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Effects of Nordic Walking on Gait Symmetry in Mild Parkinson's Disease

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Abstract: Individuals with Parkinson's disease (PD) have gait asymmetries, and exercise therapy may reduce the differences between more and less affected limbs. The Nordic walking (NW) training may contribute to reducing the asymmetry in upper and lower limb movements in people with PD. We compared the effects of 11 weeks of NW aerobic training on asymmetrical variables of gait in subjects with mild PD. Fourteen subjects with idiopathic PD, age: 66.8±9.6 years, and Hoehn and Yard stage of 1.5 points were enrolled. The kinematic analysis was performed pre and post-intervention. Data were collected at two randomized walking speeds (.28 m.s⁻¹ and .83 m.s⁻¹) during five minutes on the treadmill without poles. The more affected and less affected body side symmetries (threshold at 5% between sides) of angular kinematics and spatiotemporal gait parameters were calculated. We used Generalized Estimating Equations with Bonferroni post hoc ($\alpha=.05$). Maximal flexion of the knee ($p=.007$) and maximal abduction of the hip ($p=.041$) were asymmetrical pre and became symmetrical post NW intervention. The differences occurred in the knee was less affected and the hip was more affected. We concluded that 11 weeks of NW training promoted similarities in gait parameters and improved knee and hip angular parameters for PD subjects.

Keywords: locomotion; biomechanics; pole walking; more affected side; asymmetries; angles; spatiotemporal; aerobic training.

1. Introduction

Individuals with Parkinson's disease (PD) walk slower than able-bodied people. The lower segmental and trunk excursion are associated with a reduced stride length and increased double support time and stride variability during walking in PD subjects [14]. Additionally, the contralateral gait asymmetry is associated with the chance of a person with PD developing freezing of gait [2,5].

The literature shows that in people with PD, the tremor reduced the upper and lower limbs asymmetry, mainly at higher walking speeds [1]. During the gait cycle, the angular kinematic parameters, such as shoulder and elbow movement, hip flexion and extension, pelvic rotation, knee flexion, plantar, and dorsiflexion of ankle need to be coordinated to conserve energy. The preservation of the range of joint motion results in lower vibrations and lower impact forces during the gait as well as minor compensations during the task. Therefore, the symmetry during gait may result in lower energy expenditure [68].

Aerobic exercises improve the functionality, mechanics, and energetic parameters in people with PD [911]. In this context, Nordic Walking (NW) is an exercise modality that revealed functional improvements in older people with PD [1215]. The NW is characterized by the use of poles that

requires symmetrical and coordinated movements provided by arm participation to move the body forward [16]. Also, the range of upper limb motion is increased using poles [17] changing the muscular synergies, particularly the spatial organization [18] and the magnitude of activation [19] of upper limb muscles in comparison to free walking (FW) [18].

Although the natural history of illness suggests an increasing contralateral asymmetry in PD [4, 20, 21], the findings are controversial. For example, Delval and colleagues did not observe gait asymmetries [22], whereas the literature showed that the swing time are markedly differently between feet [4]. The asymmetries attributed to cardinal symptoms of PD seem to denote a natural functional difference between the limbs, particularly associated with propulsion and control tasks [23].

While the NW improves functional mobility and independence for PD [13, 14], the potential improvement on the contralateral asymmetry after NW intervention remains unknown. Therefore, this study aimed to characterize the contralateral gait asymmetries and to investigate the effects of NW on these asymmetries in individuals with PD. We hypothesized that the kinematic variables during gait at pre-test period should be different between the sides (asymmetric), and that at post-test period, these differences should decrease, resulting in a more symmetrical gait.

2. Materials and Methods

2.1. Experimental Design

This is an experimental study that evaluated an intentional and non-probabilistic sample of people with Parkinson's disease. We first characterized the gait asymmetry and after tested the NW in the asymmetrical variables. We conducted the study in line with the protocol approved by the Ethics Committee of Research involving human beings from Universidade Federal do Rio Grande do Sul (project number: 69919017.3.0000.5347 and clinical trials ID: NCT03860649). All subjects gave their informed consent for inclusion before they participated in the study.

2.2. Participants

We included people with the diagnosis of idiopathic PD, aged 50 to 80 years, 1 to 3 on the Hoehn & Yahr (H&Y) scale [24], and physically inactive for at least one month. They should be in medical treatment and should have the ability to understand the verbal instructions to performing the tests. The exclusion criteria are: they should not have history of vertigo, surgeries in lower limbs during the last year, and making use of prostheses in the lower limbs. Further, the participants who undergone deep brain stimulation surgery, who had severe heart diseases or other associated neurological diseases, dementia, and who did not have conditions of ambulation and who got Montreal Cognitive Assessment (MoCA) less than 21 points were excluded [25]. Subjects who missed more than 75% of classes were excluded. Also, only ambulatory individuals and individuals who were walking without aid on the treadmill were included.

Calculation of the sample size was carried out using the Gpower v.3.1 program. Values of maximal flexion of the knee and maximal abduction of the hip from the study of Ribeiro et al., (2018) were used for the calculation [26], with a level of 5% and a power of 85%. A number of 14 subjects was estimated, considering the possible sample losses and a good adhesion rate estimated at 70% [27].

2.3. Assessment and Intervention Procedures

All procedures were carried out at the in the Biodynamic sector of the Exercise Research Laboratory (LAPEx). Subjects attended three distinct moments to perform data collection. On the first day, previous evaluation of the individual was performed to verify whether it fit the eligibility criteria. After these initial procedures, the Unified Parkinson's Disease Rating Scale (UPDRS) was performed to determine the side more and less affected [28] and H&Y scale. Subsequently, after 10 minutes of rest, the individual performed the six-minute walking test (6MWT) on the ground. After 10 minutes of rest,

they were familiarized to the treadmill (INBRAMED, model ATL-Inbrasport, Porto Alegre, Brazil), and rating of perceived exertion (Borg Scale) for 15 minutes [15].

The kinematic analysis was performed pre and post-intervention of NW. The subjects walked in randomized walking speeds of .28 m.s⁻¹ and .83 m.s⁻¹ for three minutes, and the kinematic data collection was performed at the last minute. The kinematic data collection was carried out by the three-dimensional motion analysis system Vicon (Vicon Motion Capture System-Oxford Instrument Group-USA, 1984), using six infrared cameras (100Hz, three cams Bonita with a resolution of 1 MP, and three cams T10 with a resolution of 1.3 MP). Thirty-five reflective spherical markers were placed on anatomic landmarks of interest according to the model Plug-in-Gait Full-Body. The three-dimensional reconstruction of the captured kinematic data was obtained automatically by the Vicon NEXUS® 1.8.5 software. The system captured a filming space of 4 m wide, x 6 m long, and 3.5 m high.

The training period lasted 11 weeks, with two weekly sessions, being four sessions of NW technique adaptation and 18 sessions of NW training (22 sessions in total). The volume was determined by the session time in minutes and by the percentage of the distance covered in the 6MWT, which was determined individually for each subject (Equation 1, 2, and 3) [29]. Therefore, the individuals were divided in three groups of volume coefficient based on the individual capacity of the subjects. These groups include A1: those who walked at 50% of the 6MWT (coefficient less than .85), A2: those who walked at 70% of the 6MWT (coefficient between .86 and 1.2), and A3: those who walked at 100% of the 6MWT (coefficient above 1.2) in the first session. The intensity was based on the subjective intensity of gait that was comfortable, intermediate, maximal, and jog. Comfortable velocity is that speed that person normally walks in the street. The intermediate velocity is the speed between the comfortable and the maximum, and the maximum speed determines how fast as possible the person can walk without running, while the jog is the intensity in which the individuals will run for a short period.

$$\text{Volume coefficient} = \text{performed distance} / \text{predicted distance} \quad (1)$$

$$\begin{aligned} & \text{Man: predicted distance} \\ & (\text{m}) = 493 + (2.2 \times \text{height}) - (.93 \times \text{weight}) - (5.3 \times \text{age}) + 17 \text{ m} \end{aligned} \quad (2)$$

$$\begin{aligned} & \text{Woman: predicted distance} \\ & (\text{m}) = 493 + (2.2 \times \text{height}) - (.93 \times \text{weight}) - (5.3 \times \text{age}) \text{ m} \end{aligned} \quad (3)$$

The training periodization (Figure 1) was based on [15] and more details can be observed in supplementary material 1. We conducted the NW training on the athletics track (400 meters) of the School of Physical Education, Physical Therapy and Dance (ESEFID) of the Universidade Federal do Rio Grande do Sul (UFRGS).

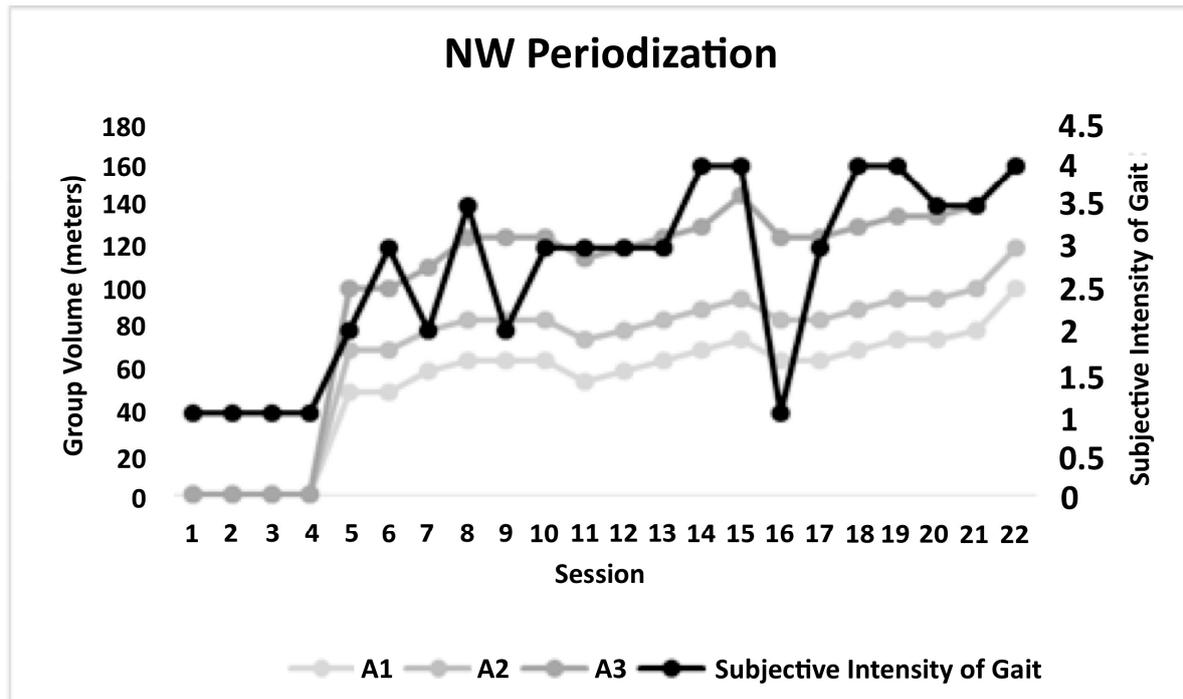


Figure 1. The training volume (grey lines, left vertical scale) is in meters, and intensity (black line, right vertical scale) is in rates of perceived speed during 22 training sessions. The subjective Intensity of Gait is the rate of perceived speed, and the number 1 represents (comfortable), 2 (comfortable and intermediate), 2.5 (intermediate and fast), 3 (comfortable, intermediate, and fast), 3.5 (intermediate and fast) and 4 (comfortable, intermediate, fast, and jog). The individuals included in the Group A1 are those who walk at 50% of the 6MWT (coefficient less than .85), A2 are those who walk at 70% of the 6MWT (coefficient between .86 and 1.2), and A3 are those walking at 100% of the 6MWT (coefficient above 1.2) in the fifth session.

2.4. Data Analysis

The kinematic analysis was performed using the Nexus software [15]. Firstly, we investigate if the subjects presented any asymmetries of maximal flexion of hip, knee, and ankle, abduction ROM of hip and the maximal abduction of hip and flexion and extension maximal of knee on touch down and, stance time(s), relative stance time (%) and double stance time(s). After, we tested the effect of NW on the asymmetrical variables. The angles were determined by software VICON NEXUS® 1.8, that use Euler calculations, all lower and upper body angles are calculated in rotation order YXZ, except for ankle angles, which are calculated in order YZX (available on Plug-in Gait Reference Guide).

The spatiotemporal variables were determined from the touch down and takeoff by 10 strides in the gait cycle. The mean of 10 strides was used to calculate angle and spatiotemporal outcomes. The data was exported from Vicon NEXUS® 1.8.5 software and processed in the LabVIEW software (National Instruments 8.5). The symmetry between the segments was considered when no statistical differences were observed in the parameters measured bilaterally [23].

2.5. Statistical Analysis

We used descriptive analysis to report the results (mean and confidence interval Wald 95%). The Generalized Estimating Equations (GEE) was used to characterize the gait asymmetries. When $p < .05$, the variables were considered asymmetric. Additionally, GEE was used to test the main effects of NW in asymmetrical variables, and the Bonferroni post hoc test was performed to identify the significant differences at $\alpha < .05$. Also, the effect size (ES) was calculated using the Hedges' g considering trivial ($< .20$), small ($.20 - .49$), moderate ($.50 - .79$), large ($> .80$), and too large (> 1.30) effects

between pre and post-tests at more affected and less affected segments in the asymmetrical variables [30,31]. Statistical analysis was performed by a highly trained researcher who was blinded to the participants, using SPSS software (Statistical Package for Social Sciences, version 21.0).

3. Results

A total of 14 participants with idiopathic PD were included in the study. Individual characteristics of the sample are shown in Table 1.

Table 1. Characteristics of the subjects.

Variable	Mean (Standard deviation)
Total subjects (male/female)	14 (7/7)
Gender (female/male)	7/7
Age (years)	66.8 (\pm 9.6)
Disease duration (years)	7.2 (\pm 5.4)
UPDRS (points)	12.2 (\pm 6.1)
H & Y	1.5 (1-3)
MoCA	26.6 (2.2)
Lower limb length (m)	.89 (.05)
Body mass (kg)	64.5 (\pm 23.5)
Height (m)	1.7 (\pm .86)

The results showed asymmetries in baseline with a significant difference for maximum knee flexion at .28 m.s⁻¹. Time-condition interaction analysis ($p = .007$) showed that the improvement occurred only in the less affected limb [$p < .001$ (ES: .82)] when compared to the more affected limb (Table 2, Figure 2A).

Table 2. Mean, confidence interval, minimal (min) and maximal (max) values, and effect size of Maximal angular of flexion and abduction in more and less affected segments at .28 m.s⁻¹.

	Speed (m.s ⁻¹)	PRE		POST		p-value			ES More affected	ES Less affected
		More affected Mean (max;min)	Less affected Mean (max;min)	More affected Mean (max;min)	Less affected Mean (max;min)	T	C	T*C		
Flexion	-	-	-	-	-	-	-	-	-	-
Knee (degree)	.28	49.9 (45.7;54.1)	42.3 (35.7; 49.0)	50.8 (46.2; 55.4)	52.3 (47.3; 57.3)	.012*	.236	.007*	.10	.82
Abduction										
Hip (degree)	.28	1.1 (-1.9; 4.1)	7.6 (4.7;10.5)	4.00 (2.04; 5.96)	6.7 (4.7;8.6)	.329	.007*	.040*	.56	.19

NOTE: ES : Effect size ; T: General effect of time ; C : General effect of condition ; T*C: Interaction between time and condition *p : <.0

Additionally, there was asymmetry in the maximal hip abduction with time-condition interaction (Table 2, Figure 2B) at speed $.28 \text{ m}\cdot\text{s}^{-1}$ ($p = .040$). The maximal hip abduction was increased between pre and post in both groups [$p = .035$ (ES = $.56$ more affected limb)] and [$p = .007$ (ES: $.19$ less affected limb)]. The other variables did not show asymmetries and are represented in supplementary material 2.

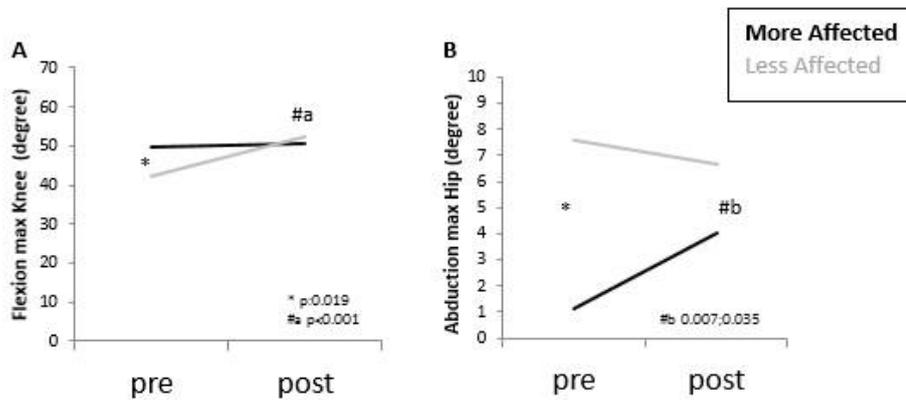


Figure 2. Asymmetric variables between less affected (grey line) and more affected (black line) limbs, pre and post-intervention at $.28 \text{ m}\cdot\text{s}^{-1}$, based in post hoc values. *: Difference between conditions on pre; (A) Difference between pre and post in the less affected side; (B) Difference between pre and post in both groups.

4. Discussion

The main purpose of this study was to characterize the gait asymmetries and then investigate the effects of NW training in the asymmetries variables. Before the intervention, the individuals with mild PD walking at $.28 \text{ m}\cdot\text{s}^{-1}$ showed asymmetries only in maximal knee flexion and maximal hip abduction. We refuted the hypothesis because most movements were symmetric in the baseline. On the other hand, secondary asymmetries were interestingly found at the knee and hip joints. The NW training was able to improve these parameters, becoming more symmetrical in these parameters after the intervention.

In PD, the basal ganglia dysfunction contributes to more significant gait disturbances and symptoms are directly associated with right or left cerebral hemisphere, though mechanisms responsible for this left-right coordination are not fully understood [32,33]. Additionally, PD asymmetry can be explained for a reduced number of neurons in one side of substantia nigra [34]. However, the asymmetrical side might be merely coincidental, and in the early stage, the degeneration is lower [35]. In our study, the asymmetry between the sides was considered when the value was less than 5% in the statistic test [23]. Probably, the general symmetry observed in the pre-test seems to be explained due to mild stage (H&Y median: 1.5 points) of PD and phase of medication "ON" utilized in the present study [26,36]. Furthermore, the disease duration is 7.3 ± 5.4 years, and, at this stage of the disease, the people with PD have a similar likelihood of unilateral and bilateral motor impairments [37]. One crucial question raised by these findings is the importance of gait analysis for detecting the motor asymmetry as a screening evaluation [38,39]. In our study, we consider gait asymmetry based on the study [23]. Also, the literature describes that gait asymmetry is related to the increase in freezing [32]. However, it is necessary to acknowledge that our PD subjects did not experience freezing of gait during the walking evaluation. Therefore, the symmetry is justified on baseline condition.

Although most kinematic variables were symmetric bilaterally, the maximum knee flexion and hip abduction at $.28 \text{ m}\cdot\text{s}^{-1}$ were asymmetric before the intervention. After the intervention, both variables became symmetric. The literature shows that exercise can improve Parkinson's gait

performance [40]. In [41], the authors observed that NW was able to increase knee power during gait, in the more and less affected side [41]. In the present study, we observed higher maximal knee flexion in the less affected side, indicating that after NW intervention, the role of compensating the impaired movement was reduced in the less affected knee during the gait cycle. We also considered that the increase in range of knee motion might be attributed to muscle regulation as a result of lower antagonist muscle stiffness, or even because of increasing muscular strength and power of the knee flexion agonist muscles. Although the main component of this increase remains unknown, greater freedom of joint movement contributes to a more symmetrical gait and a lower risk of falls.

Higher values of maximal hip abduction and symmetry between sides were found after NW intervention in our subjects. In line with these findings, [42] showed that after treadmill training, PD subjects improve the angle of hip abduction of the dominant and non-dominant sides [42]. The higher pelvic rotation could explain the higher angle of hip abduction. However, no rotational movements were measured in this study. The symmetry found in the hip abduction found out after the training period may contribute to functional mobility due to reduced energy expenditure and lower risk of falling. Also, the larger range of hip abduction motion during gait may be related to reduced muscle and joint stiffness. Although Nordic walking (NW) uses stick support, the gains acquired from training seem to benefit the free-walking pattern of subjects with PD. Besides the improvement, the maximal abduction motion observed in our study (4 to 7 degrees) is still lower than healthy people, approximately 10 degrees [6]. Another important point to highlight is that our test was measured on a treadmill, and the angular and spatiotemporal variables can be changed when compared with free walking [43]. We suggest more studies that compared gait asymmetries in these conditions, and to obtain more details, it is important to do correlations with oxygen consumption and anatomical/structural symmetry of the lower limbs [44].

The NW is an intervention where the action from upper and lower limbs is required, resulting in a synergy between upper and lower limb muscles. The poles promote more considerable support base and weight discharge [45]. These characteristics can improve the maximal ROM of the knee and hip during gait of people with PD. Therefore, the improvement in the quality of movements during gait is critical in the daily life of this population. This study has some limitations, including: 1) it did not have a control group, 2) the control regarding the physical activity quantity from the participants on baseline (very active, active, inactive, and sedentary), and 3) we did not evaluate the freezing of gait, which could have a better detection of gait asymmetry.

5. Conclusions

The hypothesis was not supported, and our findings demonstrate that subjects with mild PD had symmetric gait before the intervention, except for maximal hip abduction and maximal knee flexion. NW enhanced the kinematic pattern of knee and hip joints during free-walking on the treadmill, and the more affected and less affected side became symmetric. The improvement of the range of knee and hip motion is crucial to improve the functionality of subjects with PD.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, TIDier items S1: Nordic Walking intervention, Table 3 S2: Mean, confidence interval and statistical significance of maximal flexion and abduction variables on .28 and .83 m.s⁻¹. Table 4 S2: Mean, confidence interval and statistical significance and range of motion of more and less affected segments on .28 and .83 m.s⁻¹. Table 5 S2: Mean, confidence interval and statistical significance of spatiotemporal variables on .28 and .83 m.s⁻¹.

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