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The effects of additional arm weights on arm-swing magnitude and gait patterns in Parkinson's disease

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HIGHLIGHTS

- Decreased arm swing is a typical gait characteristic in Parkinson's disease.
- Adding weight to the arm facilitates limb movements in Parkinson's disease.
- Additional arm weight improves gait disturbance in Parkinson's disease.

ABSTRACT

Objective: Recently, arm facilitation has been interested in gait rehabilitation. However, there have been few studies concerning arm facilitation in patients with Parkinson's disease (PD). The aim of our study was to investigate the effect of increasing arm weights on gait pattern in patients with PD.
Methods: Twenty-seven patients with PD were enrolled, and they underwent gait analysis using a three-dimensional motion capture system. Sandbags were applied to the distal forearms in all participants. We compared gait parameters including arm swing, pelvic motion, spatiotemporal data, and relative rotational angle between the weighted and unweighted gaits.
Results: The total arm-swing amplitude and pelvic rotation were significantly higher when walking with additional arm weights than without arm weights. Cadence, walking speed, stride length, and swing phase were significantly higher, whereas stride time, double-support time, and stance phase were significantly lower, when walking with additional arm weights than without arm weights.
Conclusions: We conclude that adding weights to the arm during walking may facilitate arm and pelvic movements, which results in changes to gait patterns. The therapeutic use of additional arm weights could be considered for gait rehabilitation in PD to improve gait impairment.
Significance: Arm-swing facilitation using weight load improved gait in Parkinson's disease.

1. Introduction

Gait disturbance and postural instability have been thoroughly described in Parkinson's disease (PD). Slow velocity with shuffling, dragging steps, small stride/step length, forward-stooped gait, and decreased arm swing are typical gait characteristics in PD.

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Rhythmic arm swings are connected to movements of the head, trunk, and pelvis, and they play an important role for postural stability and energy efficiency during walking (Dietz et al., 2001; Gutnik et al., 2005). The reduction of arm swing is one of major characteristics in patients with PD, and arm swing would be lost in the early stage of PD (Roggendorf et al., 2012).

A variety of gait trainings in rehabilitation program for patients with PD have been performed to improve gait function and mobility by using a treadmill, assistive devices, and cueing strategies such as verbal, visual, or auditory cueing (Kegelmeyer et al., 2013; Spaulding et al., 2013). Recently, there is a growing interest on arm movements in patients with PD, such as arm-swing asymmetry or amplitude (Lewek et al., 2010; Roggendorf et al., 2012). Therefore, increasing arm swing also is one of the important purposes of gait rehabilitation for PD patients. Meyns et al. reported that arm facilitation in rehabilitation program for patients with PD is very important, but, to date, there is little information regarding this (Meyns et al., 2013).

A vast amount of evidence has suggested that an added load to the body has an effect on altered gait parameters, and it improved postural balance (Donker et al., 2005; Duysens et al., 2000). The added weight to the arms would be effective in changing arm movements, and it could lead to influence on the interaction between limb movements during walking (Donker et al., 2005). This change of arm movement could result in the improvement of gait parameters and pelvic motion. To our knowledge, previous reports have only investigated healthy subjects, and little is known regarding the facilitation of arm movement in patients with PD.

The aim of this study was to investigate whether additional arm weight could alter the gait patterns as well as arm-swing amplitude during walking in PD. We hypothesized that additional arm weight would increase arm-swing amplitude, and it would improve the spatiotemporal parameters and pelvic motion in patients with PD.

2. Methods

2.1. Study participants

Twenty-seven patients with PD (15 males and 12 females) meeting the United Kingdom Parkinson's Disease Society Brain Bank diagnostic criteria were enrolled for this study (Hughes et al., 1993). Basic demographic and clinical information were obtained including disease duration, body mass index (BMI), and disease severity. Clinical severity was assessed by the United Parkinson's Disease Rating Scale part III (UPDRS III) and Hoehn and Yahr (H&Y) stage. The demographic data of participants are presented in Table 1. Inclusion criteria for participants were as follows: (1) in H&Y stages 2–3; (2) complaining of gait disturbance but able to walk without assistance; and (3) having proper cognition to understand the study information. Exclusion criteria were recommended for (1) any primary orthopedic, neurological diseases, and visual disturbances other than PD, and (2) having complaints that affect independent walking. All patients with PD were on medication. The study was approved by the institutional review board at the Haeundae Paik Hospital (Busan, Korea). All patients understood the study procedure and purpose, and they gave written informed consent before participation.

2.2. Gait analysis

An eight-camera three-dimensional motion analysis system (Vicon, Fareham, UK) was used at a sample rate of 100 Hz for the quantification of arm swing, pelvic motions, and spatiotemporal parameters. Heel strike and toe-off were obtained from two force plates (AMTI, Watertown, MA, USA) synchronized with the Nexus program (version 1.7) for data collection at 1000 Hz, and the events of gait cycle were recorded simultaneously. In total, 16 retroreflective markers were used to indicate the segments. Twelve markers were attached on the anterior and posterior superior iliac spines, femoral epicondyle, and malleolus, second metatarsal head, and posterior calcaneus bilaterally for the kinematics of lower extremities. For the amplitude of arm swing, four markers were bilaterally placed on acromion processes and on the middle point of ulna and radius. The marker placement was performed by one experienced researcher to minimize the error.

Table 1
Participants' characteristics.

	Mean ± SD	Range
Age (years)	74.0 ± 5.7	64–90
Gender	15 males/12 females	
Height (cm)	157.5 ± 8.2	142.2–175.4
Weight (kg)	57.9 ± 9.4	42.3–74.7
BMI (kg/m^2)	23.3 ± 2.7	17.5–28.5
Duration (month)	22.2 ± 20.7	0.5–71
H&Y stage	2.5 ± 0.5	2–3
UPDRS III (points)	22.8 ± 7.7	10–43

BMI: Body mass index; H&Y stage: Hoehn and Yahr stage; UPDRS III: Unified Parkinson's disease scale part 3.

2.3. Procedures

Prior to performing the dynamic trials, all participants undertook a static trial to determine the movement of the pelvis, upper, and lower limbs. Each PD patient who took part in this study walked barefoot along a 20-foot walkway at an individually preferred pace, and the patient performed five trials with and without arm weights (in random order). Two sandbags weighing 0.45 kg (Sammons Preston, Bolingbrook, IL, USA) were used as arm weights. The patients with PD wore sandbags with Velcro straps on the distal one-third portion of the forearm bilaterally. Unfortunately, there was no report about the appropriate weight on the patient with PD. Several previous studies for healthy subjects related to the arm weight used a 1.2- or 1.8-kg weight on each arm. Considering that our subjects are old and weak, we selected 0.45 kg.

No specific instructions regarding gait posture as well as arm swing were provided to participants. Each participant took a break for 1 min between tasks to minimize the fatigue.

2.4. Data analysis

Motion data capture and post-processing of marker trajectories were performed using the Nexus 1.7 software (Vicon, Fareham, UK). The tri-planar motions of pelvis were calculated relative to the global coordinate system, and arm swing was calculated by the angle between the arm and virtual vertical axis. The kinematics of pelvic motions was presented for sagittal, coronal, and transverse planes defined as anterior–posterior tilt, obliquity, and rotation, respectively. Each pelvic motion was calculated as the amplitude (maximum–minimum values).

The arm swing was divided into anteversion and retroversion of the shoulder joint. The anteversion was defined for maximum positive values, and the retroversion was done for minimum negative values (Fig. 1(a)). In addition, all arm-swing amplitudes including total, anteversion, and retroversion were calculated as the average of the left and right side. The relative angle of the shoulder relative to the pelvis was obtained by subtracting the virtual shoulder line through the markers on the acromion from the pelvis within each single step (Fig. 1(b)). The right step indicates from left heel strike