



POSTURAL INSTABILITY IN SUBJECTS WITH PARKINSON'S DISEASE UNDERGOING DIFFERENT SENSORY PITFALLS

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ABSTRACT

Purpose. Previous research has reported postural instability in subjects with Parkinson's disease (PD). However, there are still doubts about the effect of sensory stimuli on one's balance. In this study, we further investigated the stabilometric measures of individuals with PD, analysing the impact of different sensory stimuli on the outcomes.

Methods. The total of 26 participants (13 with PD and 13 matched control peers) were submitted to 8 sensorimotor dynamics differing in relation to support base (30 cm vs. 10 cm, feet in parallel vs. feet in semi-tandem position), contact surface (foam vs. no foam), and visual conditions (eyes open vs. eyes closed). The measures used to assess one's balance were body position in space, area of support base, and velocity of postural control. The variables involved the anterior-posterior and the mediolateral axes. Participants with PD were evaluated during the off medication state. Mann-Whitney U test and Friedman's test were applied to carry out inter- and intra-group comparisons. Significance was set at 5%.

Results. Cross-sectional analyses illustrated that tasks with sensory pitfalls impacted postural stability to a larger extent in PD subjects. The differences were found in anterior-posterior body position, area of support base, anterior-posterior velocity, and mediolateral velocity. Complementary analyses confirmed considerable instability on balance when support bases were small and visual information was absent ($p < 0.05$).

Conclusions. The current results confirm worse postural stability response in subjects with PD and highlight that the interference of the sensory pitfalls is notable when individuals are off medication.

Key words: Parkinson's disease, postural stability, balance, stabilometry

Introduction

Postural instability has been widely described in subjects with Parkinson's disease (PD). A common concern for health care professionals, patients, caregivers, and families, postural instability increases one's risk of falling and is directly associated with the progression of the clinical condition [1]. Since the disease burdens the individual and their family, the overwhelming research focuses on improving symptom management or on curing the patient. However, there is little scientific evidence with regard to slowing the progression of the disease. According to Racette and Willis [2], research has made substantial advances in understanding PD

but the big picture of the disease still challenges health care professionals.

Numerous factors have been associated with postural instability in PD. Motor and cognitive functions, in particular, have been extensively studied. The combination of age-related changes and disease-related issues explains the difficulty of movement that people with PD experience [3]. Pathological and compensatory changes in a variety of locomotor brain regions occur in PD, leading to increased asymmetry, poor postural control, bradykinesia, and rigidity [4]. A previous study suggested that individuals with PD used attentional strategies to compensate their motor problems caused by a defective basal ganglia mechanism [5]. Not only did

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those authors find that divided attention ended up increasing the difficulty of the task (by requiring constant dual tasks), but they also suggested that modifications of central processing of the motor function was impacted by cognitive challenges.

In addition to the impact of motor function and cognition on balance and postural stability, there is some evidence demonstrating that the sensory system (with its visual inputs, proprioceptive and exteroceptive responses) may also play a role. Lahr et al. [6], for example, showed that PD subjects presented a higher reliance on vision on the dominant side to compensate somatosensory system impairments. Vibrotactile neurofeedback, known to stimulate the proprioception of the subjects, has been proven beneficial to subjects with PD [7].

In this study, we performed an in-depth analysis of the impact of different sensory stimuli on postural stability in individuals with mild to moderate PD. It was hypothesized that participants with PD would present worse performance when sensory information was deprived. Although there are other studies analysing one's postural stability with a similar design as ours, only a few have assessed individuals when off medication. In addition, the barriers used to measure the impact of sensory stimuli on balance are different from those adopted in the present study. According to Gera et al. [8], the analysis of different approaches is important to provide a complete understanding of balance complications in PD. Thus, we believe that our study comes to solidify the knowledge of the topic in the area of movement sciences, providing additional information to health care professionals treating PD patients.

Material and methods

Participants

The total of 13 individuals recruited from the Neurologic Outpatient Clinic of the Federal University of Mato Grosso do Sul, Brazil, and 13 matched control peers were enrolled in the study. As shown in Table 1, the groups were homogenous as for sample size, age, sex, general cognition, and executive function. The study was conducted in accordance with the principles of the World Medical Association Declaration of Helsinki. All participants provided their written consent and the research project was approved by the local human research protection office.

The inclusion criteria for the PD group involved mild to moderate [9] idiopathic PD [10]. The control group was selected in accordance with the anthropometric characteristics of the PD group. The exclusion criteria for both groups were as follows: (1) presence of a neurological condition other than PD; (2) inability to stand up and walk independently; (3) routine tasks demanding energy costs higher than 3 METs (metabolic equivalent of task); (4) cognitive impairments (tracked initially by low scores on the Mini-Mental [11] according to cut-

off points stipulated by Brucki et al. [12] and then confirmed by a neurologist); (5) use of psychotropic or antipsychotic drugs; and (6) presence of vertigo, amaurosis or chronic dizziness. Furthermore, none of the participants should have been hospitalized in the preceding 6 months.

Methodological procedures

All methodological procedures (setting, participants, variables, data measurement, and statistical methods) were reported in accordance with the STROBE statement [13]. The assessments of this study involved one main outcome (stabilometric measures) and 8 predictors, impacted by different proprioceptive and somesthetic conditions.

The stabilometric measures were assessed by means of a BIOMECH 400_V4 force platform (EMG System®) comprised by a 500 mm² plate, 4 load cells, and a calibration system of 100 Hz. Balance tests were carried out at the research laboratory as part of a set of examinations of health and functional ability. A 30-minute rest interval preceded the tests. Participants with PD were evaluated during the off phase of their anti-PD medication (12 hours after the last daily dose). The assessments involved 8 tasks, differing in relation to visual information (eyes open or eyes closed), support base (feet in parallel or semi-tandem position), and contact surface (rigid or semi-rigid, with or without a 6-cm thick foam). Figure 1 illustrates the conditions.

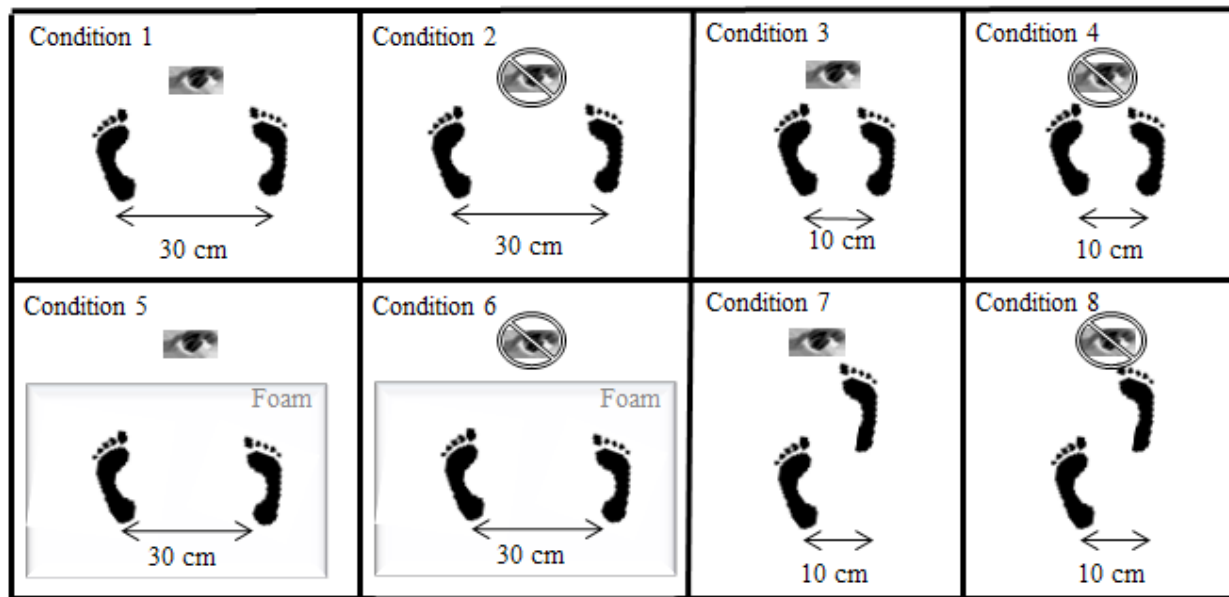
The adoption of 8 different tasks was due to an intention of assessing postural stability with several sensory barriers. The subjects performed all the tests barefoot, and they were instructed to remain on the force platform for 60 seconds. Body position in space (cm), area of support base (cm²), and velocity of postural control (cm/s) were used to evaluate the balance of the participants. The body position in space was included to verify the displacement of the subjects on the anterior-posterior (AP) and the mediolateral (ML) axes. The area of support base was included to access the surface area circled by the centre of pressure during the tasks.

Table 1. Characteristics of the participants in both groups

Variable	PD group	Control group	<i>p</i> value
Sample size (<i>n</i>)	13	13	0.999
Sex (male:female)	5:8	7:6	0.431
Age (years)	73.0 ± 9.5	66.0 ± 7.5	0.106
MMSE (points)	25.0 ± 4.0	28.0 ± 5.5	0.096
FAB (points)	15.0 ± 5.5	16.0 ± 2.5	0.151

The results are presented as median ± interquartile range. Inferential analyses involved chi-square and Mann-Whitney U tests.

MMSE – Mini-Mental State Examination, FAB – Frontal Assessment Battery, PD – Parkinson's disease



Condition 1: feet parallel, support base of 30 cm, no foam, eyes open. Condition 2: feet parallel, support base of 30 cm, no foam, eyes closed. Condition 3: feet parallel, support base of 10 cm, no foam, eyes open. Condition 4: feet parallel, support base of 10 cm, no foam, eyes closed. Condition 5: feet parallel, support base of 30 cm, a 6-cm thick foam placed on top of the force platform, eyes open. Condition 6: feet parallel, support base of 30 cm, a 6-cm thick foam placed on top of the force platform, eyes closed. Condition 7: feet in semi-tandem position (dominant leg ahead of the other as if taking a step), no foam, eyes open. Condition 8: feet in semi-tandem position (dominant leg ahead of the other as if taking a step), no foam, eyes closed.

Figure 1. Conditions of postural stability assessment

Velocity of postural control was incorporated to perform analyses of the motor response in unbalanced circumstances. For safety precautions, the participants could use their arms for balance correction when in the imminent risk of falling. Two researchers remained on each side of the subjects during the assessments, with the purpose of preventing falls.

The Mini-Mental State Examination (MMSE) [10] and the Frontal Assessment Battery (FAB) [14] were applied in all participants in order to assess general measures of cognitive and executive functioning. These instruments were utilized with the purpose of characterizing the groups.

Statistical analyses

The data analyses involved descriptive and inferential statistics. As the normality assumptions were not met for all variables, we standardized the use of non-parametric statistics.

The characteristics of the groups was expressed by median, as a central tendency measure, and interquartile range, as a variability measure. The chi-square test was implemented to compare the proportion of subjects and sex distribution in each group. The Mann-Whitney U test compared groups with regard to cognition and balance tasks. In order to investigate how different support bases, contact surfaces, and visual information affected the balance in each group, we performed longitudinal analyses with Friedman's test associated with contrast analyses. The significance was set at 5% ($p < 0.05$).

Ethical approval

The research related to human use has been complied with all the relevant national regulations, institutional policies and in accordance the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

Results

The values of postural stability in subjects ascribed to different support bases, contact surfaces, and visual information are presented in Table 2. Of the 40 cross-sectional analyses involving the comparisons of participants with PD and controls, 16 (40.0%) showed significant differences between the groups. The differences were found in AP body position, area of support base, AP velocity, and ML velocity. Even when no significant differences between the groups were found ($p > 0.05$), the analyses demonstrated worse postural balance in PD subjects compared with their control peers.

Paired analyses showed significant variations of balance when comparing the stabilometric variables under the 8 conditions. Contrast analyses confirmed considerable instability when support bases were small and visual information was restricted (Table 3).

Discussion

The study investigated the impact of sensory pitfalls on stabilometric measures in individuals with mild to moderate PD. Our findings demonstrated a worse bal-

Table 2. Median $\pm$ interquartile range of the values of stabilometric measures in the PD group (off medication) and control group during different tasks

Task	Group	AP position (cm)	ML position (cm)	Area (cm ²)	AP velocity (cm/s)	ML velocity (cm/s)
SB30-EO	Parkinson	-2.8 $\pm$ 3.7	-1.2 $\pm$ 2.8	2.7 $\pm$ 3.5	1.3 $\pm$ 1.1	1.2 $\pm$ 0.5
	Control	0.1 $\pm$ 2.3	-0.5 $\pm$ 1.1	1.5 $\pm$ 1.3	1.2 $\pm$.03	1.0 $\pm$ 0.3
	<i>p</i> _(PD $\times$ Ctl)	0.004	0.270	0.017	0.112	0.139
SB30-EC	Parkinson	-2.8 $\pm$ 5.5	-1.1 $\pm$ 3.2	1.5 $\pm$ 5.2	1.5 $\pm$ 1.0	$\pm$ 0.6
	Control	0.1 $\pm$ 2.9	-0.3 $\pm$ 1.1	1.1 $\pm$ 1.0	1.3 $\pm$ 0.6	1.0 $\pm$ 0.3
	<i>p</i> _(PD $\times$ Ctl)	0.002	0.204	0.045	0.069	0.040
SB10-EO	Parkinson	-1.8 $\pm$ 4.5	-1.2 $\pm$ 2.4	6.8 $\pm$ 8.3	1.5 $\pm$ 1.2	1.5 $\pm$ 0.9
	Control	0.7 $\pm$ 3.2	-0.6 $\pm$ 0.8	4.4 $\pm$ 1.9	1.3 $\pm$ 0.5	1.4 $\pm$ 0.4
	<i>p</i> _(PD $\times$ Ctl)	0.004	0.489	0.091	0.281	0.259
SB10-EC	Parkinson	-2.3 $\pm$ 3.5	-1.0 $\pm$ 0.9	7.9 $\pm$ 10.2	2.0 $\pm$ 1.7	1.7 $\pm$ 1.4
	Control	0.8 $\pm$ 3.1	-0.6 $\pm$ 1.1	5.7 $\pm$ 5.6	1.3 $\pm$ 1.0	1.5 $\pm$ 1.2
	<i>p</i> _(PD $\times$ Ctl)	0.008	0.259	0.191	0.090	0.505
FOAM-EO	Parkinson	-4.8 $\pm$ 2.2	-1.6 $\pm$ 6.0	11.2 $\pm$ 10.0	1.7 $\pm$ 0.9	1.8 $\pm$ 0.9
	Control	-2.6 $\pm$ 4.2	-0.6 $\pm$ 1.0	4.0 $\pm$ 3.0	1.8 $\pm$ 0.7	1.2 $\pm$ 1.0
	<i>p</i> _(PD $\times$ Ctl)	0.048	0.427	0.001	0.959	0.054
FOAM-EC	Parkinson	-0.9 $\pm$ 5.4	-0.7 $\pm$ 5.9	11.8 $\pm$ 28.5	2.0 $\pm$ 1.0	2.1 $\pm$ 1.3
	Control	-5.5 $\pm$ 2.3	-0.7 $\pm$ 0.8	4.3 $\pm$ 6.0	2.1 $\pm$ 1.0	1.6 $\pm$ 1.3
	<i>p</i> _(PD $\times$ Ctl)	0.022	0.939	0.003	0.383	0.077
ST-EO	Parkinson	-5.7 $\pm$ 6.4	-1.9 $\pm$ 4.6	12.3 $\pm$ 16.2	2.2 $\pm$ 1.3	2.3 $\pm$ 1.9
	Control	-2.0 $\pm$ 3.8	-1.2 $\pm$ 1.7	4.4 $\pm$ 5.1	1.3 $\pm$ 0.4	1.6 $\pm$ 1.0
	<i>p</i> _(PD $\times$ Ctl)	0.027	0.412	0.006	0.017	0.095
ST-EC	Parkinson	-4.7 $\pm$ 6.5	-2.4 $\pm$ 4.7	9.3 $\pm$ 9.7	1.9 $\pm$ 1.2	2.2 $\pm$ 1.7
	Control	-1.7 $\pm$ 4.7	-0.5 $\pm$ 2.4	4.9 $\pm$ 2.8	1.7 $\pm$ 0.6	1.9 $\pm$ 1.1
	<i>p</i> _(PD $\times$ Ctl)	0.020	0.096	0.020	0.329	0.218

Significant differences are highlighted in bold.

SB30-EO – support base of 30 cm, eyes open; SB30-EC – support base of 30 cm, eyes closed; SB10-EO – support base of 10 cm, eyes open; SB10-EC – support base of 10 cm, eyes closed; FOAM-EO – foam, eyes open; FOAM-EC – foam, eyes closed; ST-EO – semi-tandem, eyes open; ST-EC – semi-tandem, eyes closed; PD – Parkinson's disease; Ctl – control; AP – anterior-posterior, ML – mediolateral

Table 3. Contrast upon the paired analyses of the groups

Parkinson group				Control group		
	Contrast	Power (%)	<i>p</i>	Contrast	Power (%)	<i>p</i>
AP position	Linear	99.6	0.001	Cubic	98.1	0.001
ML position	Quadratic	29.0	0.093	Linear	79.4	0.030
Area	Linear	43.4	0.001	Linear	94.4	0.001
AP velocity	Quadratic	20.4	0.001	Quadratic	98.4	0.001
ML velocity	Linear	87.3	0.001	Linear	99.7	0.001

AP – anterior-posterior, ML – mediolateral

ance response in the PD group in comparison with matched control peers. Additionally, when the tasks presented sensory barriers, the difference between groups became higher.

Postural instability represents one of the important features of PD. The dysfunction has been attributed to

a combination of motor changes due to the disease, age-related issues, and sedentary life style [3]. Our study proved that sedentary older adults (with and without PD) had a hazardous variability of balance. Comparing the results of both groups, we found significant differences between them in 40% of the analyses. As the sample was composed of sedentary subjects advanced in age, it is suggested that changes in stabilometric measures go beyond the deleterious effects of age and sedentarism. Clinical aspects of PD seem to exert a considerable negative influence and this should guide health care professionals during treatment procedures.

Dopamine-replacement drugs constitute an important approach in patients with PD. Clinicians prescribe anti-PD medications with varying doses, in search of an increment of muscle synergy and anticipatory adjustments [15]. However, there is a gradual loss of benefit provided by the treatment, especially when motor complications occur [16]. Owing to this aspect, we

performed the present study during the off medication state of the subjects, considering that motor approaches are increasingly important in the treatment of PD – during the on and off phases of the anti-PD medication.

Individuals with PD who exhibit postural instability are at greater risk of rapid functional decline [17]. Thus, it is essential that professionals attain an accurate measurement of postural control in order to determine optimal rehabilitation goals. In this sense, Falaki et al. [18] confirmed that commitments in neuro-motor mechanisms are related to the control of postural stability in PD. Unlike with motor dysfunction – that has been widely studied, little is known about how sensory pathways affect postural stability in PD. Our study investigated, indirectly, the influence of these pathways on postural stability and provided useful information on situations of sensory pitfalls.

A previous study assessing the impact of tactile stimuli on balance showed that both young and older adults were benefited with a simple sensory feedback on their leg, reducing significantly their postural sway [19]. In PD, it is still not much explored how individuals respond to the presence of, absence of, or a conflicted sensory input. Evaluating subjects with different visual information, support base, and contact surface, we could provide more information about how visual, proprioceptive, and exteroceptive inputs impact the stability of the subject. The few studies addressing the impact of sensory barriers in PD usually explored the influence of the visual system on the postural balance. Vitória et al. [20], for example, suggest that individuals with PD are more dependent on optic flow information for successful task and postural stability than healthy controls. Suarez et al. [21] showed that the absence of visual information triggers balance control disorders in PD. Thus, the visual system plays an important role in the stability of the subject. Other sensory measures related to proprioceptive and exteroceptive receptors also turned out to be more affected in PD. Our study corroborates the results obtained by Nallegowda et al. [22] and suggests that altered proprioceptive and exteroceptive stimuli exert a deleterious influence on postural instability in PD.

Interestingly, the weight displacement in subjects with PD was concentrated on the left hemibody and on the posterior plan. As postural instability is related to the clinical condition of the subjects and suffers little impact of the anti-PD medication [23], Forsyth et al. [24] justify postural impairment to a flexed trunk of the patient. The findings of the present study prove that, even in the mild-moderate stage of the disease, postural impairment is prominent and should be addressed by health care professionals.

Since cognitive function is proven to affect postural stability in PD [25], we delineated a rigid inclu-

sion and exclusion criteria ensuring similarity between the groups on general cognition and executive function. This fact was important to isolate the effect of cognition on the results and to highlight the analysis of sensory input on the outcomes.

While one may question why we used contrast statistics to analyse the impact of the predictors instead of running in-group paired comparisons, one must consider the negative effect that several paired comparisons would cause increasing the type 1 error. As it is known, each paired comparison increases the statistical error by 5%. To ensure that the data are reliable and not biased by an excessive statistical error, we included contrast analyses in the methodological procedures.

Although the current study provides new information about postural stability in PD patients, it has some limitations that need to be considered. First, we recognize a potential bias caused by the small sample size. We opted to restrict the sample size to avoid the inclusion of 'false positive' cases – since the diagnosis of the idiopathic PD is difficult and its accuracy is low even among neurologists [26]. Second, only participants with mild to moderate degrees of compromise were included in the study. Subjects with severe compromise were excluded because independence for orthostatism is unusual in advanced stages, and cognitive impairments become common in PD [27].

Conclusions

The study demonstrated that individuals with PD have different patterns of postural control as compared with healthy controls. Under situations that make the processing of sensory stimuli difficult, PD subjects present hazardous balance. Our results may suggest the incorporation of exercises that stimulate the sensory system as a way to minimize postural impairment in PD.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

Authors state no conflict of interest.

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