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Comparing postural balance among older adults and Parkinson's disease patients

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Abstract — The objective of this study was to compare postural balance among healthy older adults and Parkinson's disease (PD) patients during one-legged stance balance. We recruited 36 individuals of both sexes and divided them into two groups: healthy older adults (HG), and individuals with PD (PG). All the participants were assessed through a single-leg balance test, with eyes open, during 30 seconds (30 seconds of rest across trials) on a force platform. Balance parameters were computed from mean across trials to quantify postural control: center of pressure (COP) area and mean velocity in both directions of movement, anterior-posterior and medial-lateral. Significant differences between-group were reported for area of COP ($P = 0.002$) and mean velocity in anterior-posterior direction ($P = 0.037$), where poor postural control was related to PD patients rather than to healthy individuals. One-legged stance balance was a sensitive task used to discriminate poor postural control in Parkinson individuals.

Keywords: Parkinson's disease, postural balance, physical therapy modalities

Introduction

The neuromuscular system suffers physiological and morphological changes during the aging process, leading to decreased muscular performance and functional capacity[1]. Postural control also deteriorates during this process and the central nervous system experiences decreased capacity to respond efficiently to vestibular, visual and proprioceptive commands, which are responsible for maintaining postural balance[2,3].

Well-documented morphological changes, such as functional, biochemical, and psychological changes, occur during the aging process and determine the progressive loss of an individual's ability to adapt. These changes are associated with a greater prevalence of disorders and decreased functional capacity, which together lead to loss of independence and autonomy for older adults, rendering these individuals vulnerable to disease and leaving them dependent on others for the performance of tasks of daily life[4,5].

Some diseases occur more frequently in this age group and are associated with the aging process, such as Parkinson's disease (PD). PD is the most common movement disorder affecting the central nervous system and presents the highest incidence among older adults, affecting between 1% and 3% of this population. Clinically, this disease is marked by the presence of resting tremors, rigidity, bradykinesia, postural instability, and gait abnormality[6,7].

It is believed that postural instability, a component of the signs and symptoms characteristic of the disease, occurs due to postural changes associated with loss of the ability to control the intentional movements of the body's center of mass over the support base during activities involving weight transfer[8]. Additionally, difficulty in maintaining postural stability in PD involves a change in movement ordination in its subcortical origin and not in the muscle *per se*[9]. In this line of thought, studies indicate the need to assess how changes caused by PD interfere in postural balance and the functionality of individuals in order to select the most appropriate therapeutic approach to rehabilitation[10].

For a reliable assessment, postural balance can be quantified by directly measuring postural control, such as through the use of parameters of the center of pressure (COP) under the feet, recorded by a force plate with different positions, including the single-leg stance[11,12]. This method is valid and reliable for the measurement of postural balance parameters concerning COP associated with the neuromuscular and biomechanical mechanisms of both young and older adults[13,14].

The results reported in the literature in the field often refer to tasks performed in a standing position. It would, however, be interesting to broaden the assessment and investigate more challenging tasks, e.g., single-leg stances, which are more challenging in the motor tasks of daily activities such as spinning, climbing stairs, walking, and dressing. This more demanding position while standing may predict the incidence of falls and be a variable that presents greater responsiveness to the effects of interventions involving physical exercise directed to the postural balance of this population[2].

We hypothesize that individuals with PD have more difficulty maintaining the single-leg stance, reflecting a higher ellipse area of COP, as well as velocity of COP oscillations recorded by the balance platform, when compared to healthy elderly.

This study's objective was to compare the postural balance of healthy older adults with that of individuals with a diagnosis of Parkinson's disease (PD) when in a single-leg stance.

Method

Sample

This cross-sectional study includes a convenience sample of 36 individuals divided into two groups: 18 healthy older adults (HG) consisting of 11 men and seven women; and 18 individuals diagnosed with Parkinson's disease (PG), also consisting of 11 men and seven women. The healthy individuals were recruited in the community and those with PD originated from the Medical Clinic at the Hospital de Clinicas at the State University of Londrina. This study was took enrollments between 2014 and 2015.

We included patients with idiopathic PD according to criteria from UK Brain Bank[15], classified in stages 1.5–3 according to the Hoehn & Yahr staging scale, and non-institutionalized elderly individuals. The selection of participants with PD was conducted in a balanced way in reference to the akinetic-rigid and hyperkinetic disorders, and they were all taking dopaminergic agonist and/or dopaminergic medication. Those who consented signed free and informed consent forms in accordance with the criteria established by the Institutional Review Board (CEP-UEL No. 066/2011) and by the National Council of Health No. 466/12.

Individuals were excluded from the study if they presented other forms of parkinsonism, other associated neurological pathologies, vestibular, cardiovascular, musculoskeletal, cognitive (cutoff points 24 in the Mini-Mental State Examination), visual or auditory disorders that affected motor performance, or if they were using orthoses or walking aids.

All study participants did not perform any physical activity for at least 3 months prior to the evaluation.

The procedures, performed always at the same time by the same evaluator in the stage "on" of the medication, were composed of the following:

- Body mass index (BMI): BMI was measured using an electronic scale (Filizzola PL150, Filizzola Ltda), precise to 0.1 kg, and height was measured using a wall stadiometer precise to 0.1cm (Sanny®, São Paulo, Brazil). BMI was computed using the equation: body mass (kg) / height^2 (m).
- Modified Hoehn & Yahr Scale (HY): This was used to assess the staging of the disease and impairment of individuals with PD. The modified version comprises seven classifying stages of the severity of the disease. Patients classified between stages 1.5 and 3 (mild to moderate impairment) were selected for the study (16).
- Unified Parkinson's Disease Rating Scale (UPDRS): This assesses the progression of the disease according to its clinical characteristics. It is composed of 42 items divided into four domains. The scores for items range from 0 to 4; the higher the score, the more severe the impairment caused by the disease. Only domains related to activities of daily living (part II) and the motor exam (part III), were used[17].
- Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MOCA): These are used to assess cognitive functions, and are composed of questions grouped into seven categories, each designed to assess specific cognitive functions, such as orientation in time and space, recording and recalling words, language, attention and calculus, and visual constructive capacity. The scores range from 0 to 30, and the cutoff point is 24. This scale has excellent sensitivity and specificity for the diagnosis of dementia[18,19].

Experimental protocol

Each participant was allowed to practice the one-leg stance before testing and choose which leg they preferred to stand on as only one leg was tested. All subjects performed three trials of one-leg stance for 30 s maximum, with a rest period of approximately 30 s between each trial[20]. The mean across three trials for each balance measure was analyzed.

The participants were instructed to stand on one leg while barefoot, with eyes opened and looking at a target at eye-level (target size: 15×15 cm) on a wall 2 m away, with their arms along the side of their body. An investigator stood close to the participants during testing to prevent falls and injuries.

Vertical ground reaction force data from a force platform (BIOMEC400, EMG System do Brasil, Ltda, SP) was sampled at 100 Hz. All force signals were filtered with a 35 Hz low-pass second-order Butterworth filter and converted into COP data using MATLAB routines (The Mathworks, Natick, MA). Stabilographic analysis of COP data was used to calculate the following balance parameters: 95% confidence ellipse area of COP (A-COP in cm^2) and mean velocity (VEL in cm/s) of COP for both anteroposterior (A/P) and mediolateral (M/L) directions. These measure were calculated over the entire 30 s, and have been found to be valid and reliable (ICC > .80) in both healthy young and elderly subjects[20].

Statistical analysis

Statistical analysis was conducted using the software SPSS 20. Data are presented according to a normal distribution and tested using the Shapiro-Wilk test (mean and standard deviation or median and quartiles). The Student's t-test for independent samples was used to compare between groups. Effect size was analyzed using Cohen's formula: (M1-M2)̊ / $^{\sigma}$polled where M1 is the mean of the target group (older adults with Parkinson), M2 is the mean of the control group and ᶜpolled is the groups' grouped standard deviation. The magnitude of effect is assessed by Cohen[21] according to the following: small 0.20–0.49, moderate 0.50–0.79 and large 0.80–1.29. A *P*-value of 5% was adopted for data to be considered statistically significant.

Results

The baseline data is presented in Table 1 and the similarity of the groups is demonstrated.

Significant differences between the groups were reported for A-COP sway ($P = 0.002$, with large effect size $d = 1.20$, HG < PG) and mean velocity (VEL) for anterior-posterior (A/P) direction of movement ($P = 0.037$, with medium effect size $d = 0.70$, HG < PG). Overall, the Parkinson's group presented poor postural control compared with healthy individuals, with significance exception only for the VEL M/L variable ($P = 0.487$). These results are reported in Table 2.

Table 1. Subject characteristics.

Variables	HG	PG
Age (years)	69,9±8,0	68±4,9
BMI (kg/m²)	26,1±4,5	26±3,5
MEEM	26±2,4	26,7±3,3
MOCA	–	24,1±2,21
H&Y	–	2,6±0,49
UPDRS (part II)	–	9,9±4,5
UPDRS (total)	–	31,3±13,3
Diagnosis time (years)	–	5,1±3,5

BMI, body mass index; H&Y, modified Hoehn & Yahr Scale; UPDRS, Unified Parkinson's Disease Rating Scale; MEEM, Mini-Mental State Examination; MOCA, Montreal Cognitive Assessment; kg, body mass; m^2, square meters.
P > 0,05 for age, BMI and MEEM.

Table 2. Postural sway variables in healthy older adults (HG) and Parkinson's disease individuals (PG).

Variables	HG	PG	P
A-COP (cm²)	10,1±2.9	16,5±7,7	0,002*
Vel A/P (cm/s)	3,0±0.8	3,6±0,9	0,03*
Vel M/L (cm/s)	3,7±1.0	3,9±0,9	0,48
Time (s)	20,0±5,0	17,8±7,4	0,36

Data are presented as mean and standard deviation (±).
COP, Area of Center of Pressure; VEL A/P, velocity anterior-posterior; VEL M/L, velocity medial-lateral; cm^2, squared centimeters; cm/s, centimeters per second.
*data statistically significant (P-value of 5%).

Discussion

Maintenance of balance and body orientation while in an upright posture is critical for performing activities of daily living. Therefore, investigation into how body balance and orientation are controlled has raised the interest of professionals from diverse fields. In each new posture adopted by an individual, neuromuscular responses are required to keep the body balanced and this maintenance is attributed to the postural control system, which includes the nervous, sensory, and motor systems responsible for this role[22].

Information regarding the development of two-legged balance is more abundant in the literature as opposed to studies addressing a single-legged stance. Performing only two-legged tests limits the clinical use of data to document balance deficits. Thus, studies addressing single-leg tests are important and necessary because individuals need to control their center of mass on one leg in order to perform various motor activities in daily living. Additionally, single-legged support may be more appropriate to provide additional information when assessing balance and determining potential disorders, as individuals may not be challenged sufficiently when performing two-legged tests[2,23,24]. In this context, Chomiak and collaborators verified in their study that not being able to remain in a single-leg stance for at least 10 seconds is related to an increased risk of falling among individuals with PD[25].

This study's main findings reveal that the PG presented a worse performance in the COP area represented by an oscillation of more than 60% when compared to the group of healthy individuals ($P = 0.002$). The speed of A/P oscillation was higher in the PG ($P = 0.03$) but not in the M/L direction ($P = 0.42$).

COP anterior-posterior and medial-lateral variation, such as ankle reactions, are perceptible in normal conditions and are characterized by small contractions of dorsiflexor, plantar-flexor, inverter and evertor muscles to regulate postural adjustments in response to small stimuli that occur in the sagittal or coronal planes.

The results also show that individuals with PD more frequently require anterior-posterior adjustments instead of medial-lateral adjustments and possibly use them in a less developed form, that is, without a level of fine control to ensure greater stability, which culminates in greater oscillation. This fact may be explained by the fact that the plantar and dorsiflexor muscles are stronger, more resilient to fatigue and, thus, compensate for the poor work of the inverter and evertor muscles[26]. As is known, automatic movements in PD are compromised and responses to postural adjustments, which vary according to demand, are automatically performed with very delicate adjustments[27]. In addition to these factors, older adults with PD present marked postural changes in the anterior-posterior direction, along with rigidity and bradykinesia, which further hampers the participants' responses and consequently, interferes in postural balance[28]. Trunk flexion posture in these individuals is related to gait abnormalities, postural instability and greater vulnerability to falls[29].

The presence of postural instability is well established in individuals with PD[8]; the literature, however, clarifies that healthy older individuals present a greater decline in balance when compared to young adults. Parreira et al.[13] verified that differences in balance between young adults and older adults are significant and time-dependent. The participants in their study remained in the one-leg stance for 30 seconds and that analysis was performed at 5, 10, 15 and 30 seconds. COP area in the first 5 seconds was significantly lower than in the remaining intervals, while there was no difference between the groups at

10, 15, and 30 seconds[13]. This fact characterizes the detrimental effect of the aging process on postural control.

Ickeinstein et al. (2012) verified balance by using a force platform with PD and healthy older adults in the Romberg position (feet together in parallel) during 30 seconds, with open and closed eyes. The COP area of individuals with PD was significantly larger, which corresponds to greater postural instability. These results are in agreement with our study's findings in regard to balance among PD individuals[30].

We emphasize that we use the single-leg stance in our research in order to provide more appropriate information about balance, as individuals cannot be challenged enough when subjected to tests in bipedal stance[25]. Moreover, there are few studies that evaluated individuals with PD under single-leg stance conditions[31,32,33] and these studies did not use similar methodology, making it difficult to compare our data.

Tsutiya and collaborators, conversely, report no statistically significant difference in the balance outcome between PD and healthy individuals. However, COP average speed values were greater in the PD group compared to healthy adults. The groups were assessed using a force plate in the two-leg position with eyes open for 20 seconds[34]. These findings contribute to our hypothesis that the two-leg position can be very stable, may not detect balance deficits, and also that 20 seconds may be insufficient to record oscillations, which agrees with the findings reported by Scoppa, Capraa, Gallaminia, Shiffera[35], suggesting that postural assessments aimed at better stratifying COP parameters should last at least 30 seconds[35].

Beretta, Gobbi, Lirani-Silva , Simieli, Orcioli-Silva, Barbieri[36] conducted one study to verify asymmetry in appendicular weight transfer among healthy and PD older adults. Two plates were used, on which participants placed one leg each, to perform two-legged, tandem and single-legged stance tests in three attempts of 30 seconds each. The conclusion was that participants with PD presented greater asymmetry than healthy individuals, especially in challenging tasks such as tandem and single-legged stance[36].

It is possible that a specific exercise program, focusing on deficits that become increasingly frequent as PD progress, can delay the process of degeneration among individuals who have not yet presented such changes or whose changes are mild. Some authors note that aspects such as mobility and postural instability, as well as balance disorders, do not respond well to medication or surgery, so prevention is an important Alternative[37].

An accurate assessment is essential for these deficits to be detected, reversed or minimized by proper and early therapeutic intervention. As posturography assesses postural control and is based on the determination of variables associated with displacement of the COP, which is the point of application of the resultant of vertical force components where they intersect with the support surface, balance measures acquired with the use of a force plate enable the identification of small changes in posture and have been described as highly sensitive, used as a reference to determine changes in postural control[38].

Therefore, it is suggested that the treatment plan includes, with an emphasis on improving the balance of these individuals, exercises that follow an evolutionary course and explore the following: 1) different bases of support, such as the Romberg position, Tandem and single-leg stance; 2) changing the center of gravity and the limits of body stability, with activities that stimulate the postural transitions; 3) activities of the arms and rotational movements of the trunk; 4) using different therapeutic resources that stimulate the reactions anticipatory and compensatory balance such as foams, balls, step bench, bosu, trampolines; 5) sensory integration exercises with open eyes and closed eyes.

Among this study's limitations, we note that results cannot be generalized to individuals in the more advanced stages of PD or to other postures, such as two-leg, Romberg or tandem, which also have functional importance.

Although, these data refer to the assessment of individuals in stage "on" of the medication. Assessments in stage "off" should be performed to compare these values.

Conclusion

Older adults with PD presented greater postural balance deficits in the single-leg stance when compared to healthy individuals. These results suggest that PD may negatively impact postural balance, leading to greater postural oscillations and, as a consequence, greater instability. The discussion previously presented consolidates the importance of introducing exercises to explore the single-leg stance in rehabilitation programs directed to participants with PD.

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