

# Effect of Muscle Vibration on Spatiotemporal Gait Parameters in Patients with Parkinson's Disease

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**Abstract.** [Purpose] The purpose of this study was to investigate the effect of muscle vibration in the lower extremities in patients with Parkinson's disease (PD) during walking. [Subjects] Nine patients with PD participated in this study and were tested with and without vibration (vibration at 60 Hz). [Methods] Eight oscillators of vibration were attached to the muscle bellies (tibialis anterior, gastrocnemius, biceps femoris, and rectus femoris) on both sides of the lower extremities with adhesive tape in this study. Spatiotemporal gait parameters were measured using a motion analysis system. [Results] Stride length and walking speed with vibration were significantly increased compared with those without vibration in PD patients. [Conclusion] These results suggest that the application of vibration to lower extremity muscles in patients with PD may improve the parkinsonian gait pattern.

**Key words:** Parkinson's disease, Muscle vibration, Spatiotemporal gait parameter

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## INTRODUCTION

Parkinson's disease (PD) was first known as shaking palsy, a term coined in 1817 by James Parkinson. It is a progressive neurologic disturbance in which the incidence rate increases with age<sup>1)</sup>. PD is associated with degeneration of the substantia nigra dopaminergic neurons<sup>2)</sup>. When approximately 60–80% of the dopamine produced by the substantia nigra dopaminergic neurons has been lost, the extrapyramidal system can no longer effectively promote movements, and the symptoms of PD appear. The clinical symptoms include hypokinesia, bradykinesia, postural instability, rigidity, and tremor<sup>3)</sup>.

Many changes also appear in the gait of patients with PD. The gait of patients with PD is characterized by reduced gait speed and short steps, improper trunk rotation or arm swings, difficulties in changes of direction, shuffling gait pattern, or acceleration gait pattern<sup>4)</sup>.

Many studies have been conducted on the gait of patients with PD. To improve the gait of patients with PD, re-

search into signals began in 1942<sup>5)</sup>, and gait analysis was conducted in relation to external cues in 1967<sup>6)</sup>. Until recently, research into the effects of methods using external cues has been conducted for various methods of improving gait in PD patients<sup>1, 7–9)</sup>. In their reviews of the gaits of PD patients with application of external cues, Rubinstein et al.<sup>10)</sup> and Darmon et al.<sup>11)</sup> advised that external cues could significantly improve the gaits of patients with PD or their gait-related activities. As external information in the form of visual or auditory cues is known to improve motor performance and motor learning<sup>12, 13)</sup>, most studies on motor learning have generally used feedback such as training with visual or auditory cues.

Recently, studies have been conducted on the use of feedback such as vibration stimuli. Haridas and Zehr<sup>14)</sup> reported that the sensory feedback during gait provided by stimuli through the skin caused reflex activities during upper and lower extremity movements and affected the activity of the central pattern generator (CPG). When applied to the muscles, vibration acts as powerful proprioceptive stimulus, strongly affecting the motion perception of not only healthy people but also patients with various neurological disorders<sup>15)</sup>. In a spatiotemporal exploratory study of three patients with left unilateral neglect, when work was performed while vibration stimuli were applied to the muscles, the subjects detected remarkably more objects<sup>16)</sup>. Sorensen et al.<sup>17)</sup> found that vibration stimuli applied to the ankles played an important role in controlling posture and balance

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**Table 1.** Comparison of spatiotemporal parameters between with and without vibration in patients with PD

Variable	Without vibration	With vibration
Cadence (steps/min)	110.2 (9.6)	111.6 (10.4)
Stride length (cm)	110.0 (15.1)	114.0 (14.5) *
Step length (cm)	55.7 (7.3)	58.1 (6.9)
Step width (cm)	11.5 (1.8)	10.9 (1.6)
Walking speed (cm/sec)	101.7 (15.7)	107.1 (17.3) *
Single support time (% cycle)	61.6 (1.8)	60.5 (1.8)
Double support time (% cycle)	11.7 (3.0)	11.1 (1.4)

\*Significant difference between with and without vibration ( $p < 0.05$ )

during gait because the stimuli caused the lower extremity to provide information about the movement of the center of gravity to the central nervous system.

By reviewing previous studies related to improvement of the gait of patients with PD, it can be seen that studies on motion perception or vibration stimuli are insufficient, although many studies have been conducted on the dependency on external cues in many approaches for improving motor control or gait ability in patients with PD. Therefore, the purpose of this study was to compare temporal and spatial gait parameters while applying vibration in patients with PD.

## SUBJECTS AND METHODS

Nine PD patients participated in this study. The subjects had an average age of  $61.82 \pm 5.57$ , an average height of  $155.36 \pm 3.71$  cm, and an average weight of  $60.15 \pm 4.38$  kg. Approval for the study was obtained from the institutional review board of the National Evidence-based Healthcare Collaborating Agency, and written informed consent was obtained from each patient before starting the study.

Eight vibrators (10 g, diameter of 1 cm) were made especially for this study. They were attached to the muscle bellies (tibialis anterior, gastrocnemius, biceps femoris, and rectus femoris) on both sides of the lower extremities of the subjects. The subjects wore short pants to minimize external stimuli, and were barefoot. To identify the effects of vibration stimuli during walking, subjects were tested with respect to spatiotemporal gait parameters with and without vibration in both lower extremities using a motion analysis system. A Hawk Digital System (60 Hz, Motion Analysis, Santa Rosa, CA, USA) was used to measure the spatiotemporal parameters during walking. The amplified motion analysis signals were sampled online with the EVaRT 5.0 software and were analyzed using the Cortex 64 and OrthoTrak 6.6.4 software. The Wilcoxon signed-rank test was performed to identify the differences in spatiotemporal parameters between with and without vibration. Significance was accepted for values of  $p < 0.05$ .

## RESULTS

Comparison between the spatiotemporal gait parameters with and without vibration in PD patients revealed that stride

length and walking speed with vibration were significantly increased compared with those without vibration ( $p < 0.05$ ). Although the other parameters were also improved, there were no statistically significant differences (Table 1).

## DISCUSSION

PD is a progressive degenerative neuronal disease occurring because of a deficiency in the dopaminergic neurons in the basal ganglia. Patients with PD show movement impairment symptoms such as bradykinesia, tremor, rigidity, and impaired balance<sup>18</sup>, and these symptoms cause changes in their gaits. Many studies on PD patients' spatiotemporal gait variables have reported that their gait patterns showed a short stride length and low walking speed<sup>3, 19, 20</sup>.

Vibration stimuli act as powerful proprioceptive stimuli that strongly affect motion perception in patients with neurological disorders<sup>15</sup> and, in particular, can cause changes in the motor control patterns of patients with damage to their basal ganglia<sup>21</sup>. Because the basal ganglia serve as a motor control function in making sequential movements, if they are not properly controlled, movements will become slower and muscle activities will decrease<sup>22</sup>. Muscle stimuli overcome the suppression of the thalamus, which plays an important role as a gateway and acts as an integration between the cerebral cortex and subcortical signals, although only for a short time, and induce thalamocortical activation, thereby improving visual perception and processing speed<sup>23</sup>.

In this study, when vibration stimuli were applied to improve the gaits of patients with PD, their stride lengths and walking speeds significantly increased. Given this, application of the vibration stimuli to patients with PD having damaged basal ganglia seemed to cause the patients' motor control patterns to improve, thus improving the gait patterns of the patients who had shown short stride lengths and low walking speeds.

Previous studies also reported that when feedback was not properly provided, movements decreased gradually<sup>24</sup>. As feedback, either external information in the form of visual or auditory cues known to improve motor performance and motor learning or vibration stimuli that stimulate proprioception to improve motor perception are used. Rubinstein et al.<sup>10</sup> noted that visual cues were one of most effective methods for stride length adjustment, and Lim et al.<sup>1</sup>

stated that the application of auditory cues was effective for improving walking speed. Vibration stimuli that brought about increases in PD patients' stride lengths and walking speeds are an effective method, like visual or auditory cues, which are known to be an effective method for improving gait in patients with PD. Therefore, vibration stimuli can be said to be a type of feedback suitable for gait training or research intended to improve the gait of patients with PD.

Because this study was conducted in patients with PD at levels 1.5–2.5 of Hoehn and Yahr's scale, the results of this study cannot be generalized to all patients with PD; however, they do suggest that application of vibration stimuli to the lower extremities can help functional ability during gait in patients with Parkinson's disease.

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