

Original Article

# Kinematic analysis of arm and trunk movements in the gait of Parkinson's disease patients based on external signals

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**Abstract.** [Purpose] To investigate the role of external cues on arm swing amplitude and trunk rotation in Parkinson's disease. [Subjects and Methods] The subjects were 13 elderly patients with Parkinson's disease. Subjects walked under four different conditions in a random order: no cue, visual cue, auditory cue, and combined cue. The auditory cue velocity consisted of a metronome beat 20% greater than the subject's general gait speed. For the visual cue condition, bright yellow colored strips of tape placed on the floor at intervals equal to 40% of each subject's height. A motion analysis system was used to measure arm swing amplitude and trunk rotation during walking. [Results] There was a significant difference in the kinematic variables (arm swing amplitude) between different cues, but there was not a significant difference in the kinematic variables with respect to the trunk rotation. [Conclusion] The findings of this study indicate that patients with Parkinson's disease are likely to focus attention on auditory cues. The measurement of arm and trunk kinematics during gait by auditory cues can increase the available methods for the analysis of complex motor programs in movement disorders.

**Key words:** Parkinson's disease, External cue, Arm swing

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## INTRODUCTION

Parkinson's disease (PD) is caused by dopamine deficiency in the basal ganglia, and patients with this condition have difficulty with sensorimotor integration<sup>1)</sup>. PD is characterized by motor disorder symptoms such as bradykinesia (slowed movement), akinesia (delay in the start of movement), tremor, ankylosis, and balance disorders<sup>2)</sup>.

The improvement of gait in patients with PD using signals has been reported since 1942<sup>3)</sup>. Gait analysis in PD based on external signals was first conducted in 1967 by Martin<sup>4)</sup>. Studies have been conducted on the effects of external signals, one of the many possible approaches for the improvement of gait in PD<sup>5-8)</sup>. The application of external signals induces temporal and spatial stimuli, thereby enabling patients with PD to move their limbs (support their ability to walk) in the absence of the body's normal gait functions, which are no longer functional due to damage to the basal ganglia<sup>9)</sup>. Investigations have indicated that the effects of external signals on patients with PD movement

performance differ based on the modality of the stimuli or signals used<sup>10, 11)</sup>.

During walking, the arms cause the body to turn in the opposite direction to that of the pelvis so as to compensate for the turning effect caused by the pelvis, thus transmitting the pelvic turns to the upper body in order to maintain balance<sup>12)</sup>. Arm swinging helps to stabilize the body during walking by regulating the angular movements of the body and reducing the lateral tilting of the center of gravity<sup>13)</sup>. The side-to-side differences in rhythmical arm movements during walking are a clinical sign frequently observed in patients with PD<sup>14)</sup>. A recent gait analysis study found significant decreases in the arm swing speed and the range of joint motions of patients with PD<sup>15, 16)</sup>.

Decreased arm swinging is the most common motor disorder associated with PD<sup>17)</sup>, and even though this symptom is related to the increased risk of falls<sup>18)</sup>, few studies have explained the changes in the movement of the upper extremities during walking in patients with PD<sup>19)</sup>. Most evaluations of gait in PD focus on the lower extremities, investigating decreased gait velocity, stride length, and the ratio of swing phase time to stance phase time<sup>20-22)</sup>.

In addition to symptoms such as bradykinesia and akinesia, PD is also associated with axial rigidity of the trunk<sup>23)</sup>. Therefore, the measurement of axial trunk rotations can help in the early detection of PD, and can also be used to evaluate the progression of the condition<sup>24)</sup>. Trunk movements are essential for movements such as walking and turning, and

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despite the fact that axial rigidity is one of typical features in PD, few researchers have yet studied it.

A review of the current literature demonstrates that, although many studies have examined the use of external signals to improve motor control or gait ability in PD, comparative studies examining the variables (the arms and the trunk when the signals are applied) are insufficient. Therefore, the present study examined whether or not differences in arm swings and trunk rotations could be found in PD patients when external signals are applied during walking compared to when no signal is applied in order to identify the appropriate external signals for use as an intervention against decreased arm swings and trunk rotations during gait training for PD.

## SUBJECTS AND METHODS

Thirteen PD patients participated in this study (Table 1). The disability and impairment status of the subjects was assessed using the Hoehn and Yahr Disability scale of PD. They were categorized as having stage 2–3 disease. 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.

For the visual cue condition, bright yellow colored strips of tape placed on the floor at intervals equal to 40% of each subject's height were used. For the auditory cue condition, subjects were instructed to walk along the walkway while keeping pace with a metronome. The metronome rate (in beats/min) was set at a walking speed 20% faster than the un-cued walking speed for each subject. For the combined cue condition, bright yellow strips were placed on the floor and the metronome beat was the same as that used for the auditory cue condition for each subject. Subjects walked under four different conditions performed in a random order: no cue, visual cue, auditory cue, combined cue.

**Table 1.** Subject characteristics

Variables	Subjects (n=13)
Age (yrs)	64.8 ± 6.8
Height (cm)	159.2 ± 9.1
Body weight (kg)	57.2 ± 8.3
Gender (F/M)	8/5
Months since diagnosis	64.2 ± 37.8

Values are means ± standard deviation

In this study, the following kinematic gait variables were tested by external cues using a motion analysis system: arm swing amplitude and trunk rotation. A Hawk Digital System (60 Hz, Motion Analysis, USA) was used to measure the arm swing amplitude and trunk rotation variables during walking. The amplified motion analysis signals were sampled on-line with EVaRT 5.0 software and then analyzed using Cortex 64 and OrthoTrak 6.6.4 software.

One-way ANOVA was performed to identify the differences in kinematic parameters between different external cues. Tukey's HSD was used as the post-hoc test. Significance was accepted for p-values < 0.05.

## RESULTS

Comparison between gait variables by external cues in PD patients revealed significant differences in arm swing amplitude ( $p < 0.05$ ), but trunk rotation was not significantly different between the groups ( $p > 0.05$ ). According post-hoc analysis, there was a significant difference between no cue and auditory cue gait with respect to arm swing amplitude ( $p < 0.05$ ) (Table 2).

## DISCUSSION

In the present study, to examine changes in arm swing and trunk rotation based on the type of external signals that are used when walking, auditory signals, visual signals, and combined auditory/visual signals were applied, and the kinematic variables for arm swing and trunk rotation during walking were measured.

Decreases in the number of arm swings during walking are a common phenomenon in PD. Recently, many studies have examined the speed and range of arm swings in relation to gait in PD. Several researchers have reported that increases in gait velocity increase the amplitude of the arm swings<sup>25–27</sup>). Through systematic studies of the effects of external signals on the gait of PD patients, Lim et al.<sup>8</sup>) reported that the application of auditory signals was effective for gait velocity. Given the results of the present study, it can be seen that auditory signals, applied at a faster rate than normal gait velocity, induce increases in arm swings during gait in PD patients. Therefore, auditory signals should be considered as a method for improving arm swings in relation to increases in gait velocity during gait training for these patients.

Researchers have advised that visual signals reinforce vision, thereby helping to ensure proper gait and stride length and increased gait velocity<sup>28–30</sup>). Lewis et al.<sup>31</sup>) reported that the kinematic gait elements of the lower extremities in PD

**Table 2.** Comparison of arm swing amplitude and trunk rotation depending on different external cues (mean ± standard error)

	No cue	Auditory cue	Visual cue	Combined cue
Arm swing amplitude (°) *	25.2 ± 2.8 <sup>b</sup>	36.4 ± 3.0 <sup>a</sup>	28.1 ± 2.8	26.5 ± 3.0
Trunk rotation (°)	6.6 ± 0.9	7.0 ± 1.3	7.2 ± 1.2	8.3 ± 1.6

\* $p < 0.05$

<sup>a</sup>Significant difference from no cue, visual & combined cue

<sup>b</sup>Significant difference from visual & combined cue

patients were improved when visual signals were applied. Therefore, visual signals are considered to induce increases in gait velocity through improvement of movement in the pelvis and the lower extremities more than improvement in arm swings. However, further studies on this matter are required.

PD patients maintain abnormal postures with the trunk bent forward at normal times, and their ranges of motions for lateral bending, torsion, and rotation of the trunk during walking are smaller than those of a normal person. A study conducted by Ferrain et al.<sup>32)</sup> reported that stimulation of the L-dopa or subthalamic nucleus of PD could reduce forward trunk tilting, increase trunk movements, and increase gait velocity and stride length. The present study also found that trunk rotations increased when auditory/visual or combined stimuli were applied, although the differences were not statistically significant.

Rochester et al.<sup>33)</sup> stated that during gait training applied with signals, dual-task training and single-task training improved the patients' condition equally. According to the results of the present study, combined auditory/visual signals did not greatly affect arm swings or trunk rotations during walking. Previous studies also found that auditory signals combined with visual signals did not improve stride length to a greater degree than visual signals alone because when visual signals and auditory signals are combined, one type of signal interferes with the other<sup>34)</sup>.

L-dopa therapy and treatment with deep brain stimulation techniques on the pedunculo-pontine nucleus site, hypothalamus, etc. are frequently used to treat the various abnormal movement patterns that arise in PD. However, the application of L-dopa has only a temporary effect, and deep brain stimulation techniques are invasive methods using surgery and are used only in cases of terminal PD with highly progressed symptoms. In addition, it has been reported that although these techniques control symptoms, such as bradykinesia and ankyloses, there are difficulties in treating the patients' damaged gait ability or balance<sup>35, 36)</sup>. Therefore, studies to improve abnormal movement patterns in PD using non-invasive methods are necessary and if the movement of the arms and trunks of these patients is to be improved using diverse sensory inputs, as found in the present study.

Since the present study was conducted with PD patients who were receiving ambulatory care, their gait conditions were fairly good. Therefore, the results of the present study cannot be easily generalized to all PD patients or to the training effects of external signals on arm swings and trunk rotations. These can be regarded as limitations of the present study. Therefore, additioThere is no conflict of interest in this study.

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