

The effect of lateral wedge on postural sway in Parkinson's disease

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Background: Although postural instability is one of the major symptoms of Parkinson's disease (PD), dopaminergic treatment is ineffective for treating postural instability. Recent reports have shown that somatosensory deficit is associated with postural instability, and that somatosensory input improved postural instability. The purpose of this study is to evaluate the effects of lateral wedges for quiet standing postural control in people with PD.

Methods: Twenty-two patients who were diagnosed with PD were enrolled in this study. The participants stood on a force plate under two conditions (wedge and no wedge) with or without having their eyes open or closed. The center of pressure (COP) range and velocity were analyzed using a two-way repeated-measures analysis of variance.

Results: The range and velocity of COP in the anteroposterior and mediolateral (ML) directions were significantly improved after the patients stood on the lateral wedge with their eyes closed ($p < 0.05$). The range in ML direction and velocity in both directions of COP were significantly decreased when their eyes were open ($p < 0.05$).

Conclusions: Regardless of vision, standing on lateral wedges improved postural sway in people with PD.

Key words: Parkinson's disease; Rehabilitation; Posture

INTRODUCTION

Postural instability is a common and major characteristic of Parkinson's disease (PD). People with postural instability are at risk of losing their abilities to live independently, and to walk; further, these symptoms can affect their quality of life as the disease progresses.¹ Previous studies have shown that people with PD display increased postural sway and impairment in mediolateral postural stability compared with elderly people who do not have PD.²

Much evidence supports a strong relationship between decreased somatosensory and poor postural stability in PD.³ Recent reports have proven that the additional somatosen-

sory information from the feet has a positive effect on balance control.^{4,5} Furthermore, various types of foot wedges that increase the stiffness of the ankle joint could generate the desired passive stiffness.⁶ Based on this evidence, applications of wedges under the feet have been widely used to adjust the normal position and balance control.

Walking backward with raised heels in PD could prevent falling, and standing on a medial or lateral wedge in healthy young people could improve postural stability in healthy people.⁷ However, little research exists which investigates the effects of foot wedges on balance control in people with PD. The purpose of this study is to clarify whether lateral wedges under the feet can improve postural control during quiet standing in people with PD. We postulated that wedges under the lateral sides of the feet would improve postural instability in PD.

MATERIALS AND METHODS

Study participants

Twenty-two patients who were clinically diagnosed with PD were recruited for this study. The sample size was set based on a previous study.⁷

Inclusion criteria were as follows: (1) patients clinically diagnosed with PD⁸; (2) patients who suffer from gait disturbance, including tremor-dominant and PIGD (postural instability and gait disturbance) type; (3) patients between the ages of 50 and 80. The exclusionary criteria were as follows: (1) patients with severe disability above 4 on the Hoehn and Yahr staging scale; and (2) patients with orthopedic problems and other neurological diseases that affect balance control.

Clinical assessment

Basic demographic factors, including disease duration, were obtained from interviews with participants. The modified Hoehn and Yahr scale and part III of the Unified Parkinson's Disease Rating Scale (UPDRS) were used for estimating disease severity and motor function. All participants underwent a procedure of taking dopaminergic medicine that was clinically in the "on" state which was taking medicine. We calculated the levodopa equivalence dosage for dopaminergic treatment. All study procedures were approved by the Hu-

man Research Ethics Committee of the Inje University Haeundae Paik Hospital, and the participants signed a written consent form.

Procedures

Subjects were asked to stand barefooted on the force platform (AMTI, Watertown, MA, USA) with their feet 10 cm apart. Ganesan et al demonstrated that the 10° lateral wedge improved postural stability in healthy controls⁷, and Stylianou et al. found that postural sway in PD was affected by the conditions of standing with eyes open and with eyes closed.⁹ Therefore, quiet standing was performed under the following four conditions: (1) no wedges with eyes open; (2) no wedges with eyes closed; (3) on 10° lateral wedges with eyes open; and (4) on 10° lateral wedges with eyes closed (Fig. 1). The wedges made based on the prior study were placed on the force platform.

The order of conditions was randomized to obviate any learned effects. Body sway was assessed by measuring the deviation in the location of the center of pressure (COP). COP refers to the point where the pressure of the body over the soles would be if it were concentrated in one spot. COP data recorded at 1,000 Hz were measured for 30 s during quiet standing.^{1,10} The primary endpoint is to compare the range and velocity of COP between standing with and without the wedge. The secondary endpoint is to compare the same parameters when a patient's eyes were closed.

Data analysis

All data were processed using Nexus software (version 1.7; VICON, Oxford, UK), because the force platform was synchronized with a motion analysis system (VICON, Oxford, UK).

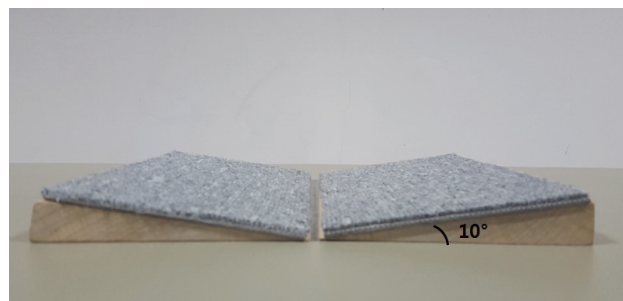


Fig. 1. Lateral wedges. Participants stood on flat surface and with lateral wedges at 10 degrees in forced platform, which can measure the center of pressure.

COP data were filtered using second-order Butterworth filters with 20 Hz low-pass. The 20 seconds of the signals for at least 30 seconds, except for the first and last 5-seconds was used for the data analysis. The range of COP excursion (maximum distance between any two points) and mean COP velocity in the anteroposterior (AP) and mediolateral (ML) direction were calculated using the following equations.

$$COP\ displacement\ range = |\max(COP) - \min(COP)|$$

$$COP\ velocity = \frac{\sum_{n=1}^N |COP[n+1] - COP[n]|}{T} \quad (N = 20,000\ (number\ of\ data); T = 20\ (period\ of\ time))$$

Statistical analysis

The SAS software package (version 9.1, Cary, NC, USA) was used to perform the statistical analysis. The outcome measures of the wedge and vision were compared using a two-way repeated measure ANOVAs. When interactions were not found, the main effects of the lateral wedge were reported, and a paired *t*-test was performed to confirm which vision or wedge differences existed. The level of significance was set at *p* < 0.05.

RESULTS

Table 1 shows the demographic factors in the participants. Two-way analysis of variance (ANOVA) showed that the COP velocity and range on the plane surface and lateral wedge in the eyes open (EO) and eyes closed (EC) conditions are

Table 1. Participant's demographic data

	PD (n = 22)
Age (years)	70.1 (10.4)
Gender	12 males/10 females
Height (cm)	160.4 (11.8)
Mass (kg)	64.0 (12.1)
BMI (kg/m ²)	24.7 (2.4)
Modified H&Y scale	1.8 (0.8)
UPDRS III	17.3 (6.4)

Values are presented as mean (SD) unless otherwise indicated. PD, Parkinson's disease; BMI, body mass index; H&Y, Hoehn and Yahr; UPDRS, Unified Parkinson's Disease Rating Scale.

shown in Table 2. Standing on the lateral wedges significantly decreased the COP velocities in AP (*p* < 0.05) and ML directions (*p* < 0.05), and the COP range in the ML direction (*p* < 0.05). When eye open, the COP velocity significantly decreased in the ML direction (*p* < 0.05). A significant wedge-by-vision interaction was not found in all conditions (*p* > 0.05) (Table 2).

DISCUSSION

The primary aim of the study was to clarify the effect of lateral wedges on postural sway during quiet standing in people with PD. Our results demonstrated that standing on the lateral wedges could improve postural stability. In particular, when vision was absent or in the ML direction, the effect of the lateral wedges was more prominent.

Although the exact mechanism of our results cannot be fully understood, several possible explanations can be deduced based on previous researches. The first possible explanation of our results is that increased postural instability was associated with higher co-activation of the ankle muscles. While standing quietly, patients with PD have been reported to have an increase in tibialis anterior and soleus muscle activity compared to the controls, and to show higher postural sway.¹¹ Lang et al. reported that intrinsic and reflex ankle stiffness were modulated by postural sway and is related to balance control.¹² We postulated passive ankle stiffness induced by lateral wedge might be contributed to reduced postural sway.

Another possible hypothesis is that standing on the wedges may play a role as a somatosensory cueing that affects postural instability. Patients with PD receive reduced somatosensory information from deteriorated peripheral receptors.¹³ It is well established that cueing, including auditory, visual and somatosensory cueing, improves the gait in patients with PD.¹⁴ Other studies have shown that vibration devices and textured insoles were effective in improving postural instability in patients with PD.¹⁰ Altogether, we consider that the foot position changed by a lateral wedge may alter compensatory muscle activation and proprioceptive properties.

Our results were consistent with previous studies by Ganesan et al. who examined healthy people standing on

Table 2. Comparison of the center of pressure based on variables in the experimental conditions

Direction	Parameters	No wedge		Wedge		p-value		
		Eyes open	Eyes closed	Eyes open	Eyes closed	Wedge	Vision	Interaction
AP direction	Range (cm)	3.17 (1.46)	3.51 (1.66)	3.32 (1.91)	3.27 (1.67)	0.805	0.627	0.264
	Velocity (cm/s)	37.07 (9.73)	36.52 (9.46)	34.52 (8.35)	33.92 (7.89)	0.002 ^a	0.059	0.925
ML direction	Range (cm)	2.47 (1.56)	2.68 (1.78)	2.05 (1.26)	2.10 (1.89)	0.002 ^a	0.529	0.559
	Velocity (cm/s)	42.71 (9.03)	43.53 (10.11)	41.67 (8.47)	41.89 (8.13)	0.008 ^a	0.026 ^a	0.232

Values are presented as mean (SD). Wedge-*p*-value < 0.05 means that there is a statistically significant difference between with and without wedge regardless of the vision. Vision-*p*-value < 0.05 means that there is a statistically significant difference between eye open and closed. Interaction-*p*-value < 0.05 means that there is a statistically significant difference between with and without wedge, eye open and closed.

AP, antero-posterior; ML, mediolateral.

^a*p* < 0.05.

lateral or medial wedges⁷, and Ushio et al. who argued that wearing wedge shoes could ameliorate unsteadiness in patients with insufficient vestibular compensation.¹⁵

In our results, the COP velocity and range were decreased in the ML direction, although only the COP velocity was decreased in the AP direction. People with PD have a tendency to be more rigid in the ML direction and more flexible in the AP direction.¹⁶ Wedges under the feet may influence the joint angle at the pelvis and trunk area as well as the lower limb because various joints interplay and compensate for each other to maintain posture.¹⁷ Standing on the lateral wedges may affect the position in the coronal plane as well, which would change the ML postural sway. Such patients may adopt a stabilizing strategy at the hip level to regain their lateral equilibrium.¹⁸

Patients with PD depend more on visual information; therefore, they have difficulty using their proprioceptive information to control postural sway when their vision is obscured.¹⁹ When patients closed their eyes and stood without a wedge, COP velocity was increased in the ML direction. However, there were no significant differences of COP velocity in the AP direction or the COP range in both directions when the eyes were closed. These findings are consistent with previous studies reporting that increased ML sway with eyes closed is characteristic of PD.¹¹

Our study had some limitations. First, we did not measure the activity of the ankle muscles during standing. It is difficult to know whether the muscles are controlled or not. Second, it was measured only in static standing without dynamic intervention and only the short-term effect was evaluated in this study; hence, we did not confirm dynamic balance and

long-term effects. Third, we did not access the kinematic data of trunk, pelvis, hip, knee, and ankle joints; therefore we are necessarily limited in our explanation of changes in the joints during the standing time on the lateral wedge. Further studies are needed to evaluate the kinematic data including the ankle muscle activity while performing functional activities.

Standing on lateral wedges significantly decreased postural sway in the ML and AP directions in people with PD. Thus, lateral wedges under the feet may be a useful tool in rehabilitation of balance in people with PD. Further study of continuous lateral wedge use for long-term rehabilitation, such as in shoe insoles, is needed.

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Conflicts of Interest

The authors have no conflicts to disclose.

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