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Fallers with Parkinson's disease exhibit restrictive trunk control during walking

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ABSTRACT

Background: The relationship between falls and static and dynamic postural control has not been established in Parkinson's disease (PD). The purpose was to compare the compensatory postural strategies among fallers and non-fallers with PD as well as older adults during static and dynamic movements.

Methods: Twenty-five individuals with PD (11 fallers) and 17 older adults were outfitted with 6 accelerometers on the wrists, ankles, lumbar spine, and sternum, stood quietly for 30 s on a force platform, and walked back and forth for 30 s along a 15 m walkway. Root-mean-square displacement amplitude of the center of pressure (COP), COP velocity, gait spatial-temporal characteristics, trunk range of motion (ROM), and peak trunk velocities were obtained.

Results: COP velocity in anterior-posterior was larger in older adults than those with PD ($p < 0.05$). Trunk frontal ROM and velocity were smaller in fallers and non-fallers with PD compared to older adults ($p < 0.05$). Trunk anterior-posterior ROM and velocity were smaller in fallers than non-fallers with PD and older adults ($p < 0.05$). In fallers with PD, negative correlations were shown between the sagittal trunk velocity and the COP velocity in the anterior-posterior direction as well as between trunk frontal velocity and COP velocity in both directions ($p < 0.05$). In non-fallers with PD, horizontal trunk ROM and velocity were positively correlated with COP ROM and velocity in the medial-lateral direction ($p < 0.01$).

Significance: Dynamic postural control revealed better discrimination between groups than static. Fallers and non-fallers with PD and older adults adopted different compensatory strategies during static and dynamic movements; thereby providing important information for falls-risk assessment.

1. Introduction

Falls are a common feature of Parkinson's disease (PD). In fact, the rate of falls ranges between 50–70 % in individuals with PD [1–4], which is approximately twice that of community-dwelling older adults [4]. Individuals with PD are also nine times more likely to suffer from recurrent falls compared to older adults [2]. The greater instability and rate of falls are a concern because they suggest that individuals with PD are unable to react and initiate appropriate compensatory postural strategies with sufficient speed to break their falls [5].

The motor and perceptual impairments inherent with PD may predispose patients to a greater risk of falls [1,6]. More specifically, the reduced level of dopamine and cerebral cortex activation associated with PD lead to various motor manifestations, including resting tremor [7], bradykinesia [8], and rigidity [9]. It has also been suggested that individuals with PD underestimate the muscle activity necessary to match the requisite movement amplitude [6]. These motor and perceptual impairments may provoke individuals with PD to adopt different compensatory postural strategies during static [7] and dynamic movements [8]. However, the ability to discriminate between fallers and non-fallers during these movements is not well understood.

Empirical evidence suggests that individuals with PD adopt different postural strategies than healthy counterparts during standing [7,10]. For instance, displacement of the center of pressure (COP) in the medial-lateral (ML) direction and velocity of the COP in both directions were larger in freezers compared to non-freezers as well as older adults during static posturography [7]. In contrast, other work has shown that static posturography discriminated between individuals with PD and healthy older adults, but not between fallers and non-fallers with PD [10]. Similarly, other work has outlined that static posturography was unable to distinguish between different levels of deficits in clinical measures such as the pull-test and tandem walking among those with

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PD [11]. Although instability has been prevalent in individuals with PD, there is no consensus on whether static posturogrphy is sensitive enough to discriminate between subgroups of individuals with PD.

Individuals with PD have also been shown to adopt different strategies during dynamic movements than healthy counterparts [8,12,13]. Emerging research suggests that gait can be used as a biomarker to identify individuals with PD who fall [12]. Healthy young and older adults have demonstrated faster walking speed, longer steps, and reduced variability of step time relative to those with PD [12]. Other research examining stepping in place has exposed larger asymmetry and arrhythmicity in freezers compared to non-freezers and older adults [13]. Freezers have also exhibited slower gait initiation and were more affected by gait inhibition compared to both older adults and non-freezers [8]. Dynamic posturography measures, such as reaction time, movement velocity, and target hit-time during leaning have also discriminated between fallers and non-fallers with PD [10]. Moreover, this literature suggests that the compensatory postural strategies during dynamic movements do not function appropriately among individuals with PD. A better understanding of the relationship between falls and static and dynamic movements may provide further insight into falls-risk assessment in this clinical population.

The overarching purpose of this study was to compare the compensatory postural strategies derived during static and dynamic movements to determine whether these tasks would be sensitive to discriminate between fallers and non-fallers with and without PD. It was hypothesized that the static and dynamic parameters would differentiate between fallers and non-fallers with PD as well as healthy older adults. It was also hypothesized that falling would be correlated with the kinetic parameters of posture and spatial-temporal aspects of gait.

2. Methods

2.1. Participants

Twenty-five participants with PD and 17 healthy older adults participated in the study (Table 1). PD participants were recruited from the PD and Movement Disorders Clinic in the Ottawa Hospital Research Institute **and had a confirmed diagnosis of PD by a neurologist**. Inclusion criteria consisted of: no history of orthopedic and musculoskeletal impairments, or neurological conditions other than PD that could impact balance and gait. Testing was performed in the optimally medicated state (dopaminergic medications). PD subjects were divided into fallers and non-fallers based on the self-reported occurrence of falls in the previous three months. Older adults were excluded if they reported previous surgeries and/or impairments that could interfere with gait or balance. The study was approved by the Institutional Review Board **in accordance with the declaration of Helsinki**. All participants provided written informed consent.

PD severity was assessed using the Unified Parkinson's Disease Rating Scale (UPDRS) III, (motor disability). Participants performed the Montreal Cognitive Assessment (MoCA) to determine cognitive impairment (i.e., scores below 26**), as well as the Freezing of Gait questionnaire (FOG-Q). Freezers were classified based on the FOG-Q and/or whether freezing episodes were observed during testing. The UPDRS III, MoCA, and FOG-Q were all administered by the same rater, who was trained by a movement disorder specialist**.

Table 1
Comparison of participant characteristics; mean (standard deviation).

Demographics	Fallers with PD (n = 11)	Non-Fallers with PD (n = 14)	Older Adults (n = 17)	P values
Age	69.8 (6.2)	62.7 (10.6)	66.3 (9.5)	0.26
Sex (male/female)	10/1	12/2	4/13	–
MoCA	25.8 (2.5)[b]	27.8 (1.6)	27.5 (1.7)	0.04
FoG-Q	9.1 (6.1)[b]	2.3 (2.8)	N/A	< 0.01
Number of freezers (*n*)	9	3	N/A	−0.01
Disease duration	7.5 (5.4)	5.8 (3.8)	N/A	0.43
UPDRS III	12.9 (5.3)	9.4 (3.1)	N/A	0.06
Falls over 3 months	2.6 (1.1)	–	0.2 (0.5)	–
Gait speed (m/s)	1.37 (0.12)	1.46 (0.11)	1.40 (0.10)	0.29

P values for the ANOVAs or Student *t*-tests.
[a]Different from older adults.
[b] Different from non-fallers with PD.

2.2. Experimental protocol

The motor tasks consisted of one quiet standing condition and one walking condition. Participants stood quietly for 30 s on a force platform with their feet at a comfortable width, their hands by their sides and looking straight ahead at a large landscape (3 m × 4 m) projected on a wall 15 m away for 30 s. Participants were provided with a verbal countdown from three to signify the beginning of each trial. Within the next three to five seconds, a visual cue with the word "walk" prompted participants to begin walking along a 15 m path for 30 s. The standing and walking trials were randomly presented twice.

2.3. Data acquisition and reduction

Ground reaction forces and moments were collected from one force platform (Kistler, Winterthur, Switzerland), capturing at 200 Hz. Data were then filtered with a zero-lag fourth-order Butterworth filter with a 4 Hz cut-off frequency. The time-varying position of the COP under the feet was calculated using the orthogonal forces and moments as recorded by the force platform. Fluctuations in the amplitude of the COP displacement were calculated using the root-mean-square displacement amplitude (RMSCOP) (mm). Mean velocity (VCOP) (mm/s) in both the anterior-posterior (AP) and ML directions was also calculated for each of the trials. For each condition, RMSCOP and VCOP were then averaged over the two trials.

During the walking trials, participants wore six accelerometers placed bilaterally on the wrists, ankles, lumbar spine (L5), and sternum (APDM, Oregon, USA). Data collection was performed at 128 Hz. Gait spatial-temporal characteristics, trunk range of motion (ROM), and peak trunk velocities in all 3 planes were calculated through APDM algorithms and extracted for each trial. Stride length asymmetry and arm asymmetry were calculated. Values for all variables were averaged over two trials for statistical analysis.

2.4. Statistical analyses

One-way analyses of variance (ANOVA) were used to compare age, MoCA scores between the three groups and Student *t*-test were used to determine any difference for disease duration and UPDRS III between PD. One-way ANOVAs were also used to compare trunk ROM and peak velocity in the three planes of motion as well gait speed and falls. Tukey post-hoc procedures were used for the postural and gait data. The Pearson product-moment correlation coefficient was used to measure the strength of the linear association between static (RMSCOP and VCOP) and dynamic (trunk ROM and peak velocity) postural balance. Statistical significance was set to $\alpha < 0.05$.

3. Results

3.1. Participants and gait characteristics

Age, disease duration, and gait speed were not statistically different between groups, while there were differences in the UPDRS III, FOG-Q and the occurrence of falls between groups ($p < 0.05$; Table 1).