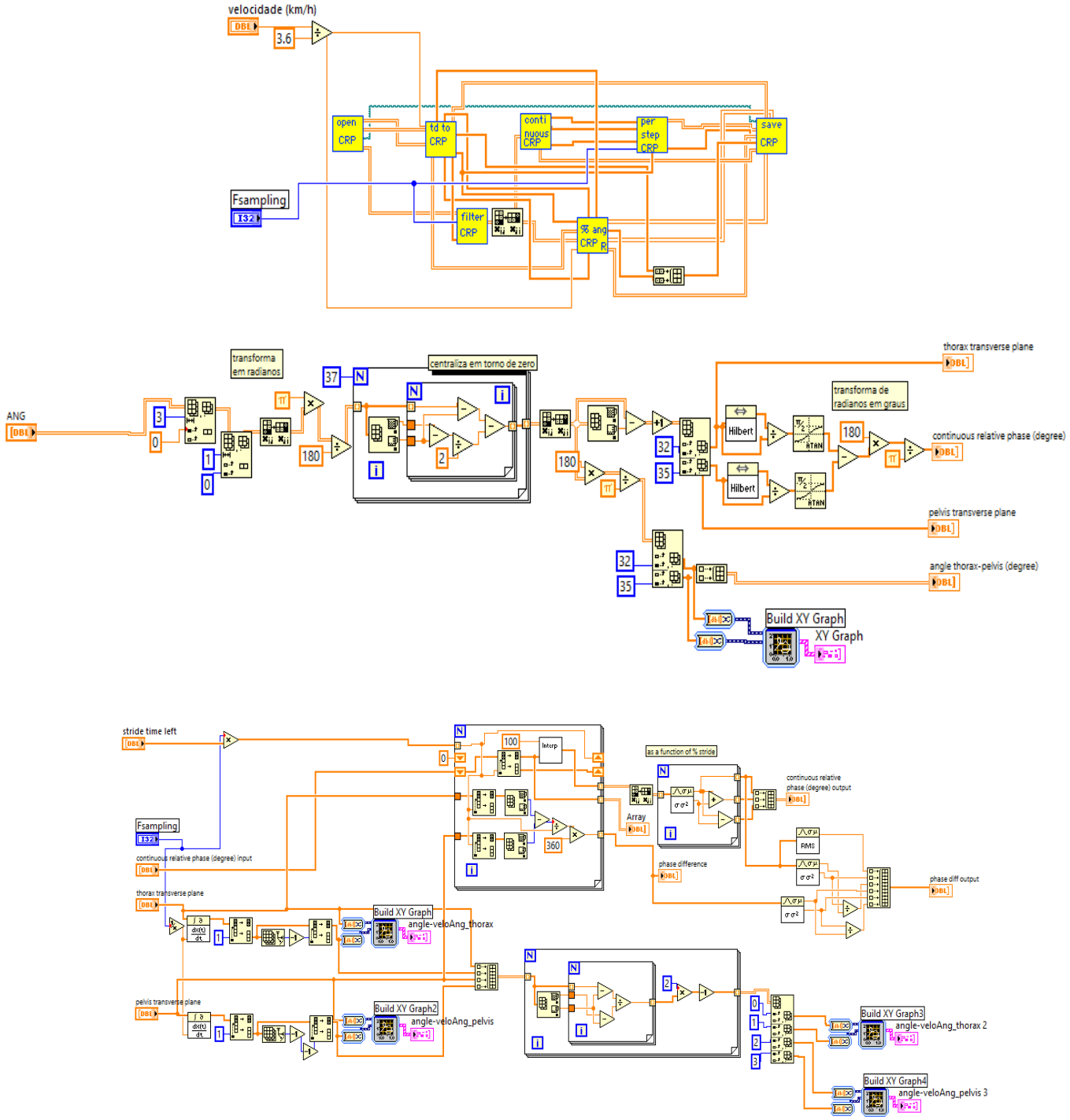
Table 3. Stretching exercises

	Interlace your fingers in front of your body with your palms facing out. Feel elongated shoulders	**Why aerobic activities like walking?** • Reduces the risks of cardiovascular diseases. • Improves strength, endurance, coordination and flexibility. • Improves mood. **Why stretch?** • Relaxes muscles by reducing fatigue. • Decreases joint pressure. • Improves body posture. • Helps increase muscle strength. **Guidance for stretching and walking exercises** • A minimum duration of 20 seconds in each stretching exercise. • Always keep the spine straight. • Keep your eyes on the horizon. • Stretching every day allows for a better result. • Perform the exercises in the "ON" state of the medicine, for greater mobility. • Warm joints with joint movements. • Walk 2 to 3 times a week for 20 to 30 minutes. • Monitor fatigue after exercise. You may feel tired, but not exhausted. • Remember to alternate arms and legs to walk. • Hydrate before, during and after walking. • During the walk, the first contact of the foot with the ground should be that of the heel.
	Interlacing your fingers above your body with your palms facing out.	
	Cross the front of the chest with one arm and press the elbow to the chest. Repeat on the other side.	
	Align the neck to the sides. Turn the neck over the shoulders slowly and as steeply as possible, reversing the senses;	

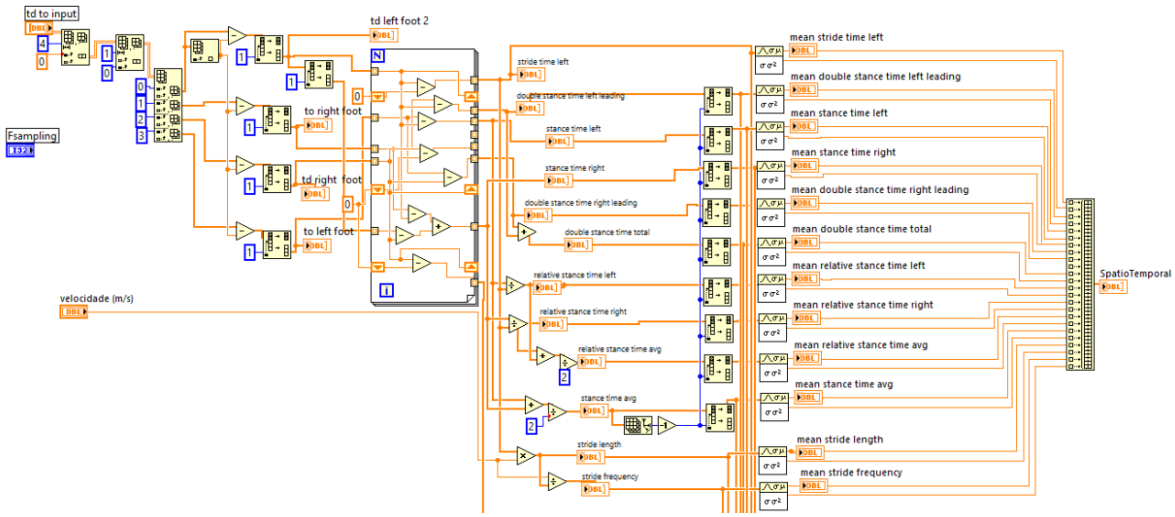
	Take a step sideways, keeping the feet parallel. Bend the left knee and keep the right leg extended. change the position of the legs and redo the exercise.	• The first step of the walk is always the longest, to avoid the episode of freezing.
	Take one step forward with the right leg and one back with the left leg, keeping the feet parallel. Bend your right knee and keep your left leg extended. change the position of the legs and redo the exercise.	
	Lightly flex your knees and release your body forward. Relax your shoulders and neck trying to reach with your hands as close to the ground as possible. Return slowly to the starting position and breathe normally.	
	Standing and facing a wall, make the slow crouching motion.	

SUPPLEMENT MATERIAL 4.9

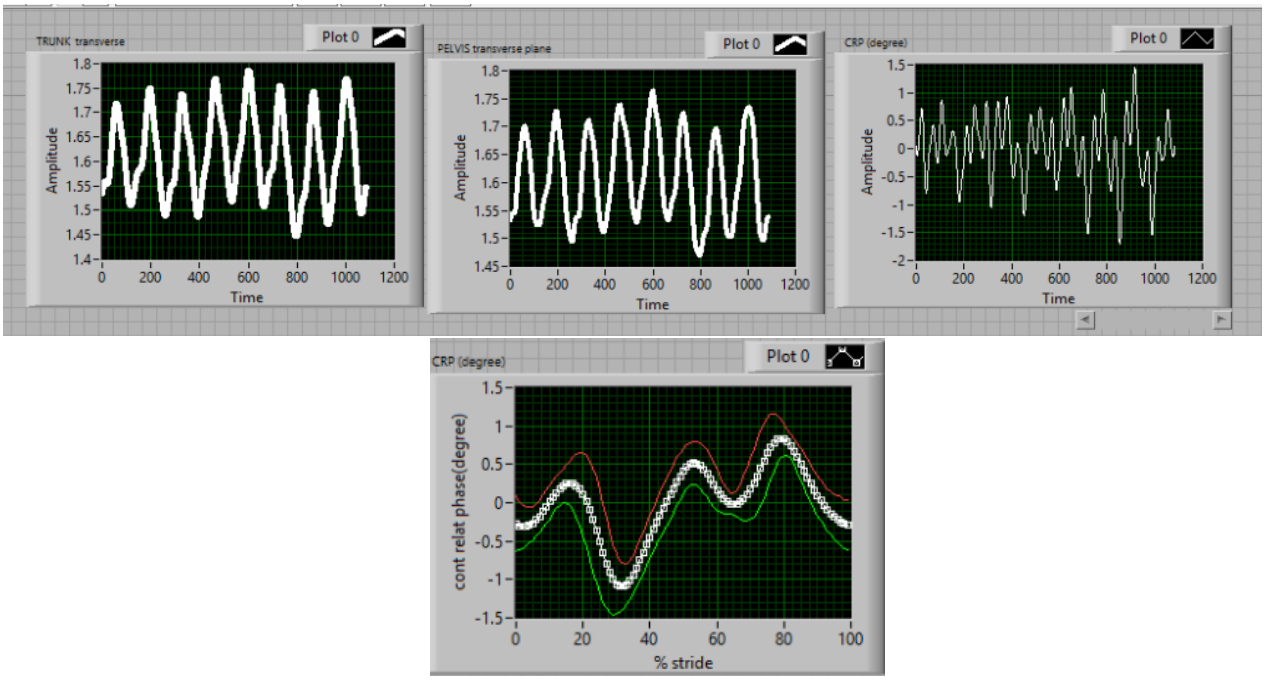
Mathematical routine built in the Labview software. **A:** Layout of all routine **B:** CRP mean and CRP variability calculus **C:** Phase difference calculus **D:** Spatiotemporal calculus **E:** Layout of CRP construction.



D



E



NOTE: Routine build by Leonardo Alexandre Peyré Tartaruga

CHAPTER 5

INTEGRATIVE ANALYSIS OF RESULTS

5.1 GENERAL DISCUSSION

Study of gait in subjects with PD is critical to help guide health and physical education professionals to aim, plan and organize the rehabilitation, and develop an exercise plan than can enable the individuals suffering with PD to improve their motor skills and thereby gain a level of independency (MIRELMAN et al., 2019). We have conducted three studies that focus on studying gait in people with PD and each of these studies was designed to answer key questions.

The literature shows that people with PD present different gait characteristics, compared with healthy control groups, such as lower speed, higher cadence, shorter stride length, and higher double limb support phase (SOFUWA et al., 2005; MONTEIRO et al., 2017). The results from our studies have quantitatively established the differences between the PD group and the healthy control group. Through our studies, we could quantitatively measure the differences mentioned in the literature and found that people with PD have a walking speed that is .17m.s^{-1} lower than that of the healthy control group. We have also confirmed that the speed of walking on the treadmill is lower than free walking. This will allow future researchers to select appropriate test methodologies for their studies.

In addition, our systematic review with meta-analysis showed that most studies only consider spatiotemporal variables, while only a few consider angle parameters. Therefore, it is necessary to conduct more original studies that consider sagittal and transversal walking angles in this population. Moreover, most PD gait studies only considered the gait values of people in early stages of the disease. As a result, these studies had homogeneous subjects, and in general no meta-analysis results was found. This finding is in agreement with Mirelman et al. (2019), suggesting that more studies are necessary to investigated several stage of PD disease. However, our main contribution to literature is the possibility to control if interventions improved PD gait parameters. Similarly, Mirelman et al. (2019) proposed more studies that evaluate these interventions as a form of prevention in early stage PD, by focusing on rhythm, variability and asymmetry of gait.

Aiming to improve and maintain the gait parameters, our second study was about a cycle and potential intervention in improved gait symmetry in people with PD.

Our main aim was to evaluate the symmetries upper and lower limbs segments in NW. Broadly, we found that our subjects did not show asymmetries in their upper and lower limb segments before the intervention. Mirelman et al. (2019) suggested that people with early stages of PD shown unilateral symptoms. The participants in our study had mild stages of PD, but they did not show asymmetries in their limb segments. However, we did not control the physical activities of the participants, and these could have influenced the parameters. Nevertheless, some knee and hip improvements were found, indicating that the use of poles may improve gait stability and can be considered a dual task (BOCCIA et al., 2018; OBATA, OGAWA & NAKAZAWA, 2019). This can be used to prevent futures asymmetries of PD gait. On the other hand, besides segments improvements, axial coordination improvements are also important to help PD patients walk independently. The literature showed that axial coordination was lower in the PD group than in the healthy control group (VAN EMMERIK et al., 1999). In 1999, Van Emmerik et al. suggested that it would be important to test the CRP of the trunk and pelvis, after different interventions, to improve axial coordination. However, even after ten years, little was known about the effects of the interventions on the CRP of the trunk and pelvis in people with PD.

In our study we can conclude that both, acyclic and cyclic interventions have considerable effecting in maintaining and potentially improving the axial coordination, when compared with the healthy control group. Cyclic interventions, such as NW, were able to modify some axial biomechanical parameters of walking coordination in people with PD.

Finally, our results showed new interventions such as, dance and NW, may improve segmental and axial alterations in the gait parameters of people with PD.

5.2 GENERAL CONCLUSION

This dissertation shows, quantitatively, the differences in spatiotemporal and lower limb angles between people with PD and a control group of healthy subjects. However, these differences may be minimized with exercises. Literature shows that new group interventions have the potential to improve gait alterations in people with PD.

To improve gait asymmetries, NW intervention was performed. NW was able to improve asymmetrical hip abduction and knee flexion of PD patients during walking.

When studying axial coordination, dance intervention was also included to analyze if a non-sagittal intervention could improve the transversal coordination between the trunk and pelvis.

Thus, dance and NW are group interventions that have the potential to improve axial coordination. Moreover, NW was able to change the biomechanical coordinative pattern in people with PD.

Finally, our results are important to understand the walking parameters of people with PD and how well and often the two dual task interventions can improve and maintain gait independency in people with PD.

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CHAPTER 6

6.1 THE PUBLISHED STUDIES DURING MASTER'S DEGREE.

6.1.1 Abstracts presented at events

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6.1.2 Papers published

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