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Short communication

# Between-leg asymmetry in automatic postural responses to stance perturbations in people with Parkinson's disease

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ABSTRACT

*Background:* People with Parkinson's disease (PwPD) showed impairments of balance control which can be aggravated by the presence of higher interlateral postural asymmetry caused by a distinct dopaminergic loss in the substantia nigra between cerebral hemispheres.
*Research question:* We evaluate asymmetries between the more and the less affected leg in PwPD in responses to unanticipated stance perturbations.
*Methods:* Sixteen 16 PwPD participated in the experiment that consisted of recovering a stable upright stance, keeping the feet in place, in response to a perturbation caused by a sudden release of a load equivalent to 7 % of the participant's body mass. Anterior displacement and velocity of the center of pressure (CoP), the latency of gastrocnemius medialis muscle (GM) activation onset, rate of GM activation, and normalized magnitude of muscular activation were analyzed.
*Results:* Analysis revealed significantly rate ($p = 0.04$) and magnitude ($p = 0.02$) higher activation of GM in the less affected limb. No significant effects of the leg were found for GM activation latency or CoP-related variables.
*Significance:* There is a higher contribution of the less affected leg in automatic postural responses in PwPD.

## 1. Introduction

Impairments of balance control in people with Parkinson's disease (PwPD) are manifested in multiple aspects like less stable standing balance, diminished postural reflexes, and impoverished reactive responses to unanticipated stance perturbations [1-3]. These impairments of body balance control increase the risk of falls and are more life-threatening in PD than in other neurological diseases [4,5]. Additionally, PwPD has been shown to have higher interlateral postural asymmetry in quiet standing than healthy controls [6,1,7,2,8]. Increased interlateral asymmetry in PwPD can be explained by distinct dopaminergic loss in the substantia nigra between the right and left cerebral hemispheres [9]. Interlateral asymmetry in PwPD is more evident in challenging postural tasks [1,10], with stability being achieved through compensation between the legs by increasing the contribution of the less impaired leg for stance control [7]. Since external perturbations balance requires more complex postural responses, it is expected that in this situation also there will be more need to use this compensatory mechanism of greatest contribution from the less impaired leg.

This study aimed to evaluate asymmetries between the more and the less affected leg in PwPD in responses to unanticipated stance perturbations. We hypothesized a higher contribution of the less affected leg in generating automatic postural responses.

## 2. Materials and methods

### 2.1. Participants

Participated 16 idiopathic PD participants (44–78 years / 9 women) recruited from the movement disorders outpatient clinic of the Hospital

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das Clínicas at USP Medical School and by social disclosure. Inclusion criteria were unassisted standing, manifest interlateral asymmetry measured through the motor score of the Unified Parkinson's Disease Rating Scale (UPDRS-III) and absence of neurological or physical dysfunctions other than those associated with PD. Clinical asymmetry was defined as the difference between the summed UPDRS scores of the left and right body sides (items 3.3–3.8 and 3.15–3.17). The most affected body side was defined as the side with the highest UPDRS score (right side: 7; left side: 9). Participants were evaluated in the state "on" of medication. Participants provided written informed consent, as approved by the University's Ethical Committee. All the sample characteristics are presented in Table 1.

### 2.2. Task and equipment

The experimental task consisted of recovering a stable upright stance, keeping the feet in place in response to a perturbation caused by a sudden release of a load equivalent to 7 % of the participant's body mass attached to their trunk with each foot supported on individual force plates (BTS Bioengineering, Italy, model P6000). The initial posture was keeping the trunk and legs in a straight line, sustaining a stance with the body slightly inclined forward while resisting against the load pulling the trunk backward (Martinelli et al. [11], for details). Bilateral activation of the gastrocnemius medialis muscle (GM), as the primary agonist for this task, was measured through wireless surface electrodes (Delsys Inc., Boston, MA, USA, model Trigno), positioned according to the SENIAM (http://www.seniam.org/) project recommendations.

### 2.3. Procedures

Initially, the evaluations were performed: UPDRS-III, H&Y, and Hospital Anxiety and Depression Scale (HADS). Afterward, the experimental task was performed with the feet parallel hip-width apart and arms crossed over the chest. The time of load release was unanticipated between 2 and 4 s after a verbal prompt. Following task familiarization, the evaluation was made through 10 sequential trials. In cases where the participant moved their feet in response to balance perturbation, the trial was rejected but not repeated.

### 2.4. Data collection and analysis

Data sampling frequency was set at 2000 Hz for EMG and 200 Hz for the force plates. Data extraction and processing were made through MATLAB (Mathworks, Natick, MA, USA) routines. Ground reaction force data were digitally low-pass filtered with a fourth-order Butterworth filter with a cut-off frequency of 10 Hz. Raw EMG signals were filtered through a fourth-order zero-lag band-pass Butterworth filter with 20–400 Hz cut-off frequency. The linear envelope of the EMG was estimated by rectification and low-pass filtering (anti causal Butterworth filter of order 4, cut-off frequency 10 Hz) during each trial.

The following dependent variables were analyzed: CoP peak (a) anterior displacement and (b) velocity, (c) latency of GM activation onset, having as a criterion the time of onset of the sustained growing linear envelope of the EMG values two standard deviations above the average in the interval of 200 ms preceding load release (d) rate of GM activation, given by the slope of the line connecting the values observed at muscular activation onset and the ensuing 100 ms in the linear envelope of the EMG signal, and (e) the normalized magnitude of muscular activation of the 0–150 ms interval following muscular activation onset (activation magnitude values were normalized to the respective baseline value – magnitude of 500 ms before load release – of the trial).

Shapiro-Wilk test indicated normal data distribution across dependent variables. Comparisons between the two legs were made through Student *t*-tests for dependent measures, using the JASP software (version 0.15.0.0). Level of significance was set at.05.

**Table 1**
Demographic, cognitive, neuropsychiatric, and clinical characteristics of the participants.

| Characteristics | Mean (standard deviation) |
|---|---|
| Age (years) | 63.68 (8.63) |
| Mass (kg) | 70.46 (12.96) |
| Height (cm) | 164.18 (10.85) |
| MMSE (score) | 26.12 (2.75) |
| Disease duration (years) | 7.50 (3.91) |
| LED (mg/day) | 720.83 (261.92) |
| UPDRS-III (score) | 28.56 (12.15) |
| H&Y – 2/3 (stages) | 5/11 |
| FES-I (score) | 35.68 (9.47) |
| HADS – Anxiety (score) | 7.75 (2.88) |
| HADS – Depression (score) | 6.81 (3.29) |

MMSE, Mini-Mental State Examination; LED, Levodopa equivalent daily dose; UPDRS-III, United Parkinson's Disease Rating Scale motor part; FES-I, Falls Efficacy Scale International; HADS, Hospital Anxiety and Depression Scale

## 3. Results

Participants' characteristics are summarized in Table 1. Analysis revealed a significantly higher GM activation rate in the less affected limb ($p = 0.04$). Analysis of GM activation magnitude also indicated significantly higher values in the less affected limb ($p = 0.02$). No significant effects of the leg were found for GM activation latency or CoP-related variables (Table 2).

## 4. Discussion

We evaluate the asymmetries between the more and the less affected leg in PwPD in responses to unanticipated stance perturbations. Our results showed that the magnitude and rate of GM activation were higher in the less than in more affected leg in PwPD, while muscular activation latency and CoP-related variables were not asymmetric between the legs in responses to unanticipated stance perturbations. These results, then, supported our hypothesis of a higher contribution of the less affected leg in automatic postural responses in PwPD. Furthermore, these results suggest that the control system activates the agonist muscles of the less affected leg with increased vigor to compensate for the deficits of the more affected leg to generate appropriate muscular responses for balance recovery.

Inter-leg asymmetry in automatic postural responses can be thought to reflect the asymmetric degeneration of dopaminergic neurons in the substantia nigra between the cerebral hemispheres, generating unilateral motor signs and symptoms in PwPD in an early stage of the disease [12]. The interlateral asymmetry may be magnified through between-leg compensatory control, with muscular activation of the less affected leg being magnified to compensate for the weak response of the more affected leg, generating sufficient net torque at the ankles to recover body balance [10,1,7,2]. This interpretation is consistent with

**Table 2**
Means (standard deviations), statistical significance and effect sizes.

| Variable | Most affected limb | Least affected limb | *p* | Cohen's d |
|---|---|---|---|---|
| CoP peak displacement (mm) | 124.34 (22.07) | 133.17 (20.25) | 0.213 | -0.34 |
| CoP peak velocity (mm/s) | 958.80 (315.64) | 1064.53 (316.79) | 0.333 | -0.26 |
| GM activation latency (ms) | 150.42 (13.58) | 154.56 (9.39) | 0.181 | -0.36 |
| GM activation rate (μV/ms) | 1.05 (0.36) | 1.45 (0.72) | 0.038 | -0.59 |
| GM magnitude (norm) | 12.43 (5.13) | 18.76 (12.45) | 0.017 | -0.70 |

GM, muscle gastrocnemius medialis

previous findings from neurologic groups with significant interlateral asymmetries between the legs [13] and in typical individuals with transient disability of a single leg [14]. The requirement of torque application at the two ankles for mediolateral stability in balance recovery may explain why CoP displacement was unaffected by the asymmetric magnitude and rate of GM activation [14].

Although our results conclude a higher contribution of the less affected leg in automatic postural responses in PwPD, it is important to highlight the potential limitations. Our sample size is relatively small considering the number of potential variables that could affect the asymmetry in postural control, no measure of ankle torque, and the lack of a control group limits our interpretations about higher use one of the limbs during postural responses, which may be present not only in PwPD.

## Conflict of interest statement

Authors declare to have no actual or potential conflict of interest including financial, personal or other relationships which might influence results and their interpretation.

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