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Effects of curved-walking training on curved-walking performance and freezing of gait in individuals with Parkinson's disease: A randomized controlled trial

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ABSTRACT

Introduction: The purpose of this study was to investigate the effects of curved-walking training (CWT) on curved-walking performance and freezing of gait (FOG) in people with Parkinson's disease (PD).
Methods: Twenty-four PD subjects were recruited and randomly assigned to the CWT group or control exercise (CE) group and received 12 sessions of either CWT with a turning-based treadmill or general exercise training for 30 min followed by 10 min of over-ground walking in each session for 4–6 weeks. The primary outcomes included curved-walking performance and FOG. All measurements were assessed at baseline, after training, and at 1-month follow-up.
Results: Our results showed significant improvements in curved-walking performance (speed, $p = 0.007$; cadence, $p = 0.003$; step length, $p < 0.001$) and FOG, measured by a FOG questionnaire ($p = 0.004$). The secondary outcomes including straight-walking performance (speed, cadence and step length, $p < 0.001$), timed up and go test ($p = 0.014$), functional gait assessment ($p < 0.001$), Unified Parkinson's disease Rating Scale III ($p = 0.001$), and quality of life ($p < 0.001$) were also improved in the experimental group. We further noted that the improvements were maintained for at least one month after training ($p < 0.05$).
Conclusion: A 12-session CWT program can improve curved-walking ability, FOG, and other measures of functional walking performance in individuals with PD. Most of the improvements were sustained for at least one month after training.

1. Introduction

Parkinson's disease (PD) is a neurological degenerative disease that leads to motor dysfunctions. With progression of the disease, people with PD show impairments in functional walking tasks. Curved-walking is one such task and is an essential part of goal-directed locomotion in daily life. Curved-walking involves complex control of the trunk and is accompanied by asymmetric motion of the lower extremities. Therefore, compared to straight-walking, curved-walking requires a specific series of demands on neural processes to attain medial-lateral stability and forward progression control [1]. Curved-walking is even more challenging for patients with PD due to their impairments in balance and posture control in coping with complex adaptations, such as shifting body weight to counteract centrifugal force and producing different step lengths between legs [2,3]. Despite the importance of curved-walking in daily life and the higher risk of falls and injuries during this advanced walking task [4], there is limited information on effective interventions for improving curved-walking ability in neurologically involved patients, not to mention patients with PD.

Freezing of gait (FOG) is also a common and disabling feature in people with PD that is characterized by sudden and transient

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interruptions to walking; FOG frequently occurs when initiating walking, turning, or facing an obstacle or narrow path [5]. Episodes of FOG increase the risk of falls and have a considerable negative impact on quality of life [6]. However, the symptom of FOG often responds poorly and sometimes paradoxically to treatment with dopaminergic medication.

Task-specific training has been shown to be more effective than traditional exercises in improving functional performance in individuals with neurological disorders. This type of training has been found to be beneficial to functional performance and balance restoration in people with PD [7]. According to Nielsen et al. learning is more effective when the task is performed repetitively and is generalized to different contexts [8]. In line with the principles of task-specific training, we have previously demonstrated that curved-walking training (CWT) on a turning-based treadmill results in beneficial effects on balance control and curved-walking performance in individuals with chronic stroke [9]. In this study, we thus aimed to investigate whether this task-specific training could exert significant effects on curved-walking ability and FOG in people with PD.

2. Methods

2.1. Participants

Participants with idiopathic PD diagnosed by a neurologist were recruited from medical centers in Taiwan. The diagnostic criteria for PD were the presence of at least two of four features (resting tremor, bradykinesia, rigidity, and asymmetric onset), and one of which had to be resting tremor or bradykinesia [10]. All participants met the following criteria: (i) Hoehn and Yahr stages I to III, (ii) independent walking, and (iii) a score of ≥24 on the mini-mental state examination (MMSE). The exclusion criteria were as follows: (i) unstable medical condition, (ii) motor fluctuations or severe dyskinesia which might interfere the training, and (iii) any history of other diseases known to interfere with participation in the study. In total, 24 participants provided informed consent, and the study procedures were approved by the Institutional Review Boards of Taipei City Hospital, Chang Gung Medical Foundation, or Mackay Memorial Hospital.

2.2. Experimental design

This study was a single-blinded parallel randomized controlled trial. An individual who was not involved with the study selected the sealed envelope that determined group assignment into either the CWT group or the control exercise (CE) group (block randomization; allocation ratio = 1). Participants in each group received 30 min of either CWT or general exercise, according to their group assignment, followed by a 10-min training in over-ground walking for a total of 12 sessions in a 4- to 6-week period by the same physical therapist. All outcomes were measured the day before the intervention (pre), the day after the intervention (post), and the 30th day after completing the intervention (follow-up) to investigate the training effects and the follow-up effects by the same rater, who was blinded to group assignment. The measurements and intervention were conducted with patients in the “on” state.

2.3. Interventions

The CWT was performed on a turning-based treadmill (Rmax Science & Technology Co. Ltd. New Taipei City, Taiwan, Fig. 1). This turning-based treadmill is similar to a regular treadmill except for its circular running motor belt. The small radius (0.8-m) of the circle forces subjects to walk in a curve rather than walk straight [9,11]. Participants were asked to walk on the treadmill in both directions, 15 min for each side, as the motor belt rotated either clockwise or counterclockwise. All participants wore a safety harness without body weight support to prevent falls during the training period. The training speed started from 80% of the participants' comfortable over-ground curved-walking speed and increased by 0.05 m/s every 5 min as tolerated. Tolerance was defined as participants being able to maintain an upright position and reporting a perceived exertion of “somewhat hard” or lower (a Borg rating of perceived exertion <13) [12]. Training was stopped immediately if subjects complain any discomfort.

In the CE group, subjects received 30 min of trunk exercise that incorporated upper extremity movements while in a sitting position. Trunk movements such as trunk flexion, extension, and rotation and side bending with different arm movements (i.e., shoulder flexion, extension, abduction, adduction and diagonal lifting/chopping) were performed in the training program.

After the 30-min main exercise training, as described above in each group, a 10-min walking program on the ground was performed. This program included S-shaped, 8-shaped, square-shaped and oval-shaped walking tasks with verbal cues for gait correction.

2.4. Primary outcome measures

The primary outcomes included curved-walking performance and FOG.

Curved-walking performance was assessed as the ability to walk along an approximately 500-cm curved path along a circumference with a radius of 80 cm [13]. Participants were asked to walk at a comfortable speed three times in each direction in a random order. The time and steps needed to walk along the curved path were recorded, and the average of three trials was used for the data analysis. Speed was derived by dividing the distance by the time, cadence was calculated as steps per minute, and step length was calculated by dividing the distance by the number of steps. The intra-rater reliability for curved-walking performance was high (speed, ICC = 0.94; cadence, ICC = 0.96) in our pilot study of healthy adults.

FOG was assessed by the freezing of gait questionnaire (FOGQ). Currently, the FOGQ is the only validated tool available to subjectively assess FOG. It assesses FOG frequency, disturbances in gait and relationships to clinical features conceptually associated with gait and motor aspects. There are 6 total items in this questionnaire, with 4 items assessing the severity of FOG, and 2 items assessing gait. The score ranges from 0 to 24, and higher scores correspond to more severe FOG. The FOGQ has good test-retest reliability [14]. The patients were classified as freezers according to the item 3 of FOGQ (item 3—*Do you feel that your feet get glued to the floor while walking, making a turn or when trying to initiate walking (freezing)?*) [15].

2.5. Secondary outcome measures

The secondary outcomes included straight-walking performance, timed up and go test (TUG), functional gait assessment (FGA), the Unified Parkinson's Disease Rating Scale III (UPDRS-III, Motor Section), and quality of life.

To assess straight-walking performance, the participants were asked to walk 600-cm along a walkway at a comfortable speed three times. The time and steps needed to complete this straight-walking task were recorded, and the average of the three trials was used for the data analysis. The speed, cadence and step length