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Parkinsonian deficits in context-dependent regulation of standing postural control

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Abstract

This study explored whether patients with Parkinson's disease alter the regulation of upright standing according to constraints imposed by the environmental context. The provision of context-dependent adaptations was inferred from the presence of adjustments to standing postural control that would serve to reduce fall risk when balance was challenged by a threatening environmental context. Participants were asked to stand as still as possible in two environmental context conditions that differed in the level of imposed postural threat: LOW threat and HIGH threat. Eight levodopa dependent patients with Parkinson's disease (PD) and eight age-matched control subjects (CTRL) provided the subject sample. PD patients were tested following a 12-h withdrawal of anti-Parkinsonian medications and approximately 1 h post-medication. The CTRL group showed altered postural control in the HIGH threat condition, in a manner that was indicative of appropriate context-dependent regulation of standing. PD patients, in the non-medicated or medicated states, did not modify stance regulation when the environmental context heightened postural threat. Our results extend the current understanding of Parkinsonian deficits in the context-dependent regulation of postural control to include upright standing.

Keywords: Parkinson's disease; Postural control; Environmental context

Instability and falling are hallmark deficits of Parkinson's disease (PD) and recent epidemiological data suggest that over half of those who suffer from this disease will experience a fall [28]. The prevalence of falling in this population reflects a disease-induced deterioration in postural control that is only marginally improved with levodopa therapy [3–5,17,25]. One component of postural control that is compromised among PD patients is the ability to adapt postural control according to constraints imposed by the demands of the task or the environmental context [10,11,15,16]. This deficit has been confirmed by impaired timing between the preparatory and voluntary components of the rise-to-toes task [15], inappropriate scaling of the magnitude of externally-triggered postural reactions following a change support surface conditions [10,11,16], and ineffective scaling of the magnitude of the anticipatory postural adjustments preceding gait initiation when stance width increased [23].

Current theory suggests that one function of the basal ganglia is to maintain the plan for action that is set by motor cortical regions according to task requirements and environmental constraints [18,27]. This theory provides foundation for documented Parkinsonian deficits in context-dependent regulation of postural control. Yet, despite evidence that context-dependent adaptation of postural control also serves the regulation of quiet stance [6,8], this dimension of postural control has remained unexplored among Parkinson's disease patients. The purpose of this study was to determine whether PD alters the provision of context-dependent adaptations to the regulation of standing. In accordance with previous studies that have demonstrated a compromised capacity of PD patients to adapt reactive and centrally-initiated postural adjustments, we expected to reveal Parkinsonian deficits in the context-dependent regulation of undisturbed quiet standing. We hypothesized that the non-neurological population would demonstrate alterations in postural control indicative of an appropriate context-dependent

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Table 1
Clinical characteristics of Parkinson's disease patients

Subject	Age	Disease duration (years)	UPDRS		Medication
			Off	On	
PD 1	64	7	43	12	*Levodopa, Pramipexole, Entacapone, Amantadine*
PD 2	66	4	35	16	*Levodopa, Pramipexole, Entacapone, Amantadine*
PD 3	66	1.5	42	15	*Levodopa, Pramipexole*
PD 4	54	9	46	18	*Levodopa, Pramipexole*
PD 5	56	8	11	5	*Pramipexole, Levodopa, Amantadine*
PD 6	64	9	46	23	*Levodopa, Pramipexole*
PD 7	80	15	45	34	*Levodopa*
PD 8	74	1	20	7	*Levodopa*

regulation of upright standing while PD patients, in either state of medication, would not demonstrate any change in the parameters of postural control that could be inferred to indicate a change in regulation.

Eight levodopa-dependent PD patients (65.5 ± 9.7 years; clinical characteristics are available in Table 1) and eight age-matched control (CTRL) subjects (67.1 ± 9.4 years) participated in this study. All participants were informed about the nature of the study and gave written content to participate prior to testing. This study was approved by the Human Research Ethics committee of the University of Lethbridge. PD patients were tested off medication (PD_{OFF}; following a minimum of 12 h withdrawal from all PD medications), and on medication (PD_{ON}; between 1 and 2 h following medication administration) in the same laboratory visit. Patients were tested in the OFF state prior to the ON state to maximize patient comfort and testing practicality. The quality of the ON condition was confirmed by patient self-report and by clinical assessment.

A hydraulic lift platform (1.2 m × 1.8 m, Pentalift, Guelph, ON) and secondary wooden platform were used to manipulate the environmental context and alter the level of postural threat imposed to the participants. The surface of the hydraulic lift platform was covered by a custom-built wooden deck (width: 1.2 m × length 1.8 m × height 0.06 m). The front of the deck was cut away to surround a forceplate (Bertec Corporation, Columbus OH). The top surface of the forceplate was flush with the surface of the deck and the front edge of the forceplate was flush to the front edge of the deck and the hydraulic lift (Fig. 1). The hydraulic lift platform was set to a fixed height such that the surface of the forceplate and surrounding deck were 0.6 m above ground level. Two testing conditions were included in this study: LOW threat, where the secondary wooden platform (height: 0.6 m; depth: 0.45 m; length: 1.2 m) was placed in front of the hydraulic platform/deck and provided the opportunity for forward stepping as a postural recovery strategy should it be necessary, and HIGH threat, where the secondary platform was removed. To ensure participant safety, an overhead harness was worn throughout testing, and a spotter stood behind the participant at all times.

Participants were asked to stand as still as possible for two 15 s quiet standing trials in each testing condition. Participants stood on the forceplate with their feet at a comfortable width apart and their toes at the front edge of the forceplate. A mandatory rest period (sitting) of minimum 30 s duration was imposed between test trials. Foot tracings were made to ensure foot placement remained constant between test trials and between test conditions. Participants completed two test trials in each condition as part of a larger study. The order of the quiet standing trials was randomized within testing conditions (LOW/HIGH), and the presentation order of the testing conditions was counterbalanced between groups.

The provision of context-dependent adaptations to postural control was inferred from spatio-temporal parameters and frequency characteristics of the movement the location of the vertical ground reaction force vector (known as the Centre of Pressure (COP)) during standing. Quantifying COP dynamics is a standard method of analysis in postural control research, with alterations in postural control reflected by changes in COP characteristics [22]. In this study, three indices of COP dynamics were used to compare context-dependent regulation of upright standing between PD and CTRL subjects: (1) Mean COP Position (MPOS), (2) Root Mean Square (RMS) distance and (3) Mean Power Frequency (MPF). MPOS represents the average position of the COP relative to the anterior edge of the forceplate. This measure provides an indication of the vertical inclination of the body, or the presence of a forward or backward lean. RMS distance represents the variability of sway during standing and Mean Power Frequency (MPF) represents the average frequency contained within the power spectrum of the COP displacement profile. The combined activity of MPF and RMS are used to provide insight into stiffness regulation across the ankle joint [8,29] and, together with the measure of MPOS, indicate the behavioral and neural strategies that are in effect for stance regulation. These indices have been used previously to demonstrate context-dependent regulation of upright standing in non-neurological groups [7,8].

Because the experimental manipulation imposed a threat to postural control in the antero-posterior dimension, and not the medio-lateral dimension, all measures were calculated using the antero-posterior dimension of the COP trajectory. Ground reaction force and moment of force data were collected from the forceplate at a sampling frequency of 600 Hz. Data were low-pass filtered with a dual pass 4th order Butterworth filter at a cut-off frequency of 5 Hz prior to the calculation of Centre of Pressure. A fast Fourier transformation was performed on the antero-posterior COP position signal to derive the power spec-