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POSTURAL AUTOMATISMS AND BIOMECHANICS OF GAIT INITIATION AND OBSTACLE NEGOTIATION IN PARKINSON'S DISEASE: CHARACTERIZATION AND EFFECTS OF DIFFERENT INTERVENTIONS

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Dissertação apresentada ao Programa de Pós-Graduação em Ciências do Movimento Humano da Escola de Educação Física, Fisioterapia e Dança da Universidade Federal do Rio Grande do Sul como requisito parcial para obtenção do título de mestre.

Orientador: Prof. Dr. Leonardo Alexandre Peyré Tartaruga
Co-orientadora: Profa. Dra. Flávia Gomes Martinez

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RESUMO

A doença de Parkinson (DP) é uma doença neurodegenerativa relacionada à perda da independência funcional, com fenômenos motores, como rigidez, desequilíbrio e alterações na marcha. Os automatismos posturais, incluindo os ajustes posturais antecipatórios (APA) e compensatórios (CPA) são essenciais para o equilíbrio em resposta a uma perturbação e seu uso eficiente pode reduzir a ocorrência de quedas em tarefas cotidianas, como iniciação da marcha e negociação de obstáculos. Evidências apontam os benefícios de programas de exercícios na melhora da locomoção e controle postural na DP, entretanto, poucos estudos investigaram os efeitos sobre os automatismos posturais. Assim, a presente dissertação tem o objetivo de caracterizar as estratégias de automatismos posturais e comportamento motor relacionados à iniciação da marcha e negociação de obstáculos de pessoas com DP e comparar os efeitos de três programas de treinamento sobre esses parâmetros. No capítulo I é feita a apresentação geral e contextualização do estudo. No capítulo II é apresentada uma revisão de literatura, com informações compiladas sobre a DP, os automatismos posturais, a locomoção e como diferentes intervenções podem auxiliar na melhora dos parâmetros alterados. As lacunas identificadas na literatura motivaram a escrita de dois estudos originais. Os objetivos dos estudos foram: 1) analisar e comparar os ajustes posturais e os parâmetros biomecânicos durante a iniciação da marcha e negociação de obstáculos de pessoas com DP rígido-acinética e hipercinética; e 2) analisar e comparar os efeitos de três programas baseados em exercício físico (dança, exercícios em água funda e caminhada Nórdica) sobre os ajustes posturais e os parâmetros biomecânicos na iniciação da marcha e negociação de obstáculos em pessoas com DP. No estudo 1, foram avaliadas, de forma transversal, pessoas com DP divididas por subtipos clínicos (rígidos-acinéticos e hipercinéticos). Para o estudo 2, um ensaio clínico, estes sujeitos foram randomizados em três grupos de intervenção de 22 sessões, sendo avaliados antes e depois. Em ambos os estudos as avaliações incluíram variáveis eletromiográficas, cinéticas e cinemáticas. No estudo I, observamos que o grupo rígido-acinético apresentou maior comprometimento neuromotor, refletido por menor ação antecipatória e compensatória de músculos estabilizadores, menor deslocamento do centro de pressão, maior tempo de duplo apoio e menores comprimento e altura de passo durante as tarefas. Além disso, no estudo II as três intervenções mostraram melhoras nos parâmetros avaliados, sendo mais evidentes nos parâmetros espaço-temporais e músculos de tronco para exercícios em água funda e caminhada Nórdica, enquanto que a Dança promoveu melhores resultados na ação dos músculos de quadril. Nossos resultados são importantes para entender as diferenças no controle motor de pacientes com diferentes manifestações clínicas da DP e para auxiliar na prescrição de programas terapêuticos. Ainda, sugerimos que as três intervenções propostas possuem potencial para a manutenção e melhora neuromotora de pessoas com DP.

Palavras-chave: desordens Parkinsonianas, automatismos posturais, equilíbrio postural, locomoção, exercício.

ABSTRACT

Parkinson's disease (PD) is a neurodegenerative disease related to loss of functional independence, with motor phenomena such as rigidity, imbalance and changes in gait. Postural automatisms, including anticipatory (APA) and compensatory (CPA) postural adjustments are essential for balance in response to a disturbance and their effective use can reduce the occurrence of falls in everyday tasks, such as gait initiation and obstacle negotiation. Evidence points to the benefits of exercise programs in improving locomotion and postural control in PD, however, few studies have investigated the effects on postural automatisms. Thus, the present dissertation aims to characterize the strategies of postural automatisms and motor behavior related to the gait initiation and obstacle negotiation in people with PD and to compare the effects of three training programs on these parameters. Chapter I presents the general presentation and context of the study. Chapter II presents a literature review, with information compiled about PD, postural automatisms, locomotion and how different interventions can help to improve altered parameters. The gaps identified in the literature motivated the writing of two original studies. The aims of the studies were: 1) to analyze and compare postural adjustments to biomechanical parameters during gait initiation and obstacle negotiation in people with akinetic-rigid (AK-R) and hyperkinetic (HYP) PD; and 2) to analyze and compare the effects of three programs based on physical exercise (Brazilian dance, deep water exercises and Nordic walking) on postural adjustments and biomechanical parameters in gait initiation and obstacle negotiation in people with PD. In study 1, people with PD divided by clinical subtypes (AK-R and HYP) were evaluated in a cross-sectional research. For study 2, a clinical trial, these subjects were randomized into three intervention groups of 22 sessions, being assessed pre and post. In both studies, evaluations included electromyographic, kinetic and kinematic variables. In study I, we observed that the AK-R group showed greater neuromotor impairment, reflected by less anticipatory and compensatory action of stabilizing muscles, less displacement of the center of pressure, longer double support time and shorter step length and height during tasks. Furthermore, in study II, the three interventions showed improvements in the parameters evaluated, being more evident in spatiotemporal parameters and trunk muscles for deep water exercises and Nordic walking, while dance promoted better results in the action of the hip muscles. Our results are important to understand the differences in motor control of patients with different clinical manifestations of PD and to assist in the prescription of therapeutic programs. In addition, we suggest that the three proposed interventions have the potential to maintain and improve neuromotor performance in people with PD.

Keywords: Parkinsonian disorders, postural automatisms, postural balance, locomotion, exercise.

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LISTA DE SIGLAS E ABREVIATURAS

µV	Microvolts
∫EMG	Integrals of electromyographic activity
6MWT	6-minute walk test
ADL	Activities of daily living
AK-R	Akinetic-rigid
APA	Anticipatory postural adjustment
BD	Brazilian dance
BF	Biceps femuralis muscle
BMI	Body mass index
BPM	Beats per minute
CoM	Center of mass
CoP	Center of pressure
CNS	Central nervous system
CPA	Compensatory postural adjustment
CPG	Central pattern generator
DBS	Deep brain stimulation surgery
DWE	Deep water exercises
DWR	Deep water running
EEL	Erector spinae longissimus muscle
EMG	Electromyographic
ES	Effect size
ESEFID	School of Physical Education, Physiotherapy and Dance
FES-I	Falls efficacy scale-international
FoG	Freezing of gait
GAM	Gastrocnemius medialis muscle

GEE	Generalized estimation equations
GLM	Gluteus medius muscle
GPCOMFA	Research Group on Motor Behavior and Aquatic Therapy
H&Y	Hoehn & Yahr scale
HYP	Hyperkinetic
IBGE	Brazilian Institute of Geography and Statistics
LOCOMOTION	Research Group of Mechanics and Energetics of Terrestrial Locomotion
MDC	Minimal detectable change
MoCA	Montreal cognitive assessment
NW	Nordic walking
OI	Obliquus internus muscle
PD	Parkinson’s disease
PPGCMH	Graduate Program in Human Movement Sciences
PPT - PARKINSON	Parkinson's Disease Prevention and Treatment Program
RF	Rectus femuralis muscle
SPSS	Statistical Package for the Social Science
SSS	Self-selected speed
TA	Tibialis anterior muscle
TUG	Timed up and go test
UFRGS	Universidade Federal do Rio Grande do Sul
UPDRS	Unified Parkinson disease rating scale

DEFINIÇÃO DE TERMOS

- **Akinetic-rigid (AK-R):** clinical subtype of Parkinson's disease with predominant motor manifestation of rigidity and akinesia.
- **Anticipatory postural adjustments (APA):** muscle responses or small displacements that occur before postural disturbances, in order to minimize the disturbances that are about to occur.
- **Brazilian dance (BD):** Dance styles typical of Brazil, created from cultural diversity. Samba and Forró are two Brazilian dances, danced in pairs, originating in the customs of African songs and dances present in Brazilian popular culture.
- **Deep water exercises (DWE):** modality of exercise performed in a deep pool, with the aid of a floating device, allowing the body to remain upright without contact with the ground.
- **Double support time:** Stride period when both feet are in contact with the ground.
- **Electromyographic activity (EMG):** Technique for monitoring the electrical activity of the excitable membranes of muscle cells, representing the action potentials triggered by reading the electrical voltage over time.
- **Gait initiation:** Transition from the static situation to the dynamic gait mechanism.
- **Hyperkinetic (HYP):** clinical subtype of Parkinson's disease with predominant motor manifestation of tremor and dyskinesia.
- **Kinematics:** analysis of the position and orientation of the body segments in relation to time, carried out through the capture by image cameras connected to a computer.
- **Kinetics:** Analysis of the forces acting on a system and the force that cause a movement.
- **Nordic walking (NW):** refers to terrestrial locomotion with the use of two appropriate poles during the walk.
- **Obstacle negotiation:** Walking with overcoming obstacle. Requires that one leg steps over the obstacle first, followed by the other leg.
- **Single support time:** Stride period when one foot is in contact with the ground.

- **Step height:** Vertical excursion (elevation) of the foot during the step.
- **Step length:** Anteroposterior distance from the center of mass between successive steps.
- **Step width:** Maximum mediolateral distance between segmental center of mass of the feet.
- **Stride:** Begins when the reference foot contacts the ground and ends with subsequent floor contact of the same foot.

SUMÁRIO

CHAPTER I

1 GENERAL INTRODUCTION

This chapter comprises three sections: 1. General Presentation, 2. Problem and Importance of Research, and 3. Aims.

1.1 GENERAL PRESENTATION

1.1.1 Contextualization and delimitation of the study

The present dissertation is the result of an experimental study for the conclusion of the master's course in the Graduate Program in Human Movement Sciences (PPGCMH), in the line Physical Activity and Performance, by Marcela Zimmermann Casal, supervised by Professor Leonardo Alexandre Peyré-Tartaruga and co-supervised by Professor Flávia Gomes Martinez.

This study followed the recommendations of resolution 93/2007, which regulates the scientific work developed at the Universidade Federal do Rio Grande do Sul (UFRGS) and, for the development of this study, the guidelines recommended by Resolution 466/12 and 510/16 of the National Health Council were followed. This research is part of a project approved by the Research Ethics Committee Involving Human Beings at UFRGS (CAAE 69919017.3.0000.5347 with approval number: 2.522.087). After ethical approval, this research was carried out in the city of Porto Alegre, at the UFRGS School of Physical Education, Physiotherapy and Dance (ESEFID) and was developed with the logistical and intellectual support of the LOCOMOTION Research Group - Mechanics and Energetics of Terrestrial Locomotion and the Research Group on Motor Behavior and Aquatic Therapy (GPCOMFA), both located at ESEFID / UFRGS.

This master's research is a line of the project entitled PPT - PARKINSON (Parkinson's Disease Prevention and Treatment Program), which seeks to investigate the effects of three intervention programs based on physical exercise (Brazilian Dance, Deep Water Exercises and Nordic Walking) on motor and non-motor symptoms of people with Parkinson's disease (PD). This project was created and carried out at ESEFID / UFRGS and is an interdisciplinary project, based on the teaching-research-extension tripod, promoting actions aimed at the academic and external community. This project is coordinated by Prof. Aline Nogueira Hass, Prof. Flávia Gomes Martinez and Prof. Leonardo Alexandre Peyré-Tartaruga, combining the practical experience and intellectual construction of the three research groups mentioned above. This project, with its different lines, has already generated course completion papers, dissertations, presentations at national and international events and articles published in journals. Still, it has other undergraduate, masters and doctoral work in progress linked to this.

The interest in this research emerged from the practical work with this population in the area of Physiotherapy and the need for new management possibilities with exercises that promote the physical, emotional and social well-being of populations with chronic neurological diseases. In addition, previous experience in the GPCOMFA group and the study with postural automatisms, previously in young and healthy individuals, aroused the interest in expanding these studies to populations with changes in motor behavior. During this period studying for a master's degree, I had the opportunity to get involved in different research and extension projects, experience teaching through internships, participate in events as a poster or oral presenter and lecturer, as well as participate in the coordination of Deep Water Exercises and Nordic Walking projects and co-mentoring undergraduate and Specialization students in Neurofunctional Physiotherapy.

It is important to note that this dissertation is the result of my involvement with these different opportunities, but more than that, it is the result of collective work, involving several other researchers and, here, I quote the main people involved: Ivan Oliveira dos Santos (Scientific Initiation), Georgio Anibal Alves Micaella (Scientific Initiation), Mariana Wolffenbuttel (Scientific Initiation), Mayara dos Santos Abrantes (Scientific Initiation), Lucas Liz Alves (Scientific Initiation), André Ivaniski Mello (Master’s student), Ana Paula Janner Zanardi (Master), Rebeca Guimenes Donida (Master), Alex de Oliveira Fagundes (Doctoral student), Marcela dos Santos Delabary (Doctoral student), Valéria Feijó Martins (Doctoral student), Elren Passos Monteiro (collaborator researcher), Gabriela Lovis Black (volunteer researcher), Glaucus Tassinari Corrêa (volunteer researcher), Daniela Faustino (volunteer researcher), Aline Nogueira Haas (professor), Flavia Gomes Martinez (professor), Leonardo Alexandre Peyré-Tartaruga (professor) and more than 100 people with PD who dedicated themselves and participated in the PPT-PARKINSON studies.

1.1.2 Structure of the dissertation

This dissertation is divided into six chapters:

Chapter I presents a general introduction and establishes the relationship between the research problem, the justification and the objectives of this dissertation.

Chapter II covers the literature review with the aim of describing the pathophysiology of Parkinson’s disease (PD) and its motor and non-motor symptoms, as well as the biomechanical aspects of motor behavior and locomotion of people with PD, especially the kinematic, kinetic and muscle activation parameters. In addition, the effects of intervention programs with physical exercise, especially the Brazilian dance (BD), deep water exercises (DWE) and Nordic walking (NW) programs, on the symptoms of the disease will be discussed.

Chapter III presents Study A, entitled “Postural automatisms and biomechanics during gait initiation and obstacle negotiation: a comparison between akinetic-rigid and hyperkinetic Parkinson’s disease". This is a cross-sectional study, which aimed to analyze and compare postural adjustments and biomechanical parameters during the gait initiation and obstacle negotiation of people with akinetic-rigid and hyperkinetic PD.

Chapter IV presents Study B: “Deep water exercises, Brazilian dance and Nordic walking: effects on postural automatisms, gait initiation and obstacle negotiation in Parkinson's disease”. This is a clinical trial, which aimed to analyze and compare the effects of three exercise-based programs (dance, deep water exercises and Nordic walking) on biomechanical parameters and postural automatisms in gait initiation and obstacle negotiation in people with PD.

Chapter V comprises a session for final considerations, containing the limitations of the study, contributions of this dissertation for the clinical management of PD and for the advancement of new research in the area of health and neuromotor rehabilitation.

And, finally, Chapter VI lists scientific production during the academic master's period at PPGCMH / UFRGS.

1.2 CENTRAL QUESTION

Parkinson's disease (PD) is a neurodegenerative, chronic and progressive disease, related to loss of functional independence (PARKINSON, 1817; CHARCOT, 1880). Its pathophysiology consists of a complex neurochemical disorder, marked by dopamine depletion in the substantia nigra pars compacta in the nuclei of the base, resulting in symptoms such as bradykinesia, rest tremor and muscle stiffness (CHO et al., 2010). In addition, postural instability, loss of balance and changes in gait are motor phenomena that can result in high energy expenditure during locomotion and a high rate of morbidity and risk of falls (JANKOVIC, 2008; SHINE et al., 2012; WILD et al., 2013).

The risk of falls can be minimized through the efficient use of motor control (MC) strategies, with an emphasis on postural automatisms, which are essential for the balance of the body in response to postural disturbances (LATASH et al., 1995). They include anticipatory postural adjustment (APA) and compensatory postural adjustment (CPA). The APA involves muscular responses or small displacements that occur before postural disorders, in order to minimize the disturbances that are about to occur (MASSION, 1992). CPA is associated with muscle activity and body movements that occur after predictable and unpredictable postural disorders (CLAUDINO et al., 2013).

In the process of gait initiation, changes in support conditions require an adaptation of the muscular activity of the lower limbs and trunk, seeking to maintain posture and control movement in order to maintain balance during the execution of the task (CHONG et al., 1999; MILLE et al., 2005). In the healthy population, the mechanism of APA involves reciprocal inhibition, with an increase in the activity of the agonist muscles corresponding to a decrease in the activity of its antagonist (ARUIN et al., 1998). Authors argue that the mechanism of co-activation of agonist and antagonist muscles may be an adaptation of the central nervous system (CNS) for cases in which there is a decrease in the ability to generate an effective corrective reaction in the face of a disturbance, which may be a strategy used by people with PD (GIBB, 1992; AZEVEDO et al., 2016).

Changes in gait biomechanics are also seen in PD and are related to poor spatiotemporal regulation, reduced length and higher stride frequency, greater double support time and greater variability of spatiotemporal parameters in relation to healthy individuals (CHO et al., 2010; KLEINER et al., 2015). Neurofunctional factors, such as bradykinesia and difficulty in initiating movements, impair locomotion in PD (SOFUWA et al., 2005). Evidence suggests that in people with PD there is greater co-contraction of the tibialis anterior and plantar flexors muscles in the support phase when compared to healthy individuals, and, consequently, in PD there is less propulsion force and lesser balance strategy during walking, which can affect functionality parameters such as step length and self-selected speed (SSS) (PETERSON & HORAK, 2016; MONTEIRO et al, 2016).

Given these characteristics, therapeutic strategies to improve motor control and locomotion of individuals with PD become important. Scientific evidence shows that exercise programs are beneficial in improving kinematic parameters of locomotion and postural control (BARTOLO et al., 2010; BELLO et al., 2013). Among these, group programs such as Nordic Walking (MONTEIRO et al., 2016; ZANARDI et al, 2019), Dance (SHANAHAN et al., 2015; DELABARY et al, 2020) and Deep Water Exercises (BROMAN et al., 2006; OLIVEIRA et al, 2020) are likely to be useful to improve functional mobility in this population.

Recent studies have demonstrated the potential of Nordic Walking - a training modality that uses two poles during locomotion - as an efficient intervention strategy for walking mobility, balance, posture, improvement of cardiorespiratory variables and improvement in the quality of life of patients affected by several diseases, including PD (EBERSBACH et al., 2010; ANDRIANOPOULOS et al., 2014; PIOTROWICZ et al., 2015; MONTEIRO et al., 2016; ZANARDI et al., 2019). The practice of Dance has also emerged as a possibility of an accessible therapeutic strategy for parkinsonians, capable of improving motor parameters - such as balance and functional mobility - and reducing symptoms of depression, increasing socialization (SHANAHAN et al., 2015; SHARP & HEWITT, 2014; HACKNEY et al, 2007; DELABARY et al., 2020).

In addition to these, exercises in the aquatic environment seem to be an interesting therapeutic option due to the effects obtained through immersion. Deep water exercises, especially Deep Water Running - a modality that simulates walking / running in a deep pool, without the feet touching the bottom - although little explored in neurological patients, have relevant effects for the elderly population, which are related to pain relief, maintaining or increasing the angular range of joints, strengthening weakened muscles and increasing exercise tolerance, improving circulation, encouraging functional activities, improving balance, motor coordination and body posture (BROMAN et al., 2006; KANITZ et al., 2015; REICHERT et al., 2016; JORGIC et al., 2012). Recently, a study that investigated the effects of a deep water exercises program in people with PD associated or not with grape juice consumption found an improvement in functional capacity, balance and BDNF levels in both groups that performed the intervention (OLIVEIRA, et al., 2020).

Although positive adaptations are found in endurance training (FRANZONI et al., 2018; KANITZ et al., 2015), the effects of training programs on postural automatisms in balance and locomotion tasks of individuals with PD are inconclusive. Among the studies on this topic, some considerations are highlighted:

i) Because PD is polysymptomatic and can be manifested in different ways, it is interesting to divide patients by clinical manifestations to more accurately assess responses to stimuli and interventions, although most of the existing studies do not make this differentiation.

ii) Although changes in postural automatisms related to locomotion tasks are studied in the population with PD, no longitudinal study that investigated the effects of physical exercise-based intervention programs on these parameters was found;

iii) Differences and methodological limitations, the lack of description of the periodization, volume and intensity of the training seems inconclusive, especially in studies that used dance or aquatic exercises for people with PD, making it difficult to reproduce in clinical practice and pointing out a most appropriate program;

iv) Only one study investigated the application of deep water exercises for people with PD, which evaluated functional parameters and biochemical markers;

v) The knowledge of the mechanisms of postural automatisms to perform tasks, particularly the initiation of gait with or without obstacles, may be important for the rehabilitation of this population, as this information can be used in the evaluation, design of an effective intervention and monitoring the benefits of this intervention in PD;

vi) Knowledge of the effects of exercise programs such as Brazilian Dance, Deep Water Exercises and Nordic Walking on these mechanisms may contribute to the clinical routine and to the determination of new management strategies for this pathology.

Given these considerations, we define these two research problems: A) Does the motor manifestation of symptoms influence postural automatisms and the biomechanics of gait initiation and obstacle negotiation in people with PD?; and B) What are the effects of Brazilian Dance, Deep Water Exercises and Nordic Walking on motor behavior during gait initiation with and without obstacle negotiation in people with PD?

1.3 DISSERTATION AIM

The general aim of this study was to characterize the strategies of postural automatisms and biomechanics related to the gait initiation and obstacle negotiation of people with PD and to compare the effects of three training programs on these parameters.

To reach the central theme of this dissertation, the specific aims served as the basis for the development of two studies and will be presented below.

1.3.1 Study A:

1.3.1.1 General Aim

To analyze the postural adjustments and biomechanical parameters during the gait initiation and obstacle negotiation of people with akinetic-rigid and hyperkinetic PD.

1.3.1.2 Specific Aims

i) Neuromuscular:

- To describe the integral of EMG signal of the erector spinae longissimus (ESL), obliquus internus (OI), gluteus medius (GLM), rectus femuralis (RF), biceps femuralis (BF), tibialis anterior (TA) and gastrocnemius medialis (GAM) during APA and CPA phases in the tasks of gait initiation and obstacles negotiation;
- To correlate EMG parameters with performance parameters (SSS, TUG and FES-I);

ii) Kinetics:

- To describe the following kinetic variables during the tasks of gait initiation and obstacles negotiation in the APA and CPA phases: mediolateral and anteroposterior displacements of the center of pressure (CoP) and vertical force peak;
- To correlate kinetic parameters with performance parameters (SSS, TUG and FES-I);

iii) Kinematics:

- To describe the following kinematic variables during the tasks of gait initiation and obstacles negotiation: step length, step height, step width, stride time, double support time, single support time and range of hip, knee and ankle motion;
- To correlate kinematic parameters with performance parameters (SSS, TUG and FES-I);

1.3.2 Study B:

1.3.2.1 General Aim

To analyze the effects of three physical exercise-based programs on postural adjustments and biomechanical parameters during the gait initiation and obstacle negotiation in people with PD.

1.3.2.2 Specific Aims

i) Neuromuscular:

- To compare the integral of the EMG signal of the EEL, OI, GLM, RF, BF, TA and GAM during APA and CPA phases in the tasks of gait initiation and obstacles negotiation pre and post training for the different interventions;

ii) Kinetics:

- To compare the following kinetic variables during the tasks of gait initiation and obstacles negotiation in the APA and CPA phases pre and post training for the different interventions: mediolateral and anteroposterior CoP displacements and vertical force peak;

iii) Kinematics:

- To compare the following kinematic variables during the tasks of gait initiation and obstacles negotiation pre and post training for the different interventions: step length, step height, step width, stride time, double support time, single support time and range of motion of the hip, knee and ankle;

1.4 REFERENCES

ANDRIANOPOULOS, V.; KLIJN, P.; FRANSSEN, F.; SPRUIT, M. Exercise training in pulmonary rehabilitation. **Clinics in Chest Medicine**, v.35, n.2, p.313-322, 2014.

ARUIN, A.S.; FORREST, W.R.; LATASH, M.L. Anticipatory postural adjustments in conditions of postural instability. **Electroencephalography and Clinical Neurophysiology**, v.109, n.4, p.350-359, 1998.

AZEVEDO, A.K.C.; CLAUDINO, R.; CONCEIÇÃO, J.S.; SWAROWSKY, A.; DOS SANTOS, M.J. Anticipatory and compensatory postural adjustments in response to external lateral shoulder perturbations in subjects with Parkinson's disease. **Plos One**, v.11, n.5, p.e0155012, 2016.

BARTOLO, M.; SERRAO, M.; TASSORELLI, C.; DON, R.; RANAVOLO, A.; DRAICCHIO, F.; PACHETTI, C.; BUSCONE, S.; PERROTTA, A.; FURNARI, A.; BRAMANTI, P.; PADUA, L.; PIERELLI, F.; SANDRINI, G. Four-week trunk-specific rehabilitation treatment improves lateral trunk-flexion in Parkinson's disease. **Movement Disorders**, v.25, n.3, p.325-331, 2010.

BELLO, O.; SANCHEZ, J.A.; LOPEZ-ALONSON, V.; MARQUEZ, G.; MORENILLA, L.; CASTRO, X.; GIRALDEZ, M.; SANTOS-GARCIA, D.; FERNANDEZ-DEL-OMO, M. The effects of treadmill or overground walking training program on gait in Parkinson's disease. **Gait & Posture**, v.38, n.4, p.590-595, 2013.

BROMAN, G.; QUINTANA, M.; LINDBERG, T.; JANSSON, E.; KAIJSER, L. High intensity deep water training can improve aerobic power in elderly women. **European Journal of Applied Physiology**, v.98, n.2, p.117-123, 2006.

CHARCOT, J.M. **Leçons sur les maladies du système nerveux faites à la Salpetrière**. Paris: Lecrosnier Éditeurs, 3ed, 1880.

CHO, C.; KUNIN, M.; KUDO, K.; OSAKI, Y.; OLANOW, C.W.; COHEN, B. Frequency-velocity mismatch: a fundamental abnormality in parkinsonian gait. **Journal of Neurophysiology**, v.103, n.3, p.1478-1489, 2010.

CHONG, R.K.Y.; JONES, C.L.; HORAK, F.B. Postural set for balance control is normal in Alzheimer's but not in Parkinson's disease. **Journal of Gerontology Medical Science**, v.54, n.3, p.129-135, 1999.

CLAUDINO, R.; DOS SANTOS, E.C.; SANTOS, M.J. Compensatory but not anticipatory adjustments are altered in older adults during lateral postural perturbations. **Clinical Neurophysiology**, v.124, n.8, p.1628-1637, 2013.

DELABARY, M.S.; MONTEIRO, E.P.; DONIDA, R.G.; WOLFFENBUTTEL, M.; PEYRÉ-TARTARUGA, L.A.; HAAS, A.N. Can Samba and Forró Brazilian rhythmic dance be more effective than walking in improving functional mobility and spatiotemporal gait parameters in patients with Parkinson's disease? **BMC Neurology**, v.20, n.305, 2020.

EBERSBACH, G.; EBERSBACH, A.; EDLER, D.; KAUFHOLD, O.; KUSCH, M.; KUPSCH, A.; WISSEL, J. Comparing exercise in Parkinson's disease – the Berlin LSVT®BIG study. **Movement Disorders**, v.25, n.12, p.1902-1908, 2010.

FRANZONI, L.T.; MONTEIRO, E.; BIANCHI, H.; DA ROSA, R.G.; COSTA, R.; RIEDER, C.; MARTINEZ, F.; PEYRÉ-TARTARUGA, L.A. A 9-week Nordic and Free Walking improve postural balance in Parkinson's disease. **Sports Medicine International Open**, v.2, n.1, p.28-34, 2018.

GIBB, W.R. Neuropathology of Parkinson's disease and related syndromes. **Neurologic Clinics**, v.10, n.2, p.361-376, 1992.

HACKNEY, M.E.; KANTOROVICH, S.; LEVIN, R.; EARHART, G.M. Effects of Tango on functional mobility in Parkinson's disease: a preliminary study. **Journal of Neurologic Physical Therapy**, v.31, n.4, p.173-179, 2007.

JANKOVIC, J. Parkinson's disease: clinical features and diagnosis. **Journal of Neurology, Neurosurgery and Psychiatry**, v.79, n.4, p.368-376, 2008.

JORGIC, B.; MILANOVIC, Z.; ALEKSANDROVIC, M.; PANTELIC, S.; DALY, D. Effects of deep water running in older adults. A Systematic review. **Healthmed,** v.6, n.1, p. 3219-3227, 2012.

KANITZ, A.C.; DELEVATTI, R.S.; REICHERT, T.; LIEDTKE, G.V.; FERRARI, R.; ALMADA, B.P.; PINTO, S.S.; ALBERTON, C.L.; KRUEL, L.F.M. Effects of two deep water training programs on cardiorespiratory and muscular strength responses in older adults. **Experimental Gerontology**, v.64, p.55-61, 2015.

KLEINER, A.; GALLI, M.; GAGLIONE, M.; HILDEBRAND, D.; SALE, P.; ALBERTINI, G. The parkinsonian gait spatiotemporal parameters quantified by a single inertial sensor before and after automated mechanical peripheral stimulation treatment. **Parkinson's Disease**, v.39, p.05-12, 2015.

LATASH, M.L.; ARUIN, A.S.; NEYMAN, I.; NICHOLAS, J.J. Anticipatory postural adjustments during self-inflicted and predictable perturbations in Parkinson's disease. **Journal of Neurology, Neurosurgery and Psychiatry**, v.53, n.3, p.326–34, 1995.

MASSION, J. Movement, posture and equilibrium: interaction and coordination. **Progress in Neurobiology**, v.38, n.1, p.35-56, 1992.

MILLE, M.L.; JOHNSON, M.E.; MARTINEZ, K.M.; ROGERS, M.W. Age-dependent differences in lateral balance recovery through protective stepping. **Clinical Biomechanics**, v.20, p. 607-616, 2005.

MONTEIRO, E.P.; FRANZONI, L.T.; CUBILLOS, D.M.; DE OLIVEIRA FAGUNDES, A.; CARVALHO, A.R.; OLIVEIRA, H.B.; PANTOJA, P.D.; SCHUCH, F.B.; RIEDER, C.R.; MARTINEZ, F.G.; PEYRÉ-TARTARUGA, L.A. Effects of Nordic walking training on functional parameters in Parkinson's disease: a randomized controlled clinical trial. **Scandinavian Journal of Medicine & Science in Sports**, v.27, n.3, p.351-358, 2016.

OLIVEIRA, G.S.; IRACI, L.; PINHEIRO, G.S.; CASAL, M.Z.; HAAS, A.N.; POCHMANN, D.; MARTINEZ, F.G.; ELSNER, V.; DANI, C. Effect of exercise and grape juice on epigenetic modulation and functional outcomes in PD: A randomized clinical trial. **Physiology & Behavior**, v.227, n.1, p.113-135, 2020.

PARKINSON, J. **An essay on the shaking palsy**. London: Whittingham & Rowland, 1817.

PETERSON, D.S.; HORAK, F.B. Neural Control of Walking in People with Parkinsonism. **Physiology**, v.126, n.31, p. 95–107, 2016.

PIOTROWICZ, E.; BUCHNER, T.; PIOTROWSKI, PIOTROWICZ, R. Influence of home-based telemonitored Nordic walking training on autonomic nervous system balance in heart failure patients. **Archives of Medical Science**, v.11, n.6, p. 1205-1212, 2015.

REICHERT, T.; KANITZ, A.C.; DELEVATTI, R.S.; BAGATINI, N.C.; BARROSO, B.M.; KRUEL, L.F.M. Continuous and interval training programs using deep water running improves functional fitness and blood pressure in the older adults. **Journal of the American Aging Association**, v.38, n.1, 2016.

SHANAHAN, J.; MORRIS, M.E.; BHRIAIN, O.N.; SAUNDERS, J.; CLIFFORD, A.M. Dance for people with Parkinson disease: What is the evidence telling us? **Archives of Physical Medicine and Rehabilitation**, v.96, n.1, p.141-53, 2015.

SHARP, K.; HEWITT, J. Dance as an intervention for people with Parkinson's disease: A systematic review and meta-analysis. **Neuroscience and Biobehavioral Reviews**, v.47, p.445-456, 2014.

SHINE, J.M.; MOORE, S.T.; BOLITHO, S.J.; MORRIS, T.R.; DILDA, V.; NAISMITH, S.L. Assessing the utility of freezing of gait questionnaires in Parkinson's disease. **Parkinsonism and Related Disorders**, v.18, p.25-29, 2012.

SOFUWA, O.; NIEUWBOER, A.; DESLOOVERE, K.; WILLEMS, A.M.; CHAVRET, F.; JONKERS, I. Quantitative gait analysis in Parkinson's disease: comparison with a healthy control group. **Archives of Physical Medicine Rehabilitation**, v.86, n.5, p.1007-1013, 2005.

WILD, L.B.; DE LIMA, D.B.; BALARDIN, J.B.; RIZZI, L.; GIACOBBO, B.L.; OLIVEIRA, H.B.; DE LIMA-ARGIMON, I.I.; PEYRÉ-TARTARUGA, L.A.; RIEDER, C.R.; BROMBERG, E. Characterization of cognitive and motor performance during dual-tasking in healthy older adults and patients with Parkinson’s disease. **Journal of Neurology**, v.260, n.2, p.580–9, 2013.

ZANARDI, A.P.J.; MARTINEZ, F.G.; SILVA, E.S.; CASAL, M.Z.; MARTINS, V.F.; PASSOS-MONTEIRO, E.; HAAS, A.N.; PEYRÉ-TARTARUGA, L.A. Effects of Nordic Walking on Gait Symmetry in Mild Parkinson’s Disease. **Symmetry**, v. 11, n. 12, p.1481, 2019.

CHAPTER II

2 LITERATURE REVIEW

The literature review of this study was structured with the aim of presenting a theoretical basis that allows understanding about the research topic. Thus, it was divided into four main topics: 1 - Parkinson's disease; 2 – Postural automatisms; 3 – Locomotion; 4 - Therapeutic strategies for PD.

2.1 PARKINSON'S DISEASE (PD)

Population aging is a worldwide phenomenon, resulting from social changes and scientific advances, especially in the field of health sciences (UNITED NATIONS, 2019). In Brazil, the current estimates are that the country exceeds 29 million older adults and the expectation is that, by 2060, this number will rise to 73 million people aged 60 or over (IBGE, 2018). According to the Brazilian Institute of Geography and Statistics (IBGE), Rio Grande do Sul is in first place in the ranking of Brazilian states with the largest share of the population over 60, representing 18.6% (about 2 million people) of the total population of the state (11,412,044), with a life expectancy of 78.8 years. The IBGE estimate is that, by 2030, the State will have about 1 million more elderly people than at present, which means that the population over 60 years old can reach 24% of the total in a decade. In Porto Alegre, the elderly represent about 15% of the population (222,566) (IBGE, 2018).

The growth in life expectancy is accompanied by a higher incidence of chronic and disabling diseases, such as neurodegenerative diseases, including PD, being an increasingly common reality in clinical practice (SOARES & PEYRÉ-TARTARUGA, 2010). Worldwide, PD is the most frequent neurodegenerative disease after Alzheimer's disease, affecting around 10 million people (ZIGMOND & SMEYNE, 2014), with an incidence of new cases ranging from 8 to 18 for every 100,000 individuals per year (ILKE et al., 2008), the which makes it necessary to plan and adapt and effective methods to control their development, in view of the compromised quality of life resulting from their symptoms.

This neurodegenerative, chronic and progressive disorder of the extrapyramidal system, whose etiology is still poorly understood, causes impairment in the cells of the substantia nigra pars compacta, resulting in a deficit in the production of dopaminergic neurons located in the nuclei of the base (NAGANO-SAITO et al., 2014). Physiopathologically it must be considered as a condition characterized by the presence of multiple monoaminergic dysfunctions, including deficits in the dopaminergic, cholinergic, serotonergic and noradrenergic systems (TEIVE, 2005). The disease is associated with the degeneration of neurons responsible for the production of dopamine, which have their cell bodies in the substantia nigra pars compacta and send their axons to the nuclei of the base. The loss of cells of the substantia nigra pars compacta is more prevalent in the ventral cell group and the loss of neurons that contain melanin produces characteristic changes in depigmentation. As the disease progresses and neurons degenerate, they develop cytoplasmic bodies, Lewy bodies (O´SULLIVAN & SCHMITZ, 1993).

The nuclei of the base perform the function of programming and automating movement, either activating or inhibiting (MORRIS et al., 2005) and have an important participation in cognitive processes essential for the vital functioning of the human being (NAGANO-SAITO et al., 2014). In PD, there would be a decrease in the activity of stimulation of the putamen over the direct route, and the loss of dopaminergic inhibition at the origin of the indirect route (CAMBIER et al., 1999). When approximately 60 to 80% of these cells that produce dopamine are damaged, the onset of the first motor symptoms begins (ROWLAND, 2007). The final effect of dopamine loss in the putamen on both pathways causes an increase in the inhibition of thalamic projections to the motor cortex (inhibition of the cortical motor pathways and the brain stem), showing bradykinesia and rigidity (CAMBIER et al., 2005), generating changes at the beginning, speed and fine adjustment of movements. The tremor is relatively independent of these elements and its cause is due to changes located from the intermediate ventral thalamic nucleus (JIANG et al., 2006). Thus, PD is characterized by a movement disorder, which can be hyperkinetic or hypokinetic.

The progression of motor symptoms has a non-linear pattern over the course of the disease, being faster in individuals in the early stage of PD when compared to those who progress with a longer duration of the disease. This is largely due to a greater loss of the pigmented neurons of the substantia nigra pars compacta that occur in the first decade of the disease (around 45%), with a 4.7% percent progression of loss per subsequent decade (XIA & MAO, 2012).

Studies demonstrate that in PD several brain areas undergo degeneration at different levels and stages (HAUSDORFF et al., 2003; MORRIS et al., 2005; ALBERTS et al., 2011; NAGANO-SAITO et al., 2014). Such neuropathological degenerations result in non-motor symptoms that include cognitive changes, sleep disorders, neuropsychiatric manifestations and depression (MARGIS et al., 2010; WILD et al., 2013; EBERSBACH et al., 2014; TUON et al., 2014), in addition to motor symptoms, such as bradykinesia, rest tremor and muscle rigidity (HAUSDORFF et al., 2003; CHO et al., 2010). In addition to these symptoms, postural instability, loss of balance and changes in gait are quite common motor phenomena in those affected by PD, which causes high energy expenditure during locomotion, risk of falls and a high rate of morbidity (SHINE et al., 2012; WILD et al., 2013).

Proprioceptive changes can occur due to impairment of the nuclei of the base and motor cortex, causing these individuals to have deficits in both peripheral sensory function and sensory-motor integration, leading to decreased motor feedback in these individuals (JENKINS et al., 2009; PRÄTORIUS et al., 2003; ABBRUZZESE & BERARDELLI, 2003). The sense of static articular position and perception of movement are altered, which compromises in particular the proprioception of this population (ABBRUZZESE & BERARDELLI, 2003).

The decrease in the production of the neurotransmitter dopamine causes disorders that act mainly in the control of movements. The lack of this neurotransmitter reflects changes in the region of movement planning and sequencing, in addition to increased cerebellar activity (PETERSON & HORAK, 2016; HAMMOND et al., 2017), which reflects in bradykinesia, akinesia, tremors, postural changes, freezing and mainly axial and intersegmental rigidity (PETERSON & HORAK, 2016). In general, patients do not have all the cardinal motor signs characteristic of PD in their diagnosis. Tremor at regular rest (4 to 5 cycles / second) is present in the extremities and occurs in approximately 75% of patients, being one of the most characteristic manifestations of PD (PONT-SUNYER et al., 2015). It occurs asymmetrically and decreases or disappears with voluntary movements, being accentuated by fatigue, efforts of intellectual concentration, emotions and disappearing during sleep (CAMBIER et al., 2005). It affects the upper limbs most commonly, and can also be triggered in the lower limbs, jaw, lips and tongue. The tremor in the hands increases when walking and can be an early sign when others are not yet present (ROWLAND, 2007).

Rigidity, also known as plastic hypertonia, causes an increase in muscle tone observed in the limbs, trunk and neck, evidenced mainly by passive mobilization at the level of the wrist and elbow where increased resistance to passive movement occurs

(BARBOSA & SALLEM, 2005). This rigidity of the passive member increases while the other member performs an active voluntary movement (CAMBIER et al., 2005; ROWLAND, 2007). Another related aspect is the exacerbation of segmental tonic reflexes, which can be more easily observed when dorsal flexion of the ankle is performed passively. This movement can trigger a prolonged contraction of the involved muscles leading to the persistence of this posture for some time (BARBOSA & SALLEM, 2005).

The term bradykinesia, or hypokinesia, is described by the slowness and difficulty in initiating movements, in addition to loss of automatic movements (ROWLAND, 2007). The person can course of the disease, progressive immobility, whose gestural expression is reduced, evidenced at the level of the face by hypomimia. Speech may become low (hypophony), with greater difficulty in understanding (CAMBIER et al, 2005; ROWLAND, 2007). The presence of rigidity combined with bradykinesia and tremor, makes complex integrative or repeated movements difficult (ROWLAND, 2007).

Bradykinesia is the main clinical sign and causes functional limitation in PD (BERARDELLI et al., 2001), affecting more than 80% of individuals (KEUS et al., 2014). It includes the hesitation or delay to start the movement (akinesia) and the reduction of the movement amplitude or poverty (hypokinesia) (ESPAY et al., 2009; HELDMAN et al., 2011) and is related to difficulties in planning, initiation and execution movement (ALVES et al., 2008) and the performance of sequential or simultaneous tasks. It manifests itself by slowing down the performance of the activities of daily living (ADL) and the reaction time; loss of spontaneous and gestural movements, micrograph, decreased oscillation of the upper limbs during gait and reduced gait speed (BOHLHALTER & KAGI, 2011).

Rigidity is defined as an increased resistance to passive movement of a limb, constant and uniform, that persists over the full range of motion. Its assessment is based on the examiner's perception of the resistance to movements imposed on the patient's wrist, elbow, neck and ankle joints (GOETZ et al., 2008) and the nature of this assessment is qualitative and highly subjective (PROCHAZKA et al., 1997). It occurs mainly in the neck and trunk, being called axial rigidity and resulting in postural abnormalities (KEUS et al., 2014). The severity of axial rigidity is related to difficulties in turning and rolling (FRANZEN et al., 2009). An inflexible pattern of excessive postural tone and a consequent reduction in movement mechanically reduces the ability to perform postural reactions effectively. For example, rigidity is associated with co-contracting the muscles around the joints in response to postural disturbances, rather than efficient postural synergies on one side of the body, making patients vulnerable to loss of balance and falls (HORAK et al., 1996).

Resting tremor, often located in the distal segments of the limbs (JANKOVIC, 2008), has a frequency of 4-6 Hz, is usually prone-supination and asymmetric and can be exacerbated by anxiety and apprehension (ALVES et al., 2008). The hallmark of resting tremor is its disappearance with the voluntary movement of the affected segment. In addition, many patients have postural tremor, which is more prominent and disabling than resting tremor and can be the first manifestation of the disease (JANKOVIC, 2008).

PD is not only characterized by neuromusculoskeletal impairments and functions related to movement, but also by a wide variety of non-motor symptoms that are responsible for considerably impacting the quality of life of these individuals (KEUS et al., 2014), which involve: olfactory dysfunctions; cognitive decline; depression; sleep disorders; visual impairments; fatigue; apathy and anxiety (ZIEMSSEN & REICHMANN, 2007), sensory fluctuations; central pain; impairments in proprioceptive function; tingling; orthostatic hypotension; voice and speech disorders; dyspnea; cold; urge incontinence (KEUS et al., 2014). Although many of these symptoms correlate with old age, disease severity and falls, they can precede motor symptoms by more than a decade (ZIEMSSEN & REICHMANN, 2007).

2.2 POSTURAL AUTOMATISMS

Postural control includes sensorimotor and musculoskeletal components involved in the control of two behavioral objectives: postural orientation and postural balance (HORAK, 2006). Postural orientation is defined as the ability to maintain an appropriate relationship between body segments and between the body and the task environment, while postural balance is the state in which all forces acting on the body are balanced, so that the body tends to remain in the desired position and orientation (static balance) or to move in a controlled manner (dynamic balance).

Postural control detects and uses information from multiple sensory systems. Central sensory integration involves the active interpretation of visual, vestibular and somatosensory inputs to orient the body in space. When sensory information is not available or in conflict, a process of sensory re-weighting occurs so that the nervous system ignores ambiguous and useless information and relies more on useful sensory information. Parkinson's disease patients may take longer for the sensory re-weighting process than healthy individuals and have difficulty perceiving small changes in the slope of the surface, that is, decreased kinesthesia (MANCINI et al., 2019), which is compensated by an excessive reliance on vision for postural orientation.

Sensory-motor coordination for dynamic balance includes energy-efficient movement strategies and control of the body's many degrees of freedom of stabilization, including automatic responses to unexpected disturbances, as well as anticipatory postural adjustments. Automatic postural reactions are associated with muscle activity and body movements after postural disorders, minimizing the destabilizing effects caused by postural disturbance, and may manifest after predictable and unpredictable disorders (CLAUDINO et al., 2013). The anticipatory postural adjustments follow voluntary and focal movements (HORAK & MACPHERSON, 2011), attenuating the effects of future disturbances before the onset of the disturbance and are an integral part of the movement, necessary to achieve the objectives of the task in a harmonious way (HORAK & MACPHERSON, 2011). PD patients may have poor anticipatory postural adjustments and inadequately organized automatic postural reactions (KIM et al., 2013), presenting in the early stages of PD an exaggerated movement preparation when performing tasks such as sitting to standing. (INKSTER & ENG, 2004). The reactive movements of the trunk are markedly reduced, causing the trunk to fall as a block in the direction of postural disturbance (CARPENTER et al., 2004). Additional deficits may be evident after the imbalance, including slower compensatory step reactions, direction-specific instability and incorrectly directed arm protection movements (GRIMBERGEN et al., 2009; HORAK et al., 2005; MANCINI et al., 2008; ROCCHI et al., 2012). Like postural responses, anticipatory postural adjustments are bradykinetic.

There are several destabilizing sources in the body: external forces due to gravity and interactions with the surrounding environment, as well as internal forces generated by the body's own movements. All forces, external or internal, end up accelerating the body to its center of mass. Postural instability in PD is a sign of worsening motor limitations (FALL et al., 2003), becoming more prevalent in later stages (HELY et al., 2005), although it may be present even at the beginning of the disease. Along with other contributing factors, including gait disorders and dyskinesias, postural instability puts PD patients at a high risk of falls (BLOEM et al., 2001). In addition, it not only correlates with falls, but also with the fear of future falls (ADKIN et al., 2003). As the disease advances, the axial and postural impairment becomes increasingly prominent. PD is characterized by postural disorders that affect orientation and stabilization and that typically include cervical anteriorization and flexion, elbow and knee semiflexion, anterior and sometimes lateral trunk flexion. Such changes are generally related to rigidity, being more marked in more advanced stages of PD (JANKOVIC, 2008). The trunk flexion posture, presented by parkinsonians, despite not being solely responsible for postural instability, can be considered as a factor that favors destabilization (JACOBS et al., 2009).

The ability to control and maintain the orthostatic position is fundamental for human movement, which is only possible due to effective motor control (KRISHNAN et al., 2012). Human beings suffer constant disturbances that defy balance, both in a static position and during gait, and these disturbances may be predictable or unpredictable. Such movements cause a displacement of the center of mass (COM), putting body stability at risk (SANTOS et al., 2010).

To maintain orthostatic balance, it is necessary for the COM to be kept inside the support base, outlined by the feet. This location of the COM relative to the support base constitutes a variable controlled by the CNS through different systems and strategies (WINTER et al., 2001). The complexity of strategies to maintain postural stability has been the focus of many studies, and it is widely argued that posture and balance in orthostasis are maintained through mechanisms of postural automatisms (LORAM & LAKIE, 2002; MULLER & REDFERN, 2004).

Faced with a situation of postural imbalance, the CNS can resort to motor control strategies (KRISHNAN et al., 2012), which involve postural automatisms, including APA and CPA. APA involve muscle activation or inhibition and small bodily dislocations that occur before predictable postural disorders, in order to minimize the disturbances that are about to occur (MASSION, 1998; SANTOS et al., 2010). CPA are associated with muscle activity and COM repairs that occur after predictable and unpredictable disturbances (CLAUDINO et al., 2013) and start with sensory feedback.

Any motor action combines the displacement of one or more segments towards a given objective and the postural stabilization of other segments (MASSION 1992; BALDISSERA & TESIO, 2017). Postural stability is achieved during voluntary movement through anticipatory and compensatory strategies aimed at minimizing predictable and unpredictable disturbances, respectively (BENNIS et al., 1996; KANEKAR & ARUIN, 2014).

Several authors have investigated anticipatory and compensatory strategies using bilateral upper limb loading / unloading tasks (BENNIS et al., 1996; MASSION et al., 1998). When a loading / unloading disorder in the forearm is unexpectedly imposed by the experimenter, CPA are observed at the level of the forearm muscles after the disturbance. CPA reflect a feedback control in which changes in muscle activity are triggered by sensory signals in response to unpredictable postural disturbances (PARK et al., 2004; ALEXANDROV et al., 2005). In contrast, when the loading / unloading disturbance in the forearm is voluntarily performed by the individual's contralateral hand, the APA of the forearm muscles precede the onset of postural disturbance. APA reflect an anticipated control in which changes are seen in muscle activity before an expected external disturbance or a nearby self-initiated movement (MASSION, 1992; ARUIN & LATASH, 1995; ARUIN et al., 1998).

In the gait initiation, changes in support conditions require an adaptation of the muscular activity of the lower limbs, in order to maintain posture and control the movement of the COM in order to maintain balance during the task (CHONG et al., 1999). This change in muscle activity occurs at the level of postural muscles and occurs prior to voluntary movement, which is why it is called a feedforward mechanism, which manifests itself through APA (ARUIN & LATASH, 1995). The APA are reflected in the oscillations of the pressure center (COP) and their purpose is to generate forces that act in order to keep the COM inside the support base, providing stability and balance to the body.

The inputs involved in these reactions can come from upward or downward (LATASH, 2008). Populations with changes in these pathways commonly present a deficit in the body's response to adaptation to situations of imbalance. Individuals with neurological impairment, such as PD, may have variations in their motor control conditions (DICKSTEIN et al., 2004; GIBB, 1992) due to sensory, motor and muscle changes (CLAUDINO et al ., 2013).

The mechanisms underlying motor control and postural stability have been the object of study in healthy populations with different affections. Its importance consists in the fact that this knowledge can determine the evolution of the postural control system and, in the case of the elderly and individuals with certain diseases, prevent the risk of falls and associated injuries (MILLE et al., 2005).

Studies argue that there is a decline in the capacity for balance related to the aging process, which has been attributed to changes in the CNS, deficits in the visual, vestibular and somatosensory systems, as well as musculoskeletal changes (MILLE et al., 2005; TJERNSTROM et al., 2002). In cases where advancing age is associated with PD, there is an even more evident declining trend, with deficits in postural control attributed to the inability to maintain the activity of motor cortex neurons in preparation for action, together with changes in timing and in the ability to maintain a stable position in the face of internal and external disturbances (MORRIS et al., 1998). These deficits in postural control often result in falls and gait instability (FRANK et al., 2000).

The initiation of gait is a common difficulty in this population and the occurrence of falls, associated with the deficit of balance and postural instability, strongly compromise the quality of life (SUTEERWATTANANON et al., 2002). The ability to maintain the orthostatic position in the most varied contexts shows that the postural control system is adaptive to various parameters of the task, whether it is originated internally or externally (VUILLERME et al., 2005). Gait initiation is accompanied by APA, which are essential to release the swing leg and, thus, create necessary conditions for progression (DELVAL et al., 2014). In fact, the amplitude and duration of APA are predictive of the speed of the subsequent step (BRENIERE & DO, 1991).

Deficit in gait initiation is a problem frequently seen in patients with advanced PD and is sometimes refractory to drug treatment (HALLIDAY et al., 1998; DELVAL et al., 2014). When starting to walk, patients with PD tend to have APA with less ground reaction force and mediolateral and anteroposterior displacement of the COP, characterizing longer and smaller magnitude adjustments (HALLIDAY et al., 1998; DIBBLE et al., 2004; HASS et al., 2005; KRYSTKOWIAK et al., 2006). APA in gait initiation are generally absent in PD patients who experience hesitation (BURLEIGH-JACOBS et al., 1997) or very slow progression. Multiple PACs can also occur and correspond to a subtype of freezing called "knee trembling" (JACOBS et al., 2009). In addition, patients with advanced PD also experience impairment in obstacle negotiation, with lower foot elevation and lower initial speed (VITORIO et al., 2010).

2.3 LOCOMOTION

A functional and efficient gait (navigation through space, evasion of obstacles and adaptation to the objective), depends on upper level control centers, including groups of nuclei at the base, cerebellum and parietal and cortical areas (TAKAKUSAKI et al., 2008). Gait difficulties have a major impact on the mobility of individuals with PD, leading to a progressive loss of autonomy and a decrease in quality of life (BLOEM et al., 2001). They are initially improved by dopaminergic medication, but they become progressively resistant to this therapy in advanced stages (FERRAYE et al., 2008).

Changes in motor coordination and gait biomechanics are also commonly seen in PD, causing decreased mobility, level of independence and increased risk of falls. The literature defines motor coordination as the existence of spatiotemporal relationships between different body segments during the execution of a task (ANGULO-BARROSO et al., 2011). Thus, when there is no efficient synchronization and coordination of segments during gait, there is a greater risk of energy loss and less functionality for individuals. For an adequate walk it is necessary that the biomechanical parameters are synchronized, since changes in the space-time and / or angular parameters can cause kinematic consequences that will influence the independence and activities of daily living (ADL) of individuals.

In the gait of people with PD, the most evident biomechanical changes are the asymmetries and decreased movement speed of the upper limbs, decreased range of motion (ROM) of the hip, knee and ankle joints (especially in the joint extension phase), asymmetry in the step, less effectiveness in changing strides, greater frequency of step, shorter step length, greater anterior trunk projection, greater rigidity and less trunk rotation (VAN EMMERIK et al., 1999; MORRIS et al., 2001; MONTEIRO et al., 2017; LIN & WAGENAAR, 2018). These factors interfere with the variability of the space-time parameters of walking and promote greater energy expenditure during locomotion (MERELLO et al., 2010; HAMLET et al., 2011).

The walk of people with PD is approximately 0.31m/s slower than in people without PD (VAN EMMERIK et al., 1999; MORRIS et al., 2001). Consequently, there is a change in the gait phases, longer contact time of the foot on the ground, both single and double support, shorter swing time which results in greater stride frequency and less stride length, increased width step, medial-lateral body displacement (DIETZ et al., 1995; MITOMA et al., 2000).

In PD, the spatiotemporal parameters of gait are characterized by small steps in the absence of a broad base, reduced gait speed and the duration of the swing phase, together with an increase in cadence in an effort to compensate for these disorders, in addition to an associated and asymmetric loss of arm balance (MORRIS et al., 1996). The average gait speed in individuals with PD is estimated at 0.88 m/s (HASS et al., 2012) and individuals with a self-selected speed less than 1.1 m/s are likely to have a higher risk of falls (NEMANICH et al., 2013).

In addition to the typical Parkinsonian gait described, patients with PD may also experience episodic gait disorders: festination and freezing. Festination is described as small quick steps taken in an attempt to maintain the center of gravity between the feet while the torso is tilted forward involuntarily, being considered a manifestation of advanced PD (GILADI et al., 2001). Freezing of Gait (FOG) is defined as a brief, episodic absence or marked reduction in the forward progression of the feet, despite the intention to walk (GILADI & NIEUWBOER, 2008), which normally lasts for a few seconds, being strongly associated with falls (GRAY & HILDEBRAND, 2000).

When FOG occurs at the beginning of gait, it is characterized by repeated and ineffective anticipatory postural adjustments, leading to a failure in gait initiation. It can also occur while patients are walking, leading to an abrupt decrease in step length, increased step frequency and step-by-step variability, which precedes a complete blockage of gait, which may result in falls. FOG is often triggered by characteristic circumstances such as obstacle clearance, spaces with narrow passage, unexpected visual or auditory stimuli, fatigue, stressful situations, cognitive load, anxiety and depression (GILADI & HAUSDORFF, 2006; SPILDOOREN et al., 2010).

Even during gait, it is possible to observe that in people with PD there is greater co-contraction of the tibialis anterior and gastrocnemius medialis in the support phase when compared to people without PD. Consequently, in PD there is less propulsion force and less balance strategy during walking, which can affect parameters of functionality such as CP and VAS (PETERSON & HORAK, 2016; MONTEIRO et al., 2017). For an adequate coordination it is necessary that the proximal and distal muscles are activating and deactivating in harmony (VAN EMMERIK et al., 1999; PETERSON & HORAK, 2016).

Changes in speed, symmetry, coordination, mobility, muscle activation and motor control present in the walk of people with PD can lead to changes in ADL, greater risk of falls, depression and mainly loss of independence in functional activities (SOARES & PEYRÉ-TARTARUGA, 2010). Studies involving changes in locomotion kinematics become important for assessing mobility, risk of falls and response to therapeutic interventions for this population. However, there are still gaps in the literature regarding motor control, especially muscle activity and space-time parameters during gait in people with PD. Thus, new studies are relevant and necessary, aiming at a better prescription of gait rehabilitation strategies, motor control and functional independence for these individuals.

2.4 THERAPEUTIC STRATEGIES FOR PD

There are several therapeutic interventions that seek greater functionality for PD patients. Medicinal (STANSLEY & YAMAMOTO, 2014), neurosurgical deep brain stimulation (DBS) (VERCRUYSSE et al., 2014) and conservative (ALBERTS et al., 2011) interventions have been proposed in an attempt to contribute to the improvement of aspects of PD. However, strategies involving medications and surgeries are methods that, in the long term, cause complications and cause many undesirable side effects in about 80% of PD patients, such as fluctuations os sympthoms, dyskinesias and mental disorders (SANTOS et al., 2010).

Drug therapy consists of dopamine replacement or the use of dopaminergic agonists (EMBORG, 2004). Most patients use Levodopa, considered to be the safest and most effective medication in the treatment of PD to date. People affected by PD uses two to three daily doses of levodopa and does not notice irregularities in its action during the day. However, with the progression of the disease, long-term treatment causes the development of dyskinesias (BARGIOTAS & KONITSIOTIS, 2013) and fluctuating motor responses to administration, the “time-off” phenomenon. Dyskinesia consists of involuntary movements, usually rhythmic and contorted in nature, which can affect the head, trunk and limbs. While for many patients dyskinesia can present mildly, for others it can become severe and be a cause of disability (OLANOW et al., 2009), in addition to the possibility of contributing to falls (BLOEM et al., 2001). The “wearing-off” phenomenon consists of alternating periods when the patient responds well to the medication (“on” period) and times when the medication does not produce satisfactory control of symptoms (“off” period). Motor fluctuations bring up some symptoms, such as rigidity and bradykinesia, favoring the difficulty to walk and problems related to balance, impacting the performance of ADL and increasing the risk of falls.

On the other hand, systematic and supervised physical exercise seems to be an effective and low-cost alternative to alleviate the deleterious symptoms of the disease (SOARES & PEYRÉ-TARTARUGA, 2010; ZIGMOND et al., 2014), with a greater impact on functional mobility (MONTEIRO et al., 2017), balance (EY et al., 2014), biomechanical kinematic parameters, depression (TUON et al., 2014), and, especially in the quality of life of patients with PD (EY et al., 2014). Traditional physical therapy through the prescription of therapeutic exercises such as stretching, muscle strengthening, gait training, mobility and balance promotes numerous benefits to patients with PD (DOMINGOS et al., 2013; TOMLINSON et al., 2012).

In addition, studies that evaluated the effects of exercise on PD, although still in an animal model, suggest that this may be a therapeutic strategy for neurorehabilitation (MURRAY et al., 2014). Overall, the results of these studies in PD rodent models offer promising support for exercise to improve cognition in humans with PD, by promoting neuronal proliferation, neuroprotection, neurogenesis and a potential reduction in brain inflammation. These findings encourage further clinical trials based on the results of rodents in this field. The evidence from studies with rodents in the aforementioned systematic review cannot yet be applied directly to mechanisms in humans but suggest that patients with PD would likely experience significant improvement in aspects of the disease in response to exercise.

Although positive adaptations are found in endurance training (FRANZONI et al., 2018; KANITZ et al., 2015), the effects of training programs on postural automatisms in balance and locomotion tasks of individuals with PD are inconclusive. Therefore, studies that investigate different therapeutic strategies to improve motor control and locomotion in individuals with PD become important. Scientific evidence points to the benefits of exercise programs in improving kinematic parameters of locomotion and postural control (BARTOLO et al., 2010; BELLO et al., 2013). Among these, programs carried out in groups, such as Nordic Walking (MONTEIRO et al., 2016), Dance (SHANAHAN et al., 2015) and Exercises in deep water (BROMAN et al., 2006) are an intervention with interesting potentialities for this population.

2.4.1 Dance

The practice of dance has emerged as a possibility of an accessible therapeutic strategy for parkinsonians, capable of providing physical and psychological benefits. It can assist in motor parameters - such as balance and functional mobility - in reducing symptoms of depression, increasing socialization. In addition, dance provides greater motivation for the practice of body experiences, better motor performance and quality of life for this population (SHANAHAN et al., 2015; HACKNEY et al., 2007).

The literature suggests that visual, auditory and somatosensory rhythmic activities, when used therapeutically in people with PD, stimulate an increase in gait speed, increase the step range and promote a tendency towards a lower stride frequency (NIEUWBOER et al., 2007). Dance activities such as tango can impact mobility, balance and walking speed of people with PD (SHARP & HEWITT, 2014; DELABARY et al., 2018). Brazilian dance, especially samba and forró rhythms, have also been the focus of studies on the effects on PD, with positive results on gait variability and improved quality of life (TILLMANN et al., 2017; TILLMANN et al., 2020; DELABARY et al., 2020).

2.4.2 Deep Water Exercises

Water exercise therapy for people with Parkinson's disease (PD) has become a focus of recent attention, given the emerging evidence that physical activity in this environment has the potential to be enjoyable and promote benefits on symptoms. The aquatic environment offers specific advantages for the prescription of physical exercises for this population due to the hydrostatic and hydrodynamic principles of buoyancy, viscosity and drag (DENNING et al., 2012). The decrease in joint compression forces generated by the buoyancy force also contributes to the facilitation of movement and, thus, the performance of muscle strengthening exercises and gait training (CAROMANO & NOWOTNY, 2002; SACCHELLI et al., 2007). Aquatic exercise, through the properties of water, such as hydrostatic pressure, turbulence and buoyancy, creates instability that increases sensory stimulation and, consequently, causes balance reactions that can contribute to improve postural control and mobility in patients with PD (VOLPE et al., 2014), as well as gait in adults with neurological problems, including PD (AYÁN et al., 2014).

Deep Water Running is a therapeutic modality that has been growing for the rehabilitation of mobility and functionality of the elderly population (BROMAN et al., 2006; KANITZ et al., 2015; REICHERT et al., 2016; JORGIC et al., 2012). This type of exercise simulates a run in the water, without the feet touching the bottom of the pool, and for that it uses float resources (PEYRÉ-TARTARUGA & KRUEL, 2006). Although only one study has been published investigating the effects of this modality in the management of PD (OLIVEIRA et al. 2020), this seems to be a viable and promising therapeutic alternative. In fact, the physical properties of water and the effects of immersion in the body help in relieving pain and muscle spasms, in maintaining or increasing joint amplitudes, in strengthening muscles and resistance to exercise, improving circulation, encouraging functional activities, maintenance and improvement of balance, motor coordination and body posture (CAMPION, 2000).

2.4.3 Nordic Walking

Recent studies have demonstrated the potential of Nordic Walking (NW) as an efficient intervention strategy for walking mobility, balance, posture, reduced impact and lower limb myoarticular pain, improved cardiorespiratory variables and improved quality of life of patients affected by various diseases, including PD (EBERSBACH et al., 2010; MONTEIRO et al., 2016, ZANARDI et al., 2019). NW is characterized by walking with poles, which are used diagonally at the moment of walking, aiming that individuals press the pole on the ground in order to propel the body forward during the activity. Considered a physical activity, NW uses movements of the upper limbs, lower limbs and trunk and is defined by a practice that has rhythm and synchrony, providing movements of the whole body (CUGUSI et al., 2017; BOMBIERI et al., 2017).

Dance, Deep Water Exercises and Nordic Walking through their rhythmic movements, synchronized and planned, have the potential to improve the coordinative and mechanical parameters of people with PD. Considering the advancement in life expectancy and the consequent increase in the number of individuals with PD, studies involving rehabilitation measures with better use of motor control, balance and locomotion may come to contribute to the clinical routine.

2.5 REFERENCES

ADKIN, A.L.; FRANK, J.S.; JOG, M.S. Fear of falling and postural control in Parkinson's disease. **Movement Disorders**, v.18, n.5, p.496-502, 2003.

ALBERTS, J.L.; LINDER, S.M.; PENKO, A.L.; LOWE, M.J.; PHILLIPS, M. It is not about the bike, it is about the pedaling: forced exercise and Parkinson's disease. **Exercise and Sport Science Reviews**, v.39, n.4, p.177-86, 2011.

ALEXANDROV, A.V.; FROLOV, A.A.; HORAK, F.B.; CARLSON-KUHTA, P.; PARK, S. Feedback equilibrium control during human standing. **Biological Cybernetics**, v.93, p.309-322, 2005.

ALVES, G.; FORSAA, E.B.; PEDERSEN, K.F.; GJERSTAD, M.D.; LARSEN, J.P. Epidemiology of Parkinson's disease. **Journal of Neurology**, v.255, p.18-32, 2008.

ANGULO-BARROSO, R.; FACIABÉN, A.B.; MAUERBERG-DECASTRO, E. El ángulo de fase y la fase relativa continua para la investigación de la coordinación motora/phase angles and continuous relative phase for research into motor coordination. **Apunts Educación Física e Deportes**, v.38, n.103, p.46-55, 2011.

ARUIN, A.S.; LATASH, M.L. The role of motor action in anticipatory postural adjustments studied with self-induced and externally triggered perturbations. **Experimental Brain Research**, v.106, n.2, p.291-300, 1995.

ARUIN, A.S.; FORREST, W.R.; LATASH, M.L. Anticipatory postural adjustments in conditions of postural instability. **Electroencephalography and Clinical Neurophysiology**, v.109, p.350-359, 1998.

AYAN, C.; CANCELA, J.M.; GUTIERREZ-SANTIAGO, A.; PRIETO, I. Effects of two different exercise programs on gait parameters in individuals with Parkinson's disease: A pilot study. **Gait & Posture**, v.39, n.1, p.648-651, 2014.

BALDISSERA, F.G.; TESIO, L. APAs Constraints to Voluntary Movements: The Case for Limb Movements Coupling. **Frontiers in Human Neuroscience**, v.11, n.152, 2017.

BARBOSA, E.R.; SALLEM, F.A.S. Doença de Parkinson: diagnóstico. **Revista Neurociências**, v.13, n.3, p.158-165, 2005.

BARGIOTAS, P.; KONITSIOTIS, S. Levodopa-induced dyskinesias in Parkinson's disease: emerging treatments. **Neuropsychiatric Disease and Treatment**, v.9, p.1605-1617, 2013.

BARTOLO, M.; SERRAO, M.; TASSORELLI, C.; DON, R.; RANAVOLO, A.; DRAICCHIO, F.; PACHETTI, C.; BUSCONE, S.; PERROTTA, A.; FURNARI, A.; BRAMANTI, P.; PADUA, L.; PIERELLI, F.; SANDRINI, G. Four-week trunk-specific rehabilitation treatment improves lateral trunk-flexion in Parkinson's disease. **Movement Disorders**, v.25, n.3, p.325-331, 2010.

BELLO, O.; SANCHEZ, J.A.; LOPEZ-ALONSON, V.; MARQUEZ, G.; MORENILLA, L.; CASTRO, X.; GIRALDEZ, M.; SANTOS-GARCIA, D.; FERNANDEZ-DEL-OMO, M. The effects of treadmill or overground walking training program on gait in Parkinson's disease. **Gait & Posture**, v.38, n.4, p.590-595, 2013.

BERARDELLI, A.; ROTHWELL, J.C.; THOMPSON, P.D.; HALLETT, M. Pathophysiology of bradykinesia in Parkinson's disease. **Brain**, v.124, n.11, p.2131-2146, 2001.

BENNIS, N.; ROBY-BRAMI, A.; DUFOSSÉ, M.; BUSSEL, B. Anticipatory responses to a self-applied load in normal subjects and hemiparetic patients. **Journal of Physiology**, v.90, n.1, p.27-42, 1996.

BLOEM, B.R.; GRIMBERGEN, Y.A.M.; CRAMER, M.; WILLEMSEN, M.; ZWINDERMAN, A.H. Prospective assessment of falls in Parkinson's disease. **Journal of Neurology**, v.248, p.950-958, 2001.

BOHLHALTER, S.; KÄGI, G. Parkinsonism: heterogeneity of a common neurological syndrome. **Swiss Medical Weekly**, v.141, p.132-139, 2011.

BOMBIERI, F.; SCHENA, F.; PELLEGRINI, B.; BARONE, P.; TINAZZI, M.; ERRO, R. Walking on four limbs: A systematic review of Nordic Walking in Parkinson disease. **Parkinson and Related Disorders**, v.38, p.8-12, 2017.

BRENIÈRE, Y.; DO, M.C. Control of gait initiation. **Journal of Motor Behavior**, v.23, p.235-240, 1991.

BROMAN, G.; QUINTANA, M.; LINDBERG, T.; JANSSON, E.; KAIJSER, L. High intensity deep water training can improve aerobic power in elderly women. **European Journal of Applied Physiology**, v.98, n.2, p.117-123, 2006.

BURLEIGH-JACOBS, A.; HORAK, F.B.; NUTT, J.G.; OBESO, J.A. Step initiation in Parkinson's disease: influence of levodopa and external sensory triggers. **Movement Disorders**, v.12, p.206-215, 1997.

CAMBIER, J.; MASSON, M.; DEHEN, H. **Manual de Neurologia**. São Paulo: Meds, 1999.

CAMBIER, J.; MASSON, M.; DEHEN, H. **Neurologia**. Rio de Janeiro: Guanabara Koogan, 2005.

CAMPION, M.R. **Hidroterapia princípios e prática**. São Paulo: Manole, 2000.

CAROMANO, F.A.; NOWOTNY, J.P. Princípios físicos que fundamentam a hidroterapia. **Fisioterapia Brasil**, v.3, n.6, 2002.

CARPENTER, M.G.; ALLUM, J.H.J.; HONEGGER, F.; ADKIN, A.L.; BLOEM, B.R. Postural abnormalities to multidirectional stance perturbations in Parkinson's disease. **Neurology, Neurosurgery & Psychiatry**, v.75, n.9, p.1245-1254, 2004.

CHONG, R.K.Y.; JONES, C.L.; HORAK, F.B. Postural set for balance control is normal in Alzheimer's but not in Parkinson's disease. **Journal of Gerontology Medical Science**, v.54, n.3, p.129-135, 1999.

CLAUDINO, R.; DOS SANTOS, E.C.; SANTOS, M.J. Compensatory but not anticipatory adjustments are altered in older adults during lateral postural perturbations. **Clinical Neurophysiology**, v.124, n.8, p.1628-1637, 2013.

CUGUSI, L.; MANCA, A.; DRAGONE, D.; DERIU, F.; SOLLA, P.; SECCI, C.; MONTICONE, M.; MERCURO, G. Nordic Walking for the management of people with Parkinson disease: A Systematic Review. **Physical Medicine and Rehabilitation**, v.9, n.11, p.1157-1166, 2017.

DELABARY, M.; KOMEROSKI, I.G.; MONTEIRO, E.P.; COSTA, R.R.; HAAS, A.N. Effects of dance practice on functional mobility, motor symptoms and quality of life in people with Parkinson’s disease: a systematic review with meta-analysis. **Aging Clinical and Experimental Research**, v.30, n.7, p.727-735, 2018.

DELABARY, M.; MONTEIRO, E.P.; DONIDA, R.G.; WOLFFENBUTTEL, M.; PEYRÉ-TARTARUGA, L.A.; HAAS, A.N. Can Samba and Forró Brazilian rhythmic dance be more effective than walking in improving functional mobility and spatiotemporal gait parameters in patients with Parkinson’s disease? BMC Neurology, v.20, n.302, 2020.

DELVAL, A.; TARD, C.; DEFEBVRE, L. Why we should study gait initiation in Parkinson's disease? Clinical Neurophysiology, v.44, n.1, p.69-76, 2014.

DENNING, W.M.; BRESSEL, E.; DOLNY, D.; BRESSEL, M.; SEELEY, M.K. A Review of Biophysical Differences between Aquatic and Land-Based Exercise. **International Journal of Aquatic Research and Education**, v.6, n.1, 2012.

DIBBLE, L.E.; NICHOLSON, D.E.; SHULTZ, B.; MACWILLIAMS, B.A.; MARCUS, R.L.; MONCUR, C. Sensory cueing effects on maximal speed gait initiation in persons with Parkinson’s disease and healthy elders. **Gait & Posture**, v.19, p.215-225, 2004.

DICKSTEIN, R.; SHEFI, S.; MARCOVITZ, M.; VILLA, Y. Anticipatory postural adjustment in selected trunk muscles in post stroke hemiparetic patients. **Archives of Physical Medicine and Rehabilitation**, v.85, n.2, p.261-267, 2004.

DIETZ, V.; ZIJLSTRA, W.; PROKOP, T.; BERGER, W. Leg muscle activation during gait in Parkinson’s disease: adaptation and interlimb coordination. **Electroencephalography and Clinical Neurophysiology**, v.97, n.6, p.408-415, 1995.

DOMINGOS, J.; COELHO, M.; FERREIRA, J.J. Referral to rehabilitation in Parkinson's disease: who, when and to what end? **Arquivos de Neuropsiquiatria,** v.71, n.12, p.967-972, 2013.

EBERSBACH, G.; EBERSBACH, A.; EDLER, D.; KAUFHOLD, O.; KUSCH, M.; KUPSCH, A.; WISSEL, J. Comparing exercise in Parkinson's disease – the Berlin LSVT®BIG study. **Movement Disorders**, v.25, n.12, p.1902-1908, 2010.

EMBORG, M.E. Evaluation of animal models of Parkinson's disease for neuroprotective strategies. **Journal of Neuroscience Methods**, v.139, n.2, p.121-143, 2004.

ESPAY, A.J.; BEATON, D.E.; MORGANTE, F.; GUNRAJ, C.A.; LANG, A.E.; CHEN, R. Impairments of speed and amplitude of movement in Parkinson's disease: A pilot study. **Movement Disorders**, v.24, n.7, p.1001-1008, 2009.

EY, U.C.; DOERSCHUG, K.C.; MAGNOTTA, V.; DAWSON, J.D.; THOMSEN, T.R.; KLINE, J.N. Phase I/II randomized trial of aerobic exercise in Parkinson disease in a community setting. **Neurology**, v.83, n.5, p.413-425, 2014.

FALL, P.; SALEH, A.; FREDRICKSON, M.; OLSSON, J.; GRANÉRUS, A. Survival time, mortality, and cause of death in elderly patients with Parkinson's disease. A 9-year follow-up. **Movement Disorders**, v.18, n.11, p.1312-1316, 2003.

FERRAYE, M.U.; DEBU, B.; FRAIX, V.; XIE-BRUSTOLIN, J.; CHABARDÈS, S.; KRACK, P.; BENABID, A.L.; POLLAK, P. Effects of subthalamic nucleus stimulation and levodopa on freezing of gait in Parkinson disease. **Neurology**, v.70, n.16, p.1431-1437, 2008.

FRANK, J.S.; HORAK, F.B.; NUTT, J. Centrally initiated postural adjustments in parkinsonian patients on and off levodopa. **Journal of Neurophysiology**, v.84, n.5, p.2440-2448, 2000.

FRANZÉN, E.; PAQUETTE, C.; GURFINKEL, V.S.; CORDO, P.J.; NUTT, J.G.; HORAK, F.B. Reduced performance in balance, walking and turning tasks is associated with increased neck tone in Parkinson's disease. **Experimental Neurology**, v.219, n.2, p.430-438, 2009.

FRANZONI, L.T.; MONTEIRO, E.; BIANCHI, H.; DA ROSA, R.; COSTA, R.; RIEDER, C.; MARTINEZ, F.; PEYRÉ-TARTARUGA, L. A 9-week Nordic and Free Walking improve postural balance in Parkinson’s disease. **Sports Medicine International Open**, v.2, n.1, p.28-34, 2018.

GIBB, W.R.G. Neuropathology of Parkinson’s disease and related syndromes. **Neurologic Clinics**, v.10, n.2, p.361-376, 1992.

GILADI, N.; TREVES, T.A.; SIMON, E.S.; SHABTAI, H.; ORLOV, Y.; KANDINOV, B.; PALEACU, D.; KORCZYN, A.D. Freezing of gait in patients with advanced Parkinson's disease. **Journal of Neural Transmission**, v.108, p.53-61, 2001.

GILADI, N.; NIEUWBOER, A. Understanding and treating freezing of gait in parkinsonism, proposed working definition, and setting the stage. **Movement Disorders**, v.23, n.S2, p.S423-S425, 2008.

GOETZ, C.G.; TILLEY, B.C.; SHAFTMAN, S.R.; STEBBINS, G.T.; FAHN, S.; MARTINEZ-MARTIN, P.; POEWE, W.; SAMPAIO, C.; STERN, M.B.; DODEL, R.; DUBOIS, B.; HOLLOWAY, R.; JANKOVIC, J.; KULISEVSKY, J.; LANG, A.E.; LEES, A.; LEURGANS, S.; LEWITT, P.A.; NYENHUIS, D.; OLANOW, C.W.; RASCOL, O.; SCHRAG, A.; TERESI, J.A.; VAN HILTEN, J.J.; LAPELLE, N. Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS): Scale presentation and clinimetric testing results. **Movement Disorders**, v.23, n.15, p.2129-2170, 2008.

GRAY, P.; HILDEBRAND, K. Fall risk factors in Parkinson's disease. **Journal of Neuroscience Nursing**, v.32, n.4, p.222-228, 2000.

GRIMBERGEN, Y.A.M.; LANGSTON, J.W.; ROOS, R.A.C.; BLOEM, B.R. Postural instability in Parkinson's disease: the adrenergic hypothesis and the locus coeruleus. **Expert Review of Neurotherapeutics**, v.9, n.2, p.279-290, 2009.

HACKNEY, M.E.; KANTOROVICH, S.; LEVIN, R.; EARHART, G.M. Effects of Tango on functional mobility in Parkinson's disease: a preliminary study. **Journal of Neurologic Physical Therapy**, v.31, n.4, p.173-179, 2007.

HALLIDAY, S.E.; WINTER, D.A.; FRANK, J.S.; PATLA, A.E.; PRINCE, F. The initiation of gait in young, elderly, and Parkinson's disease subjects. **Gait & Posture**, v.8, p.8-14, 1998.

HAMLET, S.; GEISINGER, D.; FERREIRA, E.D.; NOGUEIRA, S.; AROCENA, S.; SAN ROMAN, C. Equilíbrio na doença de Parkinson alterando as informações visuais. **Brazilian Journal of Otorhinolaryngology**, v.77, n.5, p.651-655, 2011.

HASS, C.J.; WADDELL, D.E.; FLEMING, R.P.; JUNCOS, J.L.; GREGOR, R.J. Gait initiation and dynamic balance control in Parkinson's disease. **Archives of Physical Medicine Rehabilitation**, v.86, p.2171-2176, 2005.

HELDMAN, D.A.; GIUFFRIDA, J.P.; CHEN, R.; PAYNE, M.; MAZZELLA, F.; DUKER, A.P.; SAHAY, A.; KIM, S.J.; REVILLA, F.J.; ESPAY, A.J. The modified bradykinesia rating scale for Parkinson's disease: Reliability and comparison with kinematic measures. **Movement Disorders**, v.26, n.10, p.1859-1863, 2011.

HELY, M.A.; MORRIS, J.G.L.; REID, W.G.J.; TRAFFICANTE, R. Sydney multicenter study of Parkinson's disease: Non-L-dopa–responsive problems dominate at 15 years. **Movement Disorders**, v.20, n.2, p.190-199, 2005.

HORAK, F.B.; FRANK, J.; NUTT, J. Effects of dopamine on postural control in parkinsonian subjects: scaling, set, and tone. **Journal of Neurophysiology**, v.75, n.6, p.2380-2396, 1996.

HORAK, F.B.; DIMITROVA, D.; NUTT, J. Direction-specific postural instability in subjects with Parkinson's disease. **Experimental Neurology**, v.193, n.2, p.504-521, 2005.

HORAK, F.B. Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? **Age and Ageing**, v.35, n.2, p.7-11, 2006.

HORAK, F.B.; MACPHERSON, J.M. Postural orientation and equilibrium. In: **Handbook of Physiology, Exercise: Regulation and Integration of Multiple Systems**, Oxford: Rowell LB & Shepherd, 2011.

ILKE, D.; CARDOSO, N.P.; BARALDI, I. Análise da incidência de quedas e a influência da fisioterapia no equilíbrio e na estabilidade postural de pacientes com doença de Parkinson. **Revista Fisioterapia Brasil**, v.9, p.4-8, 2008.

INKSTER, L.M.; ENG, J.J. Postural control during a sit-to-stand task in individuals with mild Parkinson's disease. **Experimental Brain Research**, v.154, p.33-38, 2004.

INSTITUTO BRASILEIRO DE GEOGRAFIA ESTATÍSTICA (IBGE). Estatísticas sociais da população, 2018. Available in: <http://www.ibge.gov.br> Acess in: April 16, 2020.

JACOBS, J.V.; LOU, J.S.; KRAAKEVIK, J.A.; HORAK, F.B. The supplementary motor area contributes to the timing of the anticipatory postural adjustment during step initiation in participants with and without Parkinson's disease. **Neuroscience**, v.164, n.2, p.877-885, 2009.

JANKOVIC, J. Parkinson’s disease: clinical features and diagnosis. **Journal of Neurology, Neurosurgery and Psychiatry**, v.79, n.4, p.368-376, 2008.

JORGIC, B.; MILANOVIC, Z.; ALEKSANDROVIC, M.; PANTELIC, S.; DALY, D. Effects of deep water running in older adults. A Systematic review. **Healthmed,** v.6, n.1, p. 3219-3227, 2012.

KANEKAR, N.; ARUIN, A.S. Aging and balance control in response to external perturbations: role of anticipatory and compensatory postural mechanisms. **Age**, v.36, p.962-971, 2014.

KANITZ, A.C.; DELEVATTI, R.S.; REICHERT, T.; LIEDTKE, G.V.; FERRARI, R.; ALMADA, B.P.; PINTO, S.S.; ALBERTON, C.L.; KRUEL, L.F.M. Effects of two deep water training programs on cardiorespiratory and muscular strength responses in older adults. **Experimental Gerontology**, v.64, p.55-61, 2015.

KEUS, S.; MUNNEKE, M.; GRAZIANO, M.; PALTAMAA, J.; PELOSIN, E.; DOMINGOS, J. **European Physiotherapy Guideline for Parkinson’s Disease**. KNGF/ParkinsonNet, the Netherlands, 1ed, 2014.

KIM, S.D.; ALLEN, N.E.; CANNING, C.G.; FUNG, V.S.C. Postural Instability in Patients with Parkinson's disease. **Epidemiology, Pathophysiology and Management**, v.27, p.97-112, 2013.

KRISHNAN, V.; LATASH, M.L.; ARUIN, A.S. Early and late components of feed-forward postural adjustments to predictable perturbations. **Clinical Neurophysiology**, v.123, n.5, p.1016-1026, 2012.

KRYSTKOWIAK, P.; DELVAL, A.; DUJARDIN, K.; BLEUSE, S.; BLATT, J.L.; BOURRIEZ, J.L. Gait abnormalities induced by acquired bilateral pallidal lesions: a motion analysis study. **Journal of Neurology**, v.253, p.594-600, 2006.

LATASH, M.L. **Synergy.** New York: Oxford University Press, 2008.

LIN, C.; WAGENAAR, R.C. The impact of walking speed on interlimb coordination in individuals with Parkinson's disease. **Journal of Physical Therapy Science**, v.30, p.658–662, 2018.

LORAM, I.D.; LAKIE, M. Direct measurement of human ankle stiffness during quiet standing: the intrinsic mechanical stiffness is insufficient for stability. **The Journal of Physiology**, v.545, n.3, p.1041-1053, 2002.

MANCINI, M.; ROCCHI, L.; HORAK, F.B.; CHIARI, L. Effects of Parkinson's disease and levodopa on functional limits of stability. **Clinical Biomechanics**, v.23, n.4, p.450-458, 2008.

MANCINI, M.; NUTT, J.; HORAK, F.B. **Balance Dysfunction in Parkinson 's disease: Basic Mechanisms to Clinical Management**. Academic Press: London, 2019.

MASSION, J. Movement, posture and equilibrium: Interaction and coordination. **Progress in Neurobiology**, v.38, n.1, p.35-56, 1992.

MASSION, J. Postural Control Systems in Developmental Perspective. **Neuroscience & Biobehavioral Reviews**, v.22, n.4, p.465-472, 1998.

MERELLO, M.; FANTACONE, N.; BALEJ, J. Kinematic study of whole body center of mass position during gait in Parkinson's disease patients with and without festination. **Movement Disorders**, v.25, n.6, p.747-754, 2010.

MILLE, M.L.; JOHNSON, M.E.; MARTINEZ. K.M.; ROGERS, M.W. Age-dependent differences in lateral balance recovery through protective stepping. **Clinical Biomechanics**, v.20, n.6, p.607-616, 2005.

MITOMA, H. et al. Characteristics of parkinsonian and ataxic gaits: A study using surface electromyograms, angular displacements and floor reaction forces. **Journal of the Neurological Sciences**, v.174, n.1, p.22–39, 2000.

MONTEIRO, E.P.; WILD, L.B.; MARTINEZ, F.G.; PAGNUSSAT, A.S.; PEYRÉ-TARTARUGA, L.A. Aspectos biomecânicos da locomoção de pessoas com doença de Parkinson: revisão narrativa. **Revista Brasileira de Ciências do Esporte**, v.39, n.4, p.450-457, 2017.

MORRIS, M.; IANSEK, R.; CHURCHYARD, A. The role of the physiotherapist in quantifying movement fluctuations in Parkinson's disease. **Australian Journal of Physiotherapy**, v.44, n.2, p.105-107, 1998.

MORRIS, S.; MORRIS, M.E.; IANSEK, R. Reliability of measurements obtained with the Timed "Up & Go" test in people with Parkinson disease. **Physical Therapy**, v.81, n.2, p.810-818, 2001.

MORRIS, M.; IANSEK, R.; MCGINLEY, J.; MATYAS, T.; HUXHAM, F. Three-dimensional gait biomechanics in Parkinson's disease: evidence for a centrally mediated amplitude regulation disorder. **Movement Disorders**, v.20, n.1, p.40-50, 2005.

MULLER, M.L.T.M.; REDFERN, M.S. Correlation between EMG and COP onset latency in response to a horizontal platform translation. **Journal of Biomechanics**, v.37, n.10, p.1573-1581, 2004.

MURRAY, D.K.; SACHELI, M.A.; ENG, J.J.; STOESSL, A.J. The effects of exercise on cognition in Parkinson's disease: a systematic review. **Translational Neurodegeneration**, v.3, n.5, 2014.

NAGANO-SAITO, A.; MARTINU, K.; MONCHI, O. Function of basal ganglia in bridging cognitive and motor modules to perform an action. **Frontiers in Neuroscience**, v.8, p.187, 2014.

NEMANICH, S.T.; DUNCAN, R.P. DIBBLE, L.E.; CAVANAUGH, J.T.; ELLIS, T.D.; FORD, M.P.; FOREMAN, K.B.; EARHAR, G.M. Predictors of gait speeds and the relationship of gait speeds to falls in men and women with Parkinson disease. **Parkinson's disease**, v.2013, 2013.

NIEUWBOER, A.; KWAKKEL, G.; ROCHESTER, L.; JONES, D.; VAN WEGEN, E.; WILLEMS, A.M.; CHAVRET, F.; HETHERINGTON, V.; BAKER, K.; LIM, I. Cueing training in the home improves gait-related mobility in Parkinson's disease: the RESCUE trial. **Journal of Neurology, Neurosurgery and Psychiatry**, v.78, n.2, p.134-40, 2007.

O´SULLIVAN, S.B.; SCHMITZ, T.J. **Fisioterapia: avaliação e tratamento**. 2 ed. São Paulo: Manole, 1993.

OLANOW, C.W.; STERN, M.B.; SETHI, K. The scientific and clinical basis for the treatment of Parkinson disease. **Neurology**, v.72, n.21, 2009.

OLIVEIRA, G.S.; IRACI, L.; PINHEIRO, G.S.; CASAL, M.Z.; HAAS, A.N.; POCHMANN, D.; MARTINEZ, F.G.; ELSNER, V.; DANI, C. Effect of exercise and grape juice on epigenetic modulation and functional outcomes in PD: A randomized clinical trial. **Physiology & Behavior**, v.227, n.1, p.113-135, 2020.

PARK, S.; HORAK, F.B.; KUO, A.D. Postural feedback responses scale with biomechanical constraints in human standing. **Experimental Brain Research**, v.154, p.417-427, 2004.

PETERSON, D.S.; HORAK, F.B. Neural Control of Walking in People with Parkinsonism. **Physiology**, v.126 n.31, p. 95–107, 2016.

PEYRE-TARTARUGA LA, KRUEL, LFM. Corrida em piscina funda: limites e possibilidades para o alto desempenho. **Revista Brasileira de Medicina do Esporte,** v.12, p.286-290, 2006.

PROCHAZKA, A.; BENNETT, D.J.; STEPHENS, M.J.; PATRICK, S.K.; SEARS-DURU, R.; ROBERTS, T.; JHAMANDAS, J.H. Measurement of rigidity in Parkinson's disease. **Movement Disorders**, v.12, n.1, p.24-32, 1997.

REICHERT, T.; KANITZ, A.C.; DELEVATTI, R.S.; BAGATINI, N.C.; BARROSO, B.M.; KRUEL, L.F.M. Continuous and interval training programs using deep water running improves functional fitness and blood pressure in the older adults. **Journal of the American Aging Association**, v.38, n.1, 2016.

ROCCHI, L.; CARLSON-KUHTA, P.; CHIARI, L.; BURCHIEL, K.L.; HOGARTH, P.; HORAK, F.B. Effects of deep brain stimulation in the subthalamic nucleus or globus pallidus internus on step initiation in Parkinson disease. **Journal of Neurosurgery**, v.117, n.6, p.983-1208, 2012.

ROWLAND, L.P. **Merrit - Tratado de Neurologia**. 11a ed. Rio de Janeiro (RJ): Guanabara Koogan; 2007.

SACCHELLI, T.; ACCACIO, L.M.P.; RADI, A.L.M. **Fisioterapia aquática**. São Paulo: Manole, 2007.

SANTOS, M.; KANEKAR, N.; ARUIN, A.S. The role of anticipatory postural adjustments in compensatory control of posture: 1. electromyography analysis. **Journal of Electromyography and Kinesiology**, v.20, p.388-397, 2010.

SHANAHAN, J.; MORRIS, M.E.; BHRIAIN, O.N.; SAUNDERS, J.; CLIFFORD, A.M. Dance for people with Parkinson disease: What is the evidence telling us? **Archives of Physical Medicine and Rehabilitation**, v.96, n.1, p.141-53, 2015.

SHARP, K.; HEWITT, J. Dance as an intervention for people with Parkinson’s disease: A systematic review and meta-analysis. **Neuroscience and Biobehavioral Reviews**, v.47, p.445-456, 2014.

SOARES, G.S.; PEYRÉ-TARTARUGA, L.A. Parkinson’s disease and physical exercise: a literature review. **Ciência e Movimento – Biociência e Saúde**, v.24, n. 12, 2010.

SPILDOOREN, J.; VERCRUYSSE, S.; DESLOOVERE, K.; VANDENBERGHE, W.; KERCKHOFS, E.; NIEUWBOER, A. Freezing of gait in Parkinson's disease: The impact of dual-tasking and turning. **Movement Disorders**, v.25, n.15, p.2563-2570, 2010.

STANSLEY, B.J.; YAMAMOTO, B.K. Chronic l-Dopa decreases serotonin neurons in a subregion of the dorsal raphe nucleus. **Journal of Pharmacology and Experimental Therapy**, v.351, p.440-447, 2014.

SUTEERWATTANANON, M.; MACNEILL, B.; PROTAS, E.J. Supported treadmill training for gait and balance in patient with progressive supranuclear palsy. **Physical Therapy**, v.82, n.5, p.485-495, 2002.

TAKAKUSAKI, K.; TOMITA, N.; YANO. M. Substrates for normal gait and pathophysiology of gait disturbances with respect to the basal ganglia dysfunction. **Journal of Neurology**, v.255, p.19-29, 2008.

TEIVE, H. Etiopatogenia da doença de Parkinson. **Revista Neurociências**, v.13, p. 201-214, 2005.

TILLMANN, A.C.; ANDRADE, A.; SWAROWSKY, A.; GUIMARÃES, A.C.A. Brazilian Samba Protocol for Individuals With Parkinson’s Disease: A Clinical Non-Randomized Study. **JMIR**, v.6, n.7, 2017.

TILLMANN, A.C.; SWAROWSKY, A.; CORREA, C.L.; ANDRADE, A.; MORATELLI, J.; BOING, L.; VIEIRA, M.C.S.; ARAUJO, C.C.R.; GUIMARÃES, A.C.A. Feasibility of a Brazilian samba protocol for patients with Parkinson's disease: a clinical non-randomized study. **Arquivos de Neuropsiquiatria**, v.78, n.1, 2020.

TJERNSTRÖM, F.; FRANSSON, A.; HAFSTRÖM, M.; MAGNUSSON, M. Adaptation of postural control to perturbations—a process that initiates long-term motor memory. **Gait & Posture**, v.15, n.1, p.75-82, 2002.

TOMLINSON, C.L.; PATEL, S.; MEEK, C. Physiotherapy intervention in Parkinson's disease: systematic review and meta-analysis. **British Medical Journal,** v.345, p.e5004, 2012.

TUON, T.; VALVASSORI, S.S.; DAL PONT, G.C.; PAGANINI, C.S.; POZZI, B.G.; LUCIANO, T.F.; SOUZA, P.S.; QUEVEDO, J.; SOUZA, C.T.; PINHO, R.A. Physical training prevents depressive symptoms and a decrease in brain-derived neurotrophic factor in Parkinson's disease. **Brain Research Bulletin**, v.108, p.106-112, 2014.

UNITED NATIONS. World population prospects: The 2019 revision. Available in: <http://esa.un.org/unpd/wpp/> Acess in: April 16, 2020.

VAN EMMERIK, R.E.E.; WAGENAAR, R.C.; WINOGRODZKA, A.; WOLTERS, E.C. Identification of axial rigidity during locomotion in Parkinson disease. **Archives of Physical Medicine and Rehabilitation**, v.80, p.186–191, 1999.

VERCRUYSSE, S.; VANDENBERGHE, W.; MUNKS, L.; NUTTIN, B.; DEVOS, H.; NIEUWBOER, A. Effects of a deep brain stimulation of the subthalamic nucleus on freezing of gait in Parkinson’s disease: a prospective controlled study. **Journal of Neurology, Neurosurgery and Psychiatry**, v.85, p.871-877, 2014.

VITÓRIO, R.; PIERUCCINI-FARIA, F.; STELLA, F.; GOBBI, S.; GOBBI, L.T.B. Effects of obstacle height on obstacle crossing in mild Parkinson’s disease. **Gait & Posture**, v.31, n.1, p.143-146, 2010.

VOLPE, D.; GIANTIN, M.G.; MAESTRI, R.; FRAZZITTA, G. Comparing the effects of hydrotherapy and land-based therapy on balance in patients with Parkinson’s disease: a randomized controlled pilot study. **Clinical Rehabilitation**, v.28, n.12, 2014.

VUILLERME, N.; PINSAULT, N.; VAILLANT, J. Postural control during quiet standing following cervical muscular fatigue: effects of changes in sensory inputs. **Neuroscience Letters**, v.378, n.3, p.135-139, 2005.

WINTER, D.A.; PATLA, A.E.; RIETDYK, S.; ISHAC, M.G. Ankle muscle stiffness in the control of balance during quiet standing. **Journal of Neurophysiology**, v.85, n.6, p.2630-2633, 2001.

ZANARDI, A.P.J.; MARTINEZ, F.G.; SILVA, E.S.; CASAL, M.Z.; MARTINS, V.F.; PASSOS-MONTEIRO, E.; HAAS, A.N.; PEYRÉ-TARTARUGA, L.A. Effects of Nordic walking on gait symmetry in mild Parkinson’s disease. **Symmetry**, v.11, n.12, 2019.

ZIEMSSEN, T.; REICHMANN, H. Non-motor dysfunction in Parkinson's disease. **Parkinsonism & Related Disorders**, v.13, n.6, p.323-332, 2007.

ZIGMOND, M.J.; SMEYNE, R.J. Exercise: is it a neuroprotective and if so, how does it work? **Parkinsonism and Related Disorders**, v.20, n.2, p.123-127, 2014.

CHAPTER V

5 GENERAL CONCLUSION AND FINAL CONSIDERATIONS

The study of motor and biomechanical behavior in daily locomotion tasks in individuals with PD is essential for a better understanding and establishment of effective therapeutic strategies, assisting health professionals in planning, prescribing and developing physical exercise-based programs that can contribute to the improvement motor skills, functional independence and quality of life of this population. We conducted two studies with a focus on postural adjustments and biomechanical parameters related to gait initiation and obstacle negotiation for people with PD and each of these studies was designed to answer key questions.

Because PD is polysymptomatic and can be manifested in different ways, it is interesting to divide patients by clinical manifestations to more accurately assess responses to stimuli and interventions, although most of the existing studies do not make this differentiation. In fact, our first study demonstrated differences between the akinetic-rigid and hyperkinetic subtypes, with greater damage on postural adjustments and biomechanical parameters for the group with a predominance of rigidity. This finding is interesting because it suggests that, although the importance of physical exercise in the treatment of PD is well established, studies are still needed to investigate how each clinical subtype responds to different stimuli, in order to assist health professionals in the best prescription and determination of most effective strategy in each clinical context.

Still in the first study, our results obtained through correlation analysis infer that the magnitude of postural adjustments and performance during gait initiation are correlated with functional mobility and also with the fear of falling for people with PD. Thus, it is important to investigate the effects of different therapeutic strategies that can minimize the damage from these mechanisms.

In order to improve or maintain the efficiency of postural automatisms and performance in daily tasks commonly related to episodes of falls in PD, the second study proposed three non-conventional interventions that provide different stimuli. Our main objective was to evaluate the effects of Nordic Walking, Deep Water Exercise and Brazilian Dance programs on muscular and kinetic APA and CPA, as well as the kinematics of the gait initiation and obstacle negotiation. In general, we found that NW and DWE seem to promote more significant changes in muscle postural adjustments and in the movement kinematics, while the BD group was limited to increased muscle activity in hip abductors.

Our training programs were periodized with a view to similar intensity among them. Thus, we believe that the particularities of each intervention were important in determining the effects. Although the three interventions have positive effects, it seems that cyclical modalities and gait simulation can have a greater impact on biomechanical variables and trunk muscles activity. On the other hand, BD showed improvement in postural adjustments, reflected in the greater integral activity of the middle gluteus, an important stabilizer, especially in situations that demand greater control of balance in single support. In general, the exercise programs seemed to cause improvements in postural control and movement performance of people with PD included in this study, especially NW and DWE. Resistance exercise has been widely advocated for the delay of degenerative processes and functional improvement. Thus, Nordic Walking, Deep Water Exercises and Brazilian Dance are group interventions that have the potential to improve postural automatisms in daily tasks.

The limitations of this study involve: 1) The absence of a healthy control group (study 1) that did not receive any intervention with exercises or that performed conventional physical therapy (study 2); 2) The evaluations were carried out only during the period of validity of the medication, which may have mitigated the effects; and 3) The inclusion of only people with mild to moderate PD. Based on the results of the present study, we suggest new clinical trials that investigate these parameters with longer training and follow-up periods, as well as assess the effects on postural and biomechanical adjustments related to other daily tasks. In addition, we also suggest evaluating the acute effects of these interventions and their effects on each clinical subtype of the disease.

Through this work we hope to contribute to a better understanding of the mechanisms related to the strategies of postural adjustment of individuals with Parkinson's disease with different clinical manifestations and how physical training programs with different characteristics can contribute to the improvement and / or maintenance of these parameters. Therefore, it is also expected to contribute to a more qualified and evidence-based approach by health professionals regarding the management of postural automatisms and their implications for the functional mobility of individuals with PD.

CHAPTER VI

6 PUBLISHED STUDIES DURING MASTER'S DEGREE

This chapter brings together the scientific production resulting from this research and other collaborations during the Master's Degree period.

6.1 PUBLISHED PAPERS

OLIVEIRA, G.S.; IRACI, L.; PINHEIRO, G.S.; PROENÇA, I.C.T.; **CASAL, M.Z.**; HAAS, A.N.; MARTINEZ, F.G.; POCHMANN, D.; ELSNER, V.; DANI, C. Effect of exercise and grape juice on epigenetic modulation and functional outcomes in PD: a randomized clinical trial. *Physiology & Behavior*, June/2020.

ZANARDI, A.P.J.; MARTINEZ, F.G.; SILVA, E.S.; **CASAL, M.Z.**; MARTINS, V.F.; PASSOS-MONTEIRO, E.; HAAS, A.N.; PEYRÉ-TARTARUGA, L.A. Effects of Nordic Walking on Gait Symmetry in Mild Parkinson's Disease. *Symmetry*, v.11, n.12, p.1481, 2019.

6.2 SUBMITTED PAPERS

ZANARDI, A.P.J.; **CASAL, M.Z.**; MONTEIRO, E.P.; DOS SANTOS, I.O.; DONIDA, R.G.; MARTINS, V.F.; MARTINEZ, F.G.; HAAS, A.N.; PEYRÉ-TARTARUGA, L.A. Effect of gestural specificity promoted by Nordic walking and dance on trunk and pelvis girdle coordination during walking in people with Parkinson's disease.

OLIVEIRA, G.; PINHEIRO, G.; PROENÇA, I.; BLEMBEEL, A.; **CASAL, M.Z.**; POCHMANN, D.; PEYRÉ-TARTARUGA, L.A.; MARTINEZ, F.G.; ARAÚJO, A.S.R.; ELSNER, V.; DANI, C. Aquatic exercise associated or not with grape juice consumption modulated the oxidative parameters in Parkinson Disease patients: a randomized intervention study. *Heliyon Journal*, June/2020.

SANTOS, B.A.; BLACK, G.L.; ROSA, B.N.; CANDOTTI, C.T.; **CASAL, M.Z.**; MARTINEZ, F.G. Therapeutic interventions with deep water running: a systematic review. *Clinical Rehabilitation*, May/2020.

PEYRÉ-TARTARUGA, L.A.; MARTINEZ, F.G.; MONTEIRO, E.P.; ZANARDI, A.P.J.; **CASAL, M.Z.**; DONIDA, R.; MARTINS, V.F.; COERTJENS, M.; DELABARY, M.;

HAAS, A.N. Samba, deep water and poles: a framework for exercise prescription in Parkinson's disease. *Sports Medicine International Open*, April/2020.

6.3 ABSTRACTS PRESENTED AT NATIONAL SCIENTIFIC EVENTS

CASAL, M.Z; ZANARDI, A.P.J.; MELLO, A.I.; SANTOS, I.O.; MARTINEZ, F.G.; PEYRÉ-TARTARUGA, L.A. Effects of exercise on anticipatory postural adjustments during gait initiation in Parkinson's disease: A pilot study. In: II SYMPOSIUM ON PHYSIOMECHANICS OF TERRESTRIAL LOCOMOTION, Florianopolis/SC, 2019.

MEDEIROS, M.; **CASAL, M.Z.**; ZANARDI, A.P.J.; SANTOS, I.O.; HAAS, A.N.; PEYRÉ-TARTARUGA, L.A.; MARTINEZ, F.G. Effects of a Deep Water Running program on the Locomotor Rehabilitation Index of people with Parkinson's disease. In: II SYMPOSIUM ON PHYSIOMECHANICS OF TERRESTRIAL LOCOMOTION, Florianopolis/SC, 2019.

SANTOS, I.O.; ZANARDI, A.P.J.; **CASAL, M.Z.**; HAAS, A.N.; MARTINEZ, F.G.; PEYRE-TARTARUGA, L.A. Do the staging and duration of Parkinson's disease correlate with the rotation of the trunk and pelvis during gait? In: II SYMPOSIUM ON PHYSIOMECHANICS OF TERRESTRIAL LOCOMOTION, Florianopolis/SC, 2019.

CASAL, M.Z.; ZANARDI, A.P.J.; DOS SANTOS, I.O.; MICAELLA, G.A.A., MARTINEZ, F.G. Effects of 12 weeks of deep water running and Nordic walking on the balance of subjects with Parkinson’s disease. In: XVIII BRAZILIAN CONGRESS OF BIOMECHANICS AND II LATIN AMERICAN MEETING OF BIOMECHANICS, Manaus/AM, 2019.

SILVEIRA, M.D.; MELLO, A.I.; **CASAL, M.Z.**; TASSINARI, G.C.; MARTINEZ, F.G. Measurement of hydrostatic weight of implements used in Aquatic Physiotherapy. In: XVIII BRAZILIAN CONGRESS OF BIOMECHANICS AND II LATIN AMERICAN MEETING OF BIOMECHANICS, Manaus/AM, 2019.

ZANARDI, A.P.J.; **CASAL, M.Z**; DOS SANTOS, I.O.; MONTEIRO, E.P; PEYRÉ-TARTARUGA, L.A. Intersegmental coordination during the walk of people with Parkinson’s disease. In: XVIII BRAZILIAN CONGRESS OF BIOMECHANICS AND II LATIN AMERICAN MEETING OF BIOMECHANICS, Manaus/AM, 2019.

CASAL, M.Z.; ANDRADE-FILHO, B.J.F.; MELLO, A.I.; LOSS, J.F.; MARTINEZ, F.G. Measurement of the force applied to a human prototype during different lumbar traction techniques in an aquatic environment. In: III Brazilian Congress of Aquatic Physiotherapy, Recife/PE, 2018.

6.4 ABSTRACTS PRESENTED AT INTERNATIONAL SCIENTIFIC EVENTS

DELABARY, M.; MONTEIRO, E.; FAGUNDES, A.; **CASAL, M.Z.**; ZANARDI, A.P.; BOENO, F.; MUNHOZ, S.; DE MENEZES, R.; OLIVEIRA, A.; MARTINEZ, F.; TARTARUGA, L.A.; HAAS, A. Can clinical outputs predict BDNF levels in people with Parkinson's disease? In: International Congress of Parkinson's disease and Movement Disorders (MDS), Virtual Congress, 2020.

FAGUNDES, A.O.; DELABARY, M.S.; MONTEIRO, E.P.; **CASAL, M.Z.**; BOENO, F.P.; MUNHOZ, S.V.V; MENEZES, R.L.; OLIVEIRA, A.R.; MARTINEZ, F.G.; PEYRÉ-TARTARUGA, L.A.; HAAS, A.N. Correlation and comparison of the lipid profile and the body fat mass in people with Parkinson's disease submitted to three physical therapies. In: International Congress of Parkinson's disease and Movement Disorders (MDS), Virtual Congress, 2020.

CASAL, M.Z.; ZANARDI, A.P.J.; IVANISKI-MELLO, A.; DOS SANTOS, I.O.; HAAS, A.N.; PEYRÉ-TARTARUGA, L.A.; MARTINEZ, F.G. Deep Water Running, Nordic Walking and Dance: Effects of exercise on anticipatory postural adjustments during gait initiation in Parkinson's disease. In: Federation of European Neuroscience Societies (FENS) Forum, Virtual Forum, 2020.

FAGUNDES, A.O.; PASSOS-MONTEIRO, E.; DELABARY, M.; ZANARDI, A.P.J.; **CASAL, M.Z.**; MARTINS, V.F.; WOLFFENBUTTEL, M.; HAAS, A.N.; MARTINEZ, F.G.; PEYRÉ-TARTARUGA, L.A. Effects of three different physical therapies in body composition of Parkinson’s disease. In: International Congress of Parkinson's disease and Movement Disorders (MDS), Nice – France, 2019.

6.5 AWARD FOR PRESENTATION AT A SCIENTIFIC EVENT

Honorable Mention - 1st Place Oral Presentation. In: III Brazilian Congress of Aquatic Physiotherapy, Brazilian Association of Aquatic Physiotherapy, Recife/PE, 2018.

6.6 LECTURES AT SCIENTIFIC AND ACADEMIC EVENTS

CASAL, M.Z. Complementary treatments in Parkinson's disease. In: X Congress of Parkinson's Associations in Brazil, Porto Alegre, 2019.

CASAL, M.Z. The role of hydrotherapy in the rehabilitation of neurological patients. In: VI Academic Symposium of Physiotherapy at UNIRITTER. Canoas/RS, 2019.

6.7 PARTICIPATION IN ONGOING RESEARCH PROJECTS

Title: Effects of different physical and dance therapies on clinical-functional parameters, muscle ultrasound quality, pendulum gait mechanism and serum BDNF levels in people with Parkinson's disease with camptocormia and Pisa syndrome.
Coordination: Prof. Dr. Leonardo Alexandre Peyré Tartaruga.
Progress: 2017 – current.

Title: Kinematic analysis of exercises in deep water in subjects with different floaters.
Coordination: Prof. Dr. Flávia Gomes Martinez
Progress: 2020 – current.

Title: Comparison of metabolic, space-time and muscle activity parameters during underwater walking at different depths and at different step frequencies by healthy adults.
Coordination: Prof. Dr. Leonardo Alexandre Peyré Tartaruga.
Progress: 2019 – current.

Title: Acute effects of different interventions on motor behavior and the biomechanics of balance and locomotion in the elderly and subjects with Parkinson's.
Coordination: Prof. Dr. Flávia Gomes Martinez.
Progress: 2019 – current.

Title: Measurement of the force applied to a human prototype during different lumbar traction techniques in an aquatic environment.
Coordination: Prof. Dr. Flávia Gomes Martinez.
Progress: 2016 – current.