

Original Article

## Effect of spinal kypho-orthosis to gait and forward flexion in Parkinson disease

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**Abstract.** [Purpose] The gait characteristics, such as short step, decreased arm swing and stooped posture, in Parkinson disease (PD) are well established. Pharmacological and non-pharmacological treatments have been attempted to improve the gait in patients with PD. Among the non-pharmacological approaches to improve gait, spinal orthosis can be applied for patients with spinal deformity. The purpose of our study was to investigate the effect of spinal kypho-orthosis to gait in PD by using a three-dimensional analysis. [Participants and Methods] Twenty-six patients with PD with gait disturbance with forward bend posture  $>15^\circ$ . All participants were instructed to walk along a 6-m track and turn  $180^\circ$  and come back to the starting point under three-dimensional motion capture. The participants performed the test again with spinal kypho-orthosis. Gait parameters during examination is compared with and without spinal kypho-orthosis. The degree of forward flexion after kypho-orthosis in patients with PD was compared. [Results] Wearing the spinal kypho-orthosis significantly improved turning performance but did not affect locomotion. The severity of forward bend posture is mildly improved after the application of spinal kypho-orthosis. [Conclusion] Spinal kypho-orthosis has a short-term effect for gait performance, particularly during turning and erect posture. Spinal kypho-orthosis can be potentially used for management of turning deficits in PD.

**Key words:** Parkinson disease, Orthotic device, Gait disorder

(This article was submitted Mar. 17, 2018, and was accepted May 7, 2018)

### INTRODUCTION

Gait disturbance is a major symptom of Parkinson disease (PD) and greatly contributes to the quality of life. The gait pattern in PD is characterized by 1) stooped posture, 2) short-step gait, and 3) shuffling gait<sup>1)</sup>. Patients with PD complained of difficulty in adaptation to change situation, such as turning, starting, and walking with dual tasks than walking forward. Freezing of gait, which is a representative gait pattern in PD, also occurs<sup>2)</sup>. In addition to Freezing of gait (FOG), many patients with PD have difficulty in turning even without FOG. Interestingly, turning deficits are presented in patients with early PD who did not alter walking forward<sup>3)</sup>.

Many treatments to improve gait, including pharmacological and non-pharmacological interventions, have been tried. Many studies demonstrated that L-dopa improves stride length and walking speed, as well as off freezing<sup>4-6)</sup>. However, the effect of L-dopa to gait was inconsistent in some reports. The effect of Deep brain stimulation targeted to subthalamic

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nucleus did not improve gait disturbance, such as stride length and gait velocity<sup>7</sup>). In sum, many aspects of gait are not adequately addressed by medication and surgery. Emerging managements for improving gait in PD has been an interest in physical rehabilitation<sup>8</sup>). Treadmill training and external cueing significantly improved gait parameters. Assistance devices and rehabilitation training have a positive effect to gait and balance<sup>9</sup>).

Wearing orthosis immediately affecting mechanical work of walking and posture has been of great interest<sup>10</sup>). Spinal orthosis also proved to improve balance and prevent falling, as well as correcting posture in patients with thoracic kyphosis<sup>11</sup>). In PD, spinal brace for hyperextension was effective in camptocormia<sup>12</sup>). Preliminary reports showed that orthosis improved balance and quality of life in PD<sup>13</sup>). However, the effect of kypho-orthosis for gait performance has not been reported.

The hypothesis of this study was that spinal kypho-orthosis has a positive effect to gait pattern and posture in patients with PD, similar to other orthopedic diseases, particular in regard to gait changes during locomotion and turning. The purpose of our study was to investigate the effect of kypho-orthosis to gait and posture by comparing the gait parameters and posture with and without spinal kypho-orthosis by using three-dimensional motion capture.

## PARTICIPANTS AND METHODS

This study was an open-label, cross-sectional study. The patients were instructed to walk on a 6-m track and return to the starting point after a 180° turn. Participants with spinal kypho-orthosis performed walked and turned using the same method. To reduce bias from fatigue, the order of test was randomly assigned. The time interval between the two conditions was 5 min. All participants performed the examination under clinical “on state.” The primary endpoint was to compare gait parameters, including step length, walking speed, turn time, and step number when turning between the two conditions. The secondary endpoint was to compare the degree of forward bend between participants with and without lumbar kypho-orthosis. MedCalc (ver 17.1, MedCalc Software, Belgium) was used for statistical data analysis. If variables were normally distributed, the paired t-test was conducted to compare stooped posture and gait parameters in participants with lumbar and without spinal kypho-orthosis.

Twenty-six patients with PD who visited the movement clinic in our hospital from March 2014 to December 2016 were enrolled. Inclusion criteria were as follows: (1) patients with PD who complained of gait disturbance; (2) patients with PD shown to have forward flexion over 15° in sagittal plane by using three-dimensional motion capture; and (3) Hoehn and Yahr stages 2 and 3. Exclusion criteria were as follows: (1) patients with spinal deformity and other spinal diseases; (2) patients with orthopedic or other neurological diseases that affect gait and posture; (3) patients with a risk for falling; (4) patients with episodic gait disorder, including freezing of gait or festination that affects turning performance.

Basic demographic data, including age, gender, height, and weight were obtained. For disease severity, unified Parkinson’s disease rating scale (UPDRS) motor scale and Hoehn and Yahr staging were used. The study was approved by the institutional review board at the Haeundae Paik Hospital (Busan, Korea, IRB file No 2017-01-028). All patients understood the study procedure and purpose, and they provided written informed consent before participation.

Postural deformity and gait parameters were measured by using a three-dimensional motion capture system (VICON, Oxford, UK). Nineteen reflective marks were attached on anatomical landmarks. The spine segment was defined with four markers located on the C7 and S1, and two dimples of Venus, horizontally to S1 for postural deformity. The pelvis and leg segments were defined with 15 markers located on the bilateral anterior superior iliac spines and the midpoint of the posterior superior iliac spine; bilateral lateral thighs; femoral epicondyles; lateral shin; and malleolus; second metatarsal heads; and posterior calcaneus for gait parameters. Postural deformity was measured based on the angle between the vertical and virtual lines connecting the two marks (C7 and S1). Cervical flexion, such as ante- or retrocollis, was not considered. Postural deformity was defined as stooped posture >15° based on the vertical line.

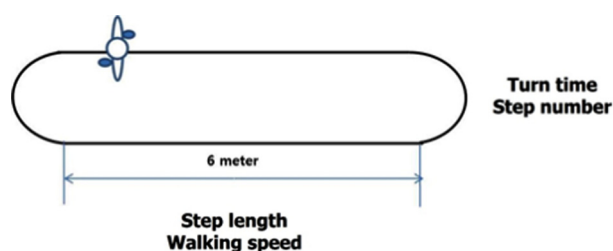
Gait parameters were divided into two components (locomotion and turning). Gait parameters for locomotion include step length and walking speed. To estimate turning, time and step number were checked clinically. A neurologist with clinical experience and a technician who performed three-dimension motion capture checked turning time and step number (Fig. 1).

Spinal kypho-orthosis was prepared with posterior back based on previous reports<sup>11</sup>). The spinal kypho-orthosis is 20 cm in length and 10 cm in width, made with a 1-kg weight pouch, which centers its weight on the posterior of the thoracic spine at T2–T10. To fix the device to the body, spinal kypho-orthosis is placed under the shoulder and waist with the ring-shaped rack (Fig. 2). The shape, weight, and location of the kypho-orthosis was determined based on previous reports suggesting that training with weighted kypho-orthosis (WKO) improved balance in women with osteoporosis<sup>14</sup>).

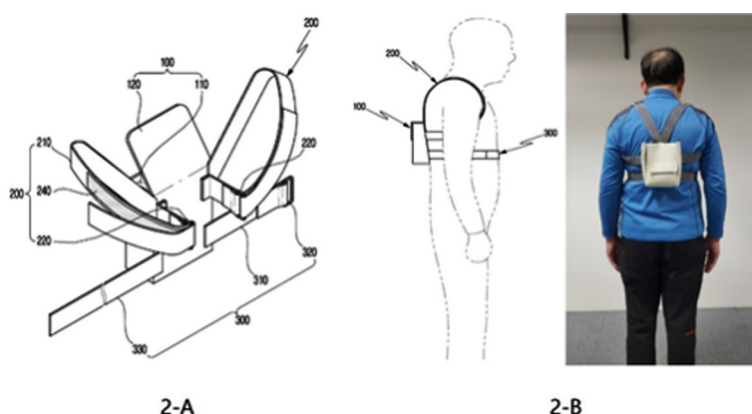
## RESULTS

Table 1 shows the basic demographic data. The mean UPDRS motor scale and Hoehn and Yahr staging were  $20.7 \pm 9.7$  and  $2.0 \pm 0.6$ , respectively. The mean disease duration was  $22.8 \pm 22.3$ .

Table 2 shows the final results. Forward flexion was significantly improved after using spinal kypho-orthosis ( $24.24 \pm 13.36$  vs.  $23.21 \pm 12.46$ ,  $p < 0.01$ ). However, no differences were found in gait parameters for walking forward, including step length and walking speed, with spinal kypho-orthosis. However, turning time ( $2.78 \pm 0.89$  vs.  $2.35 \pm 0.70$ ,  $p < 0.01$ ) and step number ( $5.38 \pm 1.55$  vs.  $4.80 \pm 1.02$ ,  $p < 0.001$ ) when turning were significantly decreased after using spinal kypho-orthosis.



**Fig. 1.** Track of walking performance, including locomotion and turning.



**Fig. 2.** Spinal kypho-orthosis (Fig. 2A) and participant in sagittal view, wearing spinal kypho-orthotic device (Fig. 2B).

**Table 1.** Demographic data in participants

	PD (n=26) mean ± SD
Age (years)	73.9 ± 8.2
Gender	5 Males/21 Females
Height (cm)	153.4 ± 7.8
Mass (kg)	57.7 ± 8.9
BMI (kg/m <sup>2</sup> )	24.5 ± 2.9
Duration (months)	22.8 ± 22.3
H&Y scale	2.0 ± 0.6
UPDRS III	20.7 ± 9.7

**Table 2.** The effect on gait and posture wearing orthosis

	Without orthosis	With orthosis
Trunk angle (°)	24.24 ± 13.36	23.21 ± 12.46*
Walking		
Stride length (m)	0.37 ± 0.15	0.36 ± 0.13
Walking speed (m/s)	0.59 ± 0.20	0.59 ± 0.19
Turning		
Turn time (sec)	2.78 ± 0.89	2.35 ± 0.70*
Step number	5.38 ± 1.55	4.80 ± 1.02**

\*p<0.01, \*\*p<0.001.

Spinal kypho-orthosis improved forward flexion and turning performance, including turn time and step number.

In three-dimensional motion capture, forward flexion significantly improved (0.9°) in the sagittal plane.

## DISCUSSION

Spinal kypho-orthosis dramatically improved turning time and step number in patients with PD. Despite a minimal change of >1°, kypho-orthosis also significantly straightened forward flexion. However, unlike our expectation, gait parameters for locomotion, including step length and walking speed, were not associated with spinal kypho-orthosis. The results are in accordance with the previous report that kyphosis due to osteoporosis had a significant negative correlation with gait performance<sup>15</sup>). Our results investigated the immediate effect of spinal orthosis, and not by exercise or physical training. Therefore, this effect might be caused by altering biomechanical or neurological process of gait and posture than muscle strength.

Turning difficulty is an apparent symptom in PD, and dopaminergic medication has a positive effect on turning<sup>16</sup>). Various etiologies can cause turning difficulty, including axial rigidity, inter-limb coordination, and asymmetry in PD. The exact mechanisms of the results are not fully investigated, and several hypotheses can be proposed.

First, straightening of the forward flexion by kypho-orthosis might affect gait performance although with minimal change. Forward bend posture with mild to moderate truncal flexion, called stooped posture, is a common form of postural deformity in PD. Little et al. investigated the effect of axial loading for back-to-coronal spinal deformity in idiopathic scoliosis<sup>17</sup>. Recently, backpack treatment weighing 6 kg for camptocormia, which is forward flexion >45° in sagittal plane, was introduced; it is simpler and more convenient than other physiotherapies<sup>18</sup>.

Whether stooping is a characteristic of the disease or a compensatory response to postural instability is controversial. A previous report proved that locomotion and bend posture highly interact with each other based on neurophysiologic data<sup>19</sup>. Based on this study, the target of therapeutic model or rehabilitation for PD has been changed from isolated component to complex coupling, including gait and posture<sup>20</sup>.

Time of timed up-and-go test, which can measure standing, gait and turning, was increased for every 5° of forward flexion<sup>21</sup>. Turning performance comprises a combination of spinal rotation and foot movement. The changes in segmental spinal range of motion are associated with postural instability while turning in healthy elderly people. Foot movements act as compensation for these changes by maintaining balance<sup>22</sup>. The closer the body mass is to the rotation axis, the lesser the angular momentum, which can lead to increased angular velocity<sup>23</sup>. Based on these previous reports, we postulated that straightening the posture with spinal kypho-orthosis may be altered by combining spinal and foot movement consequently.

Another hypothesis is that spinal orthosis directly affects turning performance as a tactile sensory cueing. Visual or vibration cueing has been well known to improve gait in patients with and without PD<sup>24</sup>. Impaired proprioceptive integration of sensory stimuli is also the contributing factor for gait and postural deformity. Previous reports demonstrated that tactile cueing improved gait in patients with PD<sup>25</sup>. Kinesio-taping, which act as an external sensory cue, also improved posture in patients with PD<sup>26</sup>.

This study has several limitations. First, the effect of the degree of straightening stooped posture has minimal clinical significance. The difference in the angle of forward flexion is approximately 1°, which might be because weight bearing on orthosis is only 1 kg. Various weight changes would be necessary for future studies. Second, the long-term effect of spinal kypho-orthosis was not investigated. The time duration for wearing the spinal kypho-orthotic device was only a few minutes, and the adaptation or fatigue caused by spinal kypho-orthosis could not be assessed. Third, the effect of spinal kypho-orthosis in age-matched healthy controls was not investigated.

In conclusion, spinal kypho-orthosis improved forward flexion and gait turning in patients with PD. However, our findings indicate that erect posture was not associated with locomotion but was associated with turning. Spinal kypho-orthosis can be potentially used in gait rehabilitation in patients with PD, particularly for turning. Future studies for long-term monitoring of spinal kypho-orthosis are necessary.

### Funding

This work was funded by a grant from Specialization project in Inje University 2016.

### Conflict of interests

All authors declare that there is no conflict of interest regarding the publication of this paper.

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