

The effects of stooped posture on gait and postural sway in Korean patients with Parkinson's disease

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Abstract

Stooped posture, a forward trunk flexion, is a common clinical feature in patients with Parkinson's disease (PD). However, the exact etiology and effects on gait and balance are not fully understood. In the present study we evaluated the effects of stooping on gait and balance using three-dimensional motion capture and clarified the relationship between the trunk angle and impaired motor function in patients with PD. Thirty-nine patients diagnosed with PD were enrolled in our study. All participants were asked to walk a 6-m tract at their preferred speed, gait parameters and trunk flexion angle were measured using a three-dimensional motion capture system. We analyzed the correlation between trunk angle and gait parameters including gait speed, length, and center of pressure distance for postural sway. Significantly negative correlations were observed between the trunk flexion angle and gait speed ($r = -0.407, p = 0.010$) and step length ($r = -0.561, p < 0.001$). Conversely, no correlation was found between trunk flexion angle and postural sway in static standing. We found that stooped posture destabilized gait pattern and did not affect postural sway in PD. Our result showed that stooped posture may not be a compensatory action for stabilizing gait and posture, but rather a symptom of PD.

Keywords: Gait, Parkinson's disease, postural sway, stooped posture

INTRODUCTION

Postural abnormalities including stooped posture, dropped head, and scoliosis are common features in patients with Parkinson's disease (PD), and among various types of deformities, stooped posture with knee flexion is the most common.^{1,2} The underlying pathophysiology of postural deformities is unknown, although several factors including muscular rigidity, impaired proprioception, and axial dystonia may influence abnormal postures.^{3,4}

As the disease progresses, patients with PD have increased narrow stance and postural instability. Severe abnormal posture can interfere with daily activities because stooped posture often increases with fatigue, over time during the day, or when walking.^{1,5,6} Whether postural deformities are associated with gait disturbance and postural instability is unclear, although postural deformities, postural stability, and gait disturbance in patients with PD have been investigated in many studies.⁷⁻⁹

To date, the severity of postural deformities is classified in most studies based on subjective

clinical characteristics such as the score on the Unified Parkinson's Disease Rating Scale part III (UPDRS III) item 11 (posture) and the Hoehn and Yahr (H&Y) stage, but without measuring trunk angle. Therefore, in this study, trunk angles, gait parameters, and postural instability were examined using a three-dimensional motion analysis system, and the relationship between trunk angle and impaired motor function was clarified in patients with PD.

METHODS

Study design and patients

The cross-sectional study consisted of 39 consecutive patients with PD (mean height, 155 ± 17.7 cm; weight, 61.9 ± 9.0 kg) diagnosed based on the United Kingdom Parkinson's Disease Society Brain Bank criteria at the movement disorder clinic in Haeundae Paik Hospital, between November 2015 and December 2016. The exclusion criteria were other forms of parkinsonism such as vascular, atypical, or drug-induced parkinsonism. The patients with PD were classified as tremor-

dominance (TD) (n=6), postural instability and gait disorder (PIGD) type (n=26) or indeterminate (n=7) following the original classification methods developed by Jankovic *et al.*¹⁰ Three-fourths of patients (n=29) were de novo PD, so the remaining one-fourth (n=10) were receiving PD medication. We used the UPDRS III to assess the severity of disease and motor function. All participants signed a written consent form, and the study procedures were approved by the Human Research Ethics Committee of the Inje University Haeundae Paik Hospital.

Measurement of trunk angles and gait parameters

An eight-camera three-dimensional motion analysis system (VICON, Oxford, UK) was used for quantification of trunk angles and spatiotemporal parameters. In total, 19 retroreflective markers were positioned on each patient to indicate the segments. The pelvis and lower limb segments were defined by 15 markers attached bilaterally to the anterior superior iliac spine, midpoint of posterior superior iliac spine, femoral epicondyle, malleolus, second metatarsal head, and posterior calcaneus to assess the kinematics of the lower extremities. The trunk segment was defined by four markers located on the spinous process of C7, the midpoint horizontal to S1, and 1 cm away from the S1 midpoint, on both sides.¹¹ One experienced researcher attached the markers to minimize error. Prior to walking, a static trial was performed. Each patient was required to stand for 5 s and then walk at least 7 m at their preferred speed. A single-gait cycle was selected for analysis when passing over the force plates embedded at the halfway point of the walkway tract. All patients walked three times on the walkway, and three trials were averaged for data analysis.

Measurement of postural stability

Postural stability was assessed by measuring the deviation in the location of the center of pressure (COP), a single location point of the ground reaction force vector. The static standing trials were performed to measure the COP; subjects stood with feet 10 cm apart on the force plate (AMTI, Watertown, MA, USA) for 30 s with eyes open. Nexus software (version 1.7) was used to process the COP data at 1,000 Hz, because the force plate was synchronized with the motion analysis system (VICON, Oxford, UK). The COP signals used for data analysis were obtained from 20 s of the 30-s trial, excluding the first and last 5 s. The COP distances in the anteroposterior (AP)

and mediolateral (ML) directions were calculated using the following equations:

$$COP \text{ distance in AP} = \sum_{i=1}^{n-1} |AP_{i+1} - AP_i|$$

$$COP \text{ distance in ML} = \sum_{i=1}^{n-1} |ML_{i+1} - ML_i|$$

Statistical analysis

SPSS (version 18) package for Windows (SPSS, Inc., Chicago, IL, USA) was used for the statistical analyses. The relationships between trunk flexion angle and gait parameters, postural stability, and the clinical characteristics of the subjects (UPDRS III score, H&Y stage, disease duration) were examined using Pearson's correlation coefficients. The significant difference of the trunk flexion angle between TD and PIGD patients was assessed using an independent *t*-test. A *p*-value < 0.05 was considered to indicate statistical significance.

RESULTS

The mean age of the patients was 72.8 years, and the mean duration of disease was 44.49 months. The mean H&Y stage was 2.19, the mean UPDRS III score was 21.15, and the mean trunk angle was 17°. The mean COP distance in the AP and ML directions were 702.10 and 847.94cm, respectively. The mean gait speed, step length, and step width were 0.57m/s, 0.35m, and 0.18m, respectively (Table 1).

Statistically significant negative correlations were observed between the trunk flexion angle and gait speed ($r = -0.407, p = 0.010$) and step length ($r = -0.561, p < 0.001$). Statistically significant positive correlations were observed between the trunk flexion angle and UPDRS III score ($r = 0.398, p = 0.012$) and H&Y stage ($r = 0.476, p = 0.002$). The other variables were not correlated with the trunk flexion angle. Conversely, COP distance in the ML direction was correlated with COP distance in the AP direction, walking speed, step length, and severity of PD (UPDRS III score, H&Y stage, and PD medication dosage was correlated with disease duration (Table 2). There was a significant difference between subtypes in trunk flexion angle ($p = 0.001$). The mean values of TD and PIGD were 7.68° and 20.89°, respectively.

DISCUSSION

In this study, the relationships of postural deformities with gait parameters, postural stability, and PD progression, including longer disease duration, age, H&Y stage, and UPDRS III score, were evaluated. The trunk flexion angle, measured

Table 1: The truncal posture, gait stability and PD staging of the study subjects

Mean (SD) values of parameters	(N=39)
	Mean (SD)
Trunk angle in sagittal plane (°)	17.00 (16.14)
COP distance in AP (cm)	702.10 (200.77)
COP distance in ML (cm)	847.94 (247.10)
Duration (month)	44.49 (41.53)
Walking speed (m/s)	0.57 (0.21)
Step length (m)	0.35 (0.11)
Step width (m)	0.18 (0.04)
Age (years)	72.77(8.15)
UPDRS III score	21.15 (11.19)
H&Y stage	2.19 (1.02)
LED (mg)	154.44 (278.82)

COP - center of pressure; AP - anteroposterior direction; ML- mediolateral direction; UPDRS - Unified Parkinson's Disease Rating Scales; H&Y - Hoehn and Yahr stage; LED – Levodopa Equivalent Dose.

to confirm postural deformity in the sagittal plane, was significantly associated with gait parameters including walking speed and step length. Severe postural deformities have been associated with more advanced PD previously^{12,13}, which is partially in agreement with our results; in contrast, another study showed that stooped posture affected postural instability.⁷ In our study, aging, longer disease duration, and postural instability were not significantly correlated with the trunk angle.

Many patients with PD develop stooped posture, which causes difficulty in daily activities. In particular, stooping increases with fatigue during walking.¹⁻³ Patients with PD experience motor disturbances due to dysfunction of the basal ganglia–brainstem system.¹⁴ Stiffness at the hip joint caused by coactivation of muscle groups prevents adjustment of the COP translations. During forward bending of the trunk, the coordination between the lumbar spine and hip joint is important. Decreased flexion at the hip joint induces excessive lumbar flexion in patients with low back pain.¹⁵ We hypothesized that PD patients with stooped posture may be affected by stiffening of their hip joints. Stooped posture may facilitate forward walking with less energy expenditure by transferring the center of mass anteriorly and lowering the center of gravity.¹⁶ Therefore, with greater lumbar flexion angle, PD patients tend to walk with slower and shorter steps.

We found that abnormal posture was associated with disease severity based on the UPDRS III

score and H&Y stage, which is consistent with previous studies.^{8,13,17,18} However, contrary to previous studies, aging was not significantly associated with abnormal posture in our study. In most studies, the trunk angle was measured using a goniometer and an image of the subject in a standing position to distinguish the camptocormia of at least 45° trunk flexion¹⁸ or the severity of trunk anterior flexion based on UPDRS III item 11.^{8,12} In our study, the thoracolumbar flexion angle was greater than 30° in 8 of 39 patients (21%) and greater than 45° in only 4 patients. The mean age of the four subjects with camptocormia was 71.5 years, which was lower than the mean age of the overall study subjects (72.8 years). The methods of measuring trunk anterior flexion angle differ among studies; more parameters were assessed in our study, but the number of patients with camptocormia was limited. In addition, we found that there was significant difference in trunk flexion angles according to PD subtype. PIGD patients showed more stooped posture than TD patients. Vervoort *et al.*¹⁹ suggested that PIGD patients had more gait and distal motor impairment compared to TD patients.

In our study, no significant relationship was observed between trunk flexion angle and postural sway during static standing. This result is in accordance with the study by Jacobs *et al.*,⁷ who reported that stooped posture in patients with PD is associated with a destabilizing effect but were unable to conclude that stooping alone causes the instability in PD patients. A dual postural control

Table 2: The correlation between trunk angle, postural sway, gait parameters, and patients' characteristics in people with PD (N=39)

	Trunk angle	COP in AP	COP in ML	Duration	Walking speed	Step length	Step width	Age	UPDRS III	H&Y
COP in AP	0.100									
COP in ML	0.246	0.909*								
Duration	0.263	0.154	0.192							
Walking speed	-0.407*	-0.438**	-0.487**	0.011						
Step length	-0.561**	-0.452**	-0.494**	-0.054	0.928**					
Step width	0.056	-0.064	0.004	-0.236	-0.151	-0.173				
Age	0.067	0.254	0.301	0.168	0.014	-0.073	0.272			
UPDRS III	0.398*	0.316	0.380*	0.038	-0.594**	-0.584**	0.141	-0.253		
H&Y	0.476**	0.395*	0.438**	0.372*	-0.492**	-0.569**	0.164	-0.028	0.539**	
LED	0.119	0.044	0.107	0.337*	0.074	-0.038	0.215	0.242	0.060	0.254

COP – center of pressure; AP – anteroposterior direction; ML – mediolateral direction; UPDRS – Unified Parkinson's Disease Rating Scales; H&Y – Hoehn and Yahr stage. LED – Levodopa Equivalent Dose. * $p < 0.05$, ** $p < 0.01$.

system manages body orientation and stabilization by operating interactively.²⁰ Stooped posture may be a response to compensate for postural instability and control stability by abandoning the center of mass position.²¹ However, the voluntary upright posture of PD patients resulted in more instability.²²

This study had several limitations. First, our sample size was too small compared with previous studies and hence, generalizing our results to all patients with PD is difficult. In addition, our subjects with heavy representation of de novo PD may restrict to explain the effect of medication. Therefore, studies with larger sample sizes and are needed in the future. Second, only the anterior flexion angle of the thoracolumbar spine was measured. Postural disorders in PD patients include Pisa syndrome as a form of lateral flexion of the trunk, dropped head, and bent knee, in addition to anterior flexion of the trunk. Finally, in our study we focused on the relationships between postural deformities and motor dysfunction in PD patients. Therefore, the relationship between trunk flexion angle and non-motor dysfunction, such as executive dysfunction and sleep disorders, should be investigated in future studies.

In conclusion, in the present study, the relationships between trunk posture in the sagittal plane and gait parameters, postural sway, and severity of disease were assessed. Our results suggest that increased stooped posture in patients with PD is significantly associated with a shorter step and slower walking speed.

DISCLOSURE

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Conflict of interest: None.

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