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Stabilometric Analysis of Parkinson's Disease Patients

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Abstract— **Parkinson's disease (PD) is considered a movement disease; it is a progressive and degenerative neurological disorder, causing disabling motor dysfunctions. Investigate the body instability of PD patients through the stabilometry test is the aim of this study. A sample of 40 participants with PD were staged between the stages of the disease using Hoehn and Yahr Modified Scale 1.5 to 3.0 in static posture with eyes open and closed to assess stabilometry in the distance from the center of pressure (CoP), as well as anteroposterior (AP) and mediolateral axis (ML). There were found no differences in the body oscillation variables on the AP and ML axis. There was a difference in CoP displacement and oscillation speed between stage 1.5 to 3.0. It was concluded that participants with PD in stage 3.0 had greater distances from the CoP and greater speed of body sway, and that these instabilities become more evident with the progression of the disease.**

Clinical Relevance— **Early interventions are recommended to alleviate the symptoms of the disease. Since study shows that disease symptoms increase mainly at stage 3.0.**

I. Introduction

Parkinson's disease (PD) is a dysfunction that deteriorates central nervous system, characterized by insufficient dopamine in the substantia nigra, presenting an imbalance of inhibitory and/or excitatory signals, implying motor impairment and leading to deficits both mobility and cognitive [1].

It is observed that in PD, there is an inability between the systems responsible for body, vestibular and visual balance, indicating the existence of changes in proprioception associated with postural instability [2], [3]. Consequently, the center of gravity changes in these individuals and, therefore, perform compensatory movements to establish balance [4].

Balance disorder is one of the most common problems in PD and that often results in falls. This event can be explained by changes in postural control in the disease that are associated with sensory problems that prevent central nervous system from determining position and movement of the body in relation to supporting surfaces [5]. So, great pressure is exerted on the feet of individuals with PD, as they are the basis of support for entire human body [6].

In this sense, stabilometry is an exam that has the ability to assess possible changes in the feet, through plantar pressure mapping, providing records of the reaction forces of the feet [6]. It is a biomedical evaluation device, developed to analyze the plantar pressure points adopted by the body, either statically or dynamically, capturing points that reproduce the body's stability in space [7]. In addition, it measures postural instability, complementing the conventional diagnosis and is relevant to determine the conduct in the treatment and prognosis of various diseases, being able to point out the first signs of loss of balance in different conditions, such as open eyes, closed eyes and unstable surfaces [8].

Monteiro et al. [9] mention that formulating objective documentation is the basis of scientific evaluation for treatment of dysfunctions of the musculoskeletal system. A reliable means of assessing foot dysfunction and its relationship with other body segments is an important step in understanding the postural influences on the feet or in reverse, since dynamic gait stability involves biomechanical aspects of balance and postural control.

Therefore, this study aims to investigate the posture adopted by the body among PD patients in their different stages of the disease, using stabilometry.

II. Material and Methods

Currently, there are several scales validated by the scientific literature to assess motor and non-motor symptoms resulting from PD. The most used is Hoehn and Yahr Scale, originally published in 1967, and included five stages of progression of Parkinson's disease. Since then, it has been modified with addition of stages 1.5 and 2.5 to explain the intermediate course of Parkinson's disease [10]. This method of assessment allows us to observe the impact of the disease on the quality of life of individuals in early stages. Therefore, it provides mechanisms to measure the degree of impairment of PD patients, suggesting early intervention to delay disease progression.

Participants from both sexes, aged from 50-80 years and between all stages of the disease were included. All participants were undergoing treatment at Association of Parkinsonism Patients (APPP) in the city of Curitiba-PR, Brazil. Those who were unable to remain in the orthostatic position were excluded; other evident neurological or mental changes, amputation of any limb, severe visual impairment or any other change that could impair the understanding and performance of the proposed tasks.

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In total, 40 participants were evaluated, including 22 men (55%) and 18 women (45%). Still, the sample was separated by stage of disease, ten in each of stages 1.5, 2.0, 2.5 and 3.0. Data collection took place over a six-month period, from August 2018 to February 2019.

The experimental procedures involving human subjects described in this paper were approved by the Research Ethics Committee of Federal Technological University of Paraná under the number CAAE: 85988218.0.0000.5547 and met ethical recommendations of Resolution 466/12.

For measurement of body mass, a digital electronic scale calibrated in kilograms and division of 100g of the Omron® brand was used. Participants were instructed to remain in an orthostatic position, with their arms extended along body, wearing clothes and without shoes. For height assessment, a stadiometer calibrated in centimeters with millimeter resolution of Sanny® brand was used. The assessment that determines disease stage of each participant was granted by APPP's physiotherapy sector professionals, using updated documents and records attached to their medical records.

The Kinetec EPS Capacitive Baropodometric Platform and the Biomech Studio software (Letsense group) were used to perform stabilometry, which has mechanical characteristics in dimensions of 57.5cm by 45cm, with a total weight of 3kg and a thickness of 5mm.

Regarding protocol, two different postures were selected: bipedal support on the platform with eyes open and bipedal support on the platform with eyes closed. Since, during locomotion [11], vision is necessary to monitor and analyze the location and movement of body, as well as environmental conditions to which motor system should respond.

Initially, each participant was instructed to remain stationary on platform from about 15-seconds in order to get used to situation and provide a first contact with baropodometry. Then, participant was asked to remove himself from device and then asked to position himself in a comfortable and habitual way, performing first posture, with his feet hip-width apart, arms extended along body and with his eyes open, staying in same position for 30-seconds. Then, participant was instructed to descend from platform, remaining in 60-second lathes at rest. Then, climbing on platform again, performing second posture, maintaining the position with eyes closed, in a comfortable and habitual way. The sequence was used for all participants.

This technique has the advantage of representing how patient is positioned naturally [10]. All participants with PD were in ON state of the medication (using levodopa as dopamine-replacement therapy).

Some aspects influence patterns of plantar pressure distribution such as: walking speed, cadence and step length, height, body weight, range of motion of the ankle and deformities of toes, these factors are determinant for pressure peaks that can be seen for the architecture of skeleton, anatomy variation and composition and location of plantar fat plates that distribute the weight [12].

In view of this variability in functional, anatomical behaviors and also protocols for carrying out tests using the force platform, it was decided to carry out an exploratory-bibliometric research [8] aimed at building protocol exposed here. This research also made it possible to highlight data most used in the articles found: position of participants; time spent on the platform; repetition of exam and observed variables. Thus, variables analyzed in this study were: distance from center of pressure (CoP), average speed, anteroposterior (AP) and mediolateral axis (ML) oscillation.

Data of collected variables were submitted to exploratory asymmetry test by means of Kolmogorov-Smirnov. Values of age, weight and height were presented as mean and standard deviation. Furthermore, stabilometry variables central tendency was presented as median and interquartile range. To compare results between groups, non-parametric test Kruskal Wallis, Dunn post-hoc and Mann-Whitney test were applied. Value of $p < 0.05$ was adopted as statistical significance and these were performed using statistical packages Statistical Package for the Social Sciences (SPSS), version 17.0 (SPSS Inc. Chicago, IL).

III. Results

Regarding age of participants, it was found that youngest individual was 52 years old and was inserted within stage 1.5 of disease, presenting mild unilateral complaints. On the other hand, older person, who was in stage 2.5 of the disease, was 78 years old, already presenting moderate complaints of postural instability. Table I shows the descriptive analysis of the participants' anthropometric data.

TABLE I. Descriptive Analysis of Age and Anthropometric Data

Variables/ Groups	Total	Stage				p
		1.5	*2.0*	*2.5*	*3.0*	
Number of participants	40	10	10	10	10	
Age (years)	68.2 (6.5)	61.3 (6.0)	67.9 (3.9)	69.8 (5.8)	73.9 (3.0)	0.000
Weight (kg)	68.3 (11.2)	76.0 (11.6)	62.4 (10.6)	68.4 (11.6)	66.4 (7.4)	0.044
Height (m)	1.65 (0.1)	1.70 (0.1)	1.60 (0.1)	1.66 (0.1)	1.63 (0.1)	0.075

Table II shows proportion between dominant side and side affected by disease. It is noted that 27% of participants have dominant side and affected side in the same segment, which can predispose the most accentuated oscillations due to loss of reference due to limb's dominance.

According to Table III, stabilometry variables in bipedal posture with eyes open, body oscillations on the AP and on ML axis did not have significant results with evolution of stages.

TABLE II. ANALYSIS OF THE PROPORTION BETWEEN THE DOMINANT SIDE AND THE AFFECTED SIDE

Ratio analysis between dominant side and affected side			**Affected side**		**Total**
			right	***left***	
Dominate side	Right	N	25	12	37
		% Total	25%	12%	37%
	Left	N	1	2	3%
		% Total	1%	2%	3%

TABLE III. COMPARATIVE ANALYSIS BETWEEN GROUPS FOR STABILOMETRY VARIABLES (N=10 IN EACH PD STAGE)

Variables	**PD Stage**	**N**	**Eyes Opened**		**Eyes Closed**	
			Median (Interquartile Range)	**p**	**Median (Interquartile Range)**	**p**
CoP_AP (mm)	1.5	10	-0.55 (0.73)	0.494	-0.40 (1.350	0.320
	2.0	10	-0.30 (1.43)		-0.35 (1.23)	
	2.5	10	-0.60 (0.78		-0.50 (1.63)	
	3.0	10	-0.35 (1.70)		-1.00 (2.83)	
	Total	40	-0.35 (1.20)		-0.40 (1.38)	
CoP_ML (mm)	1.5	10	-2.75 (2.25)	0.960	-2.00 (1.15)	0.066
	2	10	-3.05 (2.78)		-2.80 (2.25)	
	2.5	10	-3.20 (3.48)		-3.40 (3.98)	
	3	10	-4.20 (4.50)		-3.90 (2.35)	
	Total	40	-3.20 (2.75)		-2.80 (2.63)	
CoP distance (mm)	1.5	10	12.70 (2.88)	0.000	11.55 (6.20)	0.002
	2	10	23.60 (16.40)		19.30 (13.23)	
	2.5	10	17.35 (12.63)		19.30 (14.60)	
	3	10	210.90 (187.73)		226.90 (114.83)	
	Total	40	18.55 (88.98)		20.90 (125.10)	
Average Speed (mm/seg)	1.5	10	2.55 (0.63)	0.000	2.30 (1.23)	0.002
	2	10	4.70 (3.30)		3.85 (2.65)	
	2.5	10	3.50 (2.53)		3.85 (2.90)	
	3	10	25.60 (46.38)		25.25 (49.93)	
	Total	40	3.70 (4.800		4.15 (5.13)	

Differences of CoP distance and average speed in PD stage was observed (p<0.05). To explore those differences, the Dunn post-hoc test was applied between PD stages. Regarding the CoP distance, participants who were staged in the stage 1.5 - 2.0 - 2.5 did not present statistical differences between them. On the other hand, individuals staged in the 3.0, presented a decline in the body response 16 times greater than participants who were in stage 1.5; as well as, 10 times higher than those in the 2.0 and 2.5 stages (p=0.000). Concerning to average speed in posture with eyes open, no statistical differences were identified between stages 1.5 - 2.0 - 2.5 in the post-hoc analysis, however, individuals in stage 3.0 demonstrated a 12-fold greater speed reduction than participants in stage 1.5 and seven times higher than stage 2.0 and 2.5 (p=0.000).

Same can be observed to variables of stabilometry in bipedal posture with closed eyes, in which body oscillations in anteroposterior axis and in mediolateral axis also did not show significant results with evolution of disease stages for patients of PD.

Analyzing the CoP distance in posture with eyes closed, differences were found as disease reaches stage 3.0 (p=0.000). Participants referenced in stage 1.5 - 2.0 - 2.5 did not obtain differences when confronted, however, individuals allocated in stage 3.0, presented a reduction of corporal activity of CoP 17 times greater in relation to participants who were allocated in stage 1.5, such as 11 times greater than those in stage 2.0 and 2.5.

Relating to body average speed in posture with eyes closed, no differences were found between stages 1.5 - 2.0 and 2.5. However, subjects in stage 3.0 demonstrated a reduction in speed of approximately 11 times greater than participants in stage 1.5 and seven times greater than those who were in stage 2.0 and 2.5.

Therefore, static stabilometry in bipedal posture with eyes open and eyes closed, pointed to a significant drop in CoP measurements and body average speed when it reaches stage 3.0 of disease.

IV. DISCUSSION

General characteristic of participants with PD evaluated in this research portrayed an elderly population formed mostly by men. Although PD is a disease that affects both sexes, epidemiological studies show a higher frequency of disease in males [13]. According to Ferreira [1], PD affects 1% of population over 60 years of age. In this survey the average age of the participants was 68 years old [1].

Four sensory conditions were evaluated: AP and ML body oscillation, CoP distance and detachment speed in bipedal static posture with eyes open and eyes closed. There was a significant difference in variables CoP distance and body displacement speed with disease progression. This finding indicates that PD patients use increased CoP distance and speed to stabilize balance around their own body axis.

Similar to our findings, we can mention the study by Paolucci et al [14], which evaluated 29 participants with PD in drug therapy in the ON state, aged between 40 and 80 years between stages 1.0 to 3.0 per modified Hoehn and Yahr scale. Stabilometry test was used as evaluation method, where it was possible to register position of the CoP and, through this, to evaluate function of visual afference in postural control [14].

As also reported by Paolucci et al. [14], significant findings were found, proving that patients with PD have a considerable increase in CoP length and body speed, with p <0.001. This finding is in line with results presented in this research, where it was possible to verify that PD patients in stage 3 had a deficit of 17 times greater in distance of CoP and three times greater in speed of corporal displacement, when evaluated with eyes closed, after analyzing stabilometry with eyes open and closed.

Other study mentions that the visual function reveals an intimate relationship with mobility, because during locomotion, vision is necessary to analyze location and movement of body, as well as environmental situations for which motor system should respond, corroborating again with findings in the present study [11].

Geroin et al [15] used a monoaxial platform (Technobody©) to assess oscillations with eyes open and closed of 10 participants with PD in ON stage of pharmacological therapy. Outcome was a significant increase in displacement of CoP in the PD and treading syndrome groups compared to control group, p = 0.001, however, there was no significant effect on the AP and ML oscillations, a result that also corroborates our findings [15].

Cabeleira et al [16] verified correlations between dopamine depletion and gait disorders in two groups. Groups were composed by healthy (n=39) and mild and moderate PD patients (n=32). Participants were assessed for gait kinematics using a three-dimensional motion capture system, consisting of six infrared chambers and postural control using stabilometry using a force plate. The comparison between the groups shows a significant deficit in the PD group between relationship of stabilometric variables (CoP) (p <0.001) [16]; similarly, to our findings. 100 participants in healthy group and 100 participants in PD group where evaluated as balance instability by examining baropodometry, using postures with eyes open and eyes closed. It was found that PD group has a median CoP from stage 2.5 a deficit approximately twice as great when compared to healthy group, and from stage 3.0 PD group demonstrates a deficit eight times greater than median of healthy ones [17].

PD patients assume a very characteristic posture, keeping their head and torso flexed and they have great difficulty in adjusting their posture when bending over or when there are sudden movements of the body, which favors the occurrence of falls [18].

These results demonstrate importance of investigating changes in balance in PD patients and should receive due relevance, as these variations may increase the risk of falls, leaving these individuals more susceptible to these events and consequences of these, affecting the autonomy of this population, an important indicator for quality of life.

V. Conclusion

We concluded that individuals with PD present progressive deficits of balance, and that these instabilities were accentuated according to evolution of PD, being more evident in stage 3.0 by the Hoehn and Modified Yahr scale. It is also observed that oscillations were increased with the decrease in visual perception, once the closed eyes posture presented greater instability in relation to the open eyes.

For future studies, we suggest to analyze interference or reflex of physical training through physiotherapy protocols in improving these dysfunctions in PD patients. Checking the need to adapt the intervention to needs of each individual, and providing a better quality of life.

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