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Original Article

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The Effects of Walking and Turning and Treadmill Training on Postural Balance and Walking in People with Parkinson's Disease

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| Abstract |

Purpose: The aim of our study was to evaluate the therapeutic effects of walking and turning plus treadmill training on the functional balance and walking ability of individuals with Parkinson's disease (PD).

Methods: Twenty-four participants with Stage 1 to 3 (2.13 ± 0.64) PD based on the Hoehn and Yahr scale were randomly allocated to the experimental group (EG) and control group (CG), with 12 participants in each group. The measured outcomes included the motor subscale of the unified Parkinson's disease rating scale (UPDRS-M), the Berg balance scale (BBS), the Timed Up and Go (TUG) test, the 10-meter walk test (10MWT), and the 6-minute walk test (6MWT).

Results: Pre-to-post intervention improvements were noted for all the outcome measures for both groups ($p < 0.05$). Post intervention, there was a significant improvement in the EG compared to the CG for the following measured outcomes ($p < 0.05$): UPDRS-M ($p = 0.021$; 95% CI, 0.081–6.519), BBS ($p = 0.042$; 95% CI, 1.375–4.541), TUG ($p = 0.034$; 95% CI, −3.315–−0.143), 10MWT ($p = 0.011$; 95% CI, −2.032–−0.289), and 6MWT ($p = 0.002$; 95% CI, 24.39–91.273).

Conclusion: Our study suggests that walking and turning plus treadmill training improves balance and walking compared to treadmill training only in patients with PD.

Key Words: Balance, Parkinson's disease, Walking

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Ⅰ. Introduction

Patients with Parkinson's disease (PD) demonstrate progressive impairment in balance and ambulation (Carpinella et al., 2017). There is a loss of the nigrostriatal neurons, which disrupts the frontostriatal circuits (premotor areas, primary motor cortex and dorsolateral prefrontal cortex) that are involved in motor and cognitive functions (Kish et al., 1988; Tremblay et al., 2016). PD is characterized by four primary motor symptoms: bradykinesia, rigidity, resting tremor, and postural instability (Klamroth et al., 2016). These symptoms often cause balance and gait deficits, such as reduced gait speed and shorter stride length. Such deficits can lead to walking disability, increased risk of falling, and reduced quality of life (Soh et al., 2011).

The clinical management of patients with PD combines dopaminergic medication and physical activity training (Koller, 2002). However, the effects of medication on an individual's balance, walking ability and fall risk remain uncertain (Bloem et al., 2001). Intensive aerobic exercise can mitigate the effects of neurodegenerative changes on motor function (Frazzitta et al., 2013) through its influence on multiple factors. Two recent systematic reviews provided evidence of the effectiveness of walking on a treadmill to improve walking speed, stride length, rhythm, and walking capacity in individuals with PD (Herman et al., 2009; Kang et al., 2016; Mehrholz et al., 2015).

Thirty-five to forty-five percent of walking with daily activities occur during turning motions (Glaister et al., 2007). A turning motion is initiated by rotation of the head followed by the trunk, pelvis and feet, which move inward (Bengevoord et al., 2016). In healthy subjects, the center of mass (COM) deviates towards the inner side of the turn, a pattern which becomes more exaggerated with faster turning speed (Bengevoord et al., 2016). In the elderly, turning is slower and the COM is less medially oriented (Thigpen et al., 2000). However, treadmill walking does not consist of a turning action, and the ability to turn is already impaired in the early stages of the PD (Conradsson et al., 2017; Thigpen et al., 2000). The goals of treatment for gait disorders in PD are to decrease the severity, improve the ability to carry out daily activities, and minimize the risk of falling. Therefore, turning movements may offer a useful strategy to improve balance and walking ability in individuals with PD, engaging the rotation muscles of the head, trunk and pelvis (Thigpen et al., 2000). Walking turns training is a necessary component to improve postural control and mobility of individuals with PD, as well as quality of life (Soh et al., 2011).

Yang et al. (2016) reported that turning difficulty is common among patients with PD. Patients with PD turn slowly with prominent small steps, demonstrating gait disturbances such as freezing. These factors cause an increase in the risk of falls with turning. Therefore, improvement of turning ability in PD is important for fall prevention and improved walking. However, there is a paucity of literature on turn training in patients with PD. Thus, the aim of the present study was to examine the effect of walking turns plus treadmill training on postural balance and walking for patients with PD. The research hypotheses for this study are as follows: (1) walking turns plus treadmill training will improve balance and walking ability, and (2) walking turns plus treadmill training will be superior to conventional plus treadmill training in patients with PD.

Ⅱ. Methods

1. Participants

Patients with a diagnosis of PD, confirmed by several neurologists to make a diagnosis, were recruited from the Wonkwang University Medical Center in the Republic of Korea. For eligibility, patients had to present with two or more of the four classic motor features of PD: resting tremor, bradykinesia, rigidity, and asymmetric onset, in which the resting tremor or bradykinesia had to be present (Gelb et al., 1999). The specific inclusion criteria were: (1) Hoehn and Yahr stages 1 to 3, (2) ability to walk independently without walking aids, (3) stable medication, and (4) a score of ≥24 on the mini-mental state examination. The exclusion criteria were: (1) any comorbidity or disability that precluded training, (2) a past history of a seizure, and (3) any uncontrolled health condition for which exercise is contraindicated. Twenty-four patients were recruited into our study and randomized to two groups: the walking turns plus treadmill training group (experimental group, EG) or the conventional plus treadmill training group (control group, CG). Randomization was done after baseline testing by a physical therapist who was blinded to the study. All participants gave written consent prior to participation in the study and all procedures were approved by our institutional review board (IRB).

2. Experimental design

This study was a single-blinded randomized controlled trial, with an analyst that was blinded to the treatment. Assessments were taken by an experienced physical therapist who was qualified to use the measurement tools and was also blinded to treatment groups. Randomization of participants to the EG or CG was done by a physical therapist who was not a part of the study. Randomization occurred by selecting an opaque, sealed envelope with the group assignments that was given to the physiotherapist.

After randomization, the interventions were carried out during regularly scheduled therapy sessions. The training program consisted of twenty 1-hour (30 min + 30 min), sessions, performed five days per week for 4 weeks.

3. Training interventions

Participants in the EG performed two different turning conditions (pre-planned and unplanned) that were in a random order for 30 minutes. For walking turns training (Conradsson et al., 2017), participants in the EG walked at their comfort level velocity along a 10-meter walking lane, where the turning position was indicated by two cones. For preplanned and unplanned turns, one of the following three tasks was performed in a randomized order: walking straight, or walking and turning 360° to the right or to the left. Participants in the EG were instructed to walk and turn to the indicated direction without stopping until they reached the target. Participants in the EG started each trail 4 m from the turning intersection, which provided an adequate distance to reach a steady-state velocity, while straight walking before initiating a turn. For the preplanned condition, the same visual signal was present approximately one step before the intersection. The participants were allowed to rest when needed during training.

Participants in the CG performed the conventional training for 30 minutes. Each session included 5 minutes of muscle stretching (hamstring, quadriceps, and calves) and mobilization exercises (e.g., trunk rotation, hip adduction, flexion), followed by 25 minutes of balance and gait exercises any without turning motions. Participants executed the tasks as instructed by the physiotherapist.

Both groups undertook the treadmill exercises (Mehrholz et al., 2015) and performed 30 minutes of supported walking exercise. The treadmill was equipped with hand railings and a sensor that would stop the treadmill if there was a problem with balance or safety.

The treadmill exercise was conducted with a zero degree inclination on the treadmill. The maximum overground walking speed was determined before the first training session. Half of this speed was used for a 5 minute warm-up on the treadmill. After the warm-up, the first speed-dependent training phase began. During a period of 1 to 2 minutes, the speed was increased to the higher speed at which the participant could walk safety based on feedback from the participants. The maximum-achieved speed was held for 10 seconds, followed by a recovery period to allow the participant's pulse to return to its resting level. If the participant maintained the speed and felt safe during the 10 seconds at the maximum-achieved speed, the speed was then increased by 10% during the next training. If the participant, was unable to maintain the speed or felt unsafe during any phase, the speed was reduced by 10% in the next training. Treadmill training was conducted for 30 minutes per day. After the treadmill exercise, the participants finished the training with deep breathing and stretching.

4. Outcome measures

The participants performed the tests after gaining sufficient familiarity with the test protocols. The primary outcomes were balance and self-selected gait speed, assessed with the Berg balance scale (BBS) (Wee et al., 1999) and 10-m walk test (10MWT), respectively (van Loo et al., 2004). The BBS is a 14-item performance-based balance measure with scores ranging from 0 to 56. The BBS score is moderately associated with motor deficits and activities of daily living, with a higher score that indicates better balance. The 10MWT provides a measure of walking speed over 10 m. A 14-m walkway was used, which provided 2 m for acceleration and 2 m for deceleration. Participants performed three trials with the average time used for analysis.

Secondary outcomes included the motor score of the unified Parkinson disease rating scale (UPDRS- M), the timed up-and-go test (TUG) and the 6-minute walk test (6MWT). The UPDRS-M (Cakit et al., 2007) assesses the severity of motor deficits, including speech, facial expression, tremor, rigidity, limb coordination, mobility, gait, and postural stability. Higher scores indicate more severe deficits. The TUG (Podsiadlo & Richardson, 1991) measures the dynamic balance and functional mobility with consecutive sit-to-stand, walking, turning, and stand-to-sit movements; where a shorter completion time indicates better dynamic balance and functional mobility. The 6MWT (O'Keeffe et al., 1998) provides a measure of walking endurance. Patients were asked to walk as 'fast' as possible for 6 minutes. The test was performed in a 100-m long corridor, with the total distance walked (m) measured.

5. Data and statistical analysis

All data were analyzed using the Statistical Package for the Social Sciences, version 18.0 (SPSS Inc., Chicago, IL, USA). Descriptive and analytical statistics were performed (Table 1 and 3). Data were presented as a mean and standard deviation (SD). Between-group differences at the time points of measurement were evaluated using independent t-tests. Within-group changes from pre- to post-test measurements were evaluated using paired t-tests. Effect sizes were calculated as the difference between the means of the EG and CG divided by the mean SD at baseline (Cohen, 1988). Significance was set at $p<0.05$.

Ⅲ. Results

All participants completed all training and assessment sessions. There were no between-group differences in terms of sex, age, height, weight, Mini-Mental State Examination score, and duration of PD (Table 1). A total of the 24 participants were documented during the 4-week study period (Table 2). There were no significant differences in the incidence rate of falls between groups (p>0.05). The mean (SD) scores on the Hoehn and Yahr stage, BBS, 10MWT, UPDRS- M, TUG, and 6MWT are reported in (Table 3).

The mean age of the participants was 60.40 (+5.76) years in EG and 61.53 (+6.59) years in the CG. The total

Table 1. Demographic data of the participants

	Experimental group (n=12)	Control group (n=12)	*p*-value
Sex (n)			
Men	9	10	0.62
Women	3	2	
Age (years), mean (SD)	60.40(5.76)	61.53(6.59)	0.52
Height (cm)	164.40(6.69)	158.70(11.84)	0.46
Weight (kg)	64.76(10.56)	67.87(7.67)	0.57
MMSE (scores), mean (SD)	26.87(1.25)	27.24(1.27)	0.87
Disease duration (months)	16.48(5.18)	17.24(4.26)	0.38

NOTE. Baseline demographic data for participants include in the two different groups and significance level at $p < 0.05$ for difference between the groups.
Abbreviations: MMSE, mini-mental state examination.

Table 2. Comparison of self-reported falls during the 4-week intervention

Falls (No. of falls)	Experimental group (n=12)		Control group (n=12)	
	Before-intervention	During-intervention	Before-intervention	During-intervention
0	2(16.7%)	4(33.3 %)	1(8%)	1(8%)
1	0(0%)	3(25%)	1(8%)	2(17%)
2	3(25%)	3(25%)	3(25%)	5(42%)
≥3	7(58.3%)	2(17%)	7(58.3%)	4(33.3%)

Falls were defined as unintentionally coming to rest on the floor or the ground or falling and hitting objects such as stairs or pieces of furniture.

Table 3. Descriptive measurements

Variables	Experimental group (n=12)		Control group (n=12)	
	Pre-test	Post-test	Pre-test	Post-test
Hoehn and Yahr scale (g)	2.25(0.62)[a]	1.78(0.42)*	2.21(0.67)	1.85(0.63)*
UPDRS- M (scores)	21.33(2.81)	16.91(2.58)*†	20.08(2.14)	18.65(1.47)*
Berg balance scale (scores)	37. 42(2.47)	45.41(2.68)*†	38.75(3.72)	43.83(4.65)*
Timed up-and-go test (sec)	13.38(2.17)	9.25(1.68)*†	14.03(1.98)	10.98(2.05)*
10-meter walk test (sec)	13.97(1.29)	10.27(1.01)*†	13.73(1.97)	11.43(1.05)*
6-minute walk test (m)	259.17(40.99)	318.00(42.59)*†	228.08(43.21)	260.17(45.85)*

[a]Means (SD); *Significant difference within groups; †Significant difference between groups.
Abbreviations: UPDRS- M, unified Parkinson disease rating scale motor subscale.

number of men was 19 (79%) and the total number of women was 5 (20%). At the end of the fourth weeks, mean scores significantly increased for several outcome measures (BBS, TUG, 10MWT, and 6MWT) in both groups. However, the mean values in the EG were greater than those in the CG, showing significantly better improvement in the EG ($p<0.05$) (Table 3).

In the primary outcomes, the mean change in balance function measure by BBS was significantly greater in the EG than in the CG (8.00±2.05 vs. 5.08±2.68 scores, $p=0.01$); and the mean change in walking speed measured by the 10MWT was significantly greater in the EG than in the CG (3.69±1.42 vs. 2.30±1.61 seconds, $p=0.01$). For the secondary outcomes, the mean TUG change for dynamic balance was significantly greater in the EG than in the CG (4.13±1.60 seconds vs. 3.05±1.67 seconds, $p=0.04$); and the mean changes in the 6MWT for walking endurance was significantly greater in the EG than in the CG (58.83±20.54 vs. 32.08±16.58m, $p=0.00$).

Ⅳ. Discussion

This study highlights the importance of turning motion in patients with PD. Our randomized controlled pilot trial provided evidence of the effectiveness of walking turns training to improve balance and walking ability in people with PD. The major findings of this study were that the walking turns plus treadmill training group showed significantly more improvement than the conventional training plus treadmill training group in the UPDRS- M, BBS, TUG, 10MWT, and 6MWT, over time. These results indicate that walking turns plus treadmill training may be more effective than conventional plus treadmill training to improve balance and walking ability in people with PD.

We hypothesized that walking turns plus treadmill training was superior to conventional training plus treadmill training in improving balance and walking ability. The results showed that both groups (EG and CG) had improvement in balance and walking ability after 4 weeks when compared to baseline. These results may be the direct result of the repetitive treadmill training applied in this study. One possible explanation for this was that all participants received treadmill training. The effectiveness of treadmill training to improve balance and walking ability in people with PD has been previously reported (Frazzitta et al., 2013; Mehrholz et al., 2015). Cakit et al. (2007) suggested that treadmill training in people with PD may be more effective than gait training without the use of a treadmill. Treadmill training helps the patients with PD to improve the balance and lengthen their stride, which may be an important factor in their walking ability. Miyai et al. (2006) reported that cortical reorganization, especially in the supplementary motor area, might also be a possible mechanism underlying the improvement when patients with PD train with a treadmill.

Walking turns involve an interaction between the linear component (i.e. forward progression of the body) and the angular component (i.e. rotation in relation to the longitudinal axis) (Conradsson et al., 2017). Cross steps, while turning, is a complex motor task that requires a high level of balance control that could induce instability due to the drastic changes in the base of support. It is also an important contributor to body rotation (Huxham et al., 2008). Consequently, problems modulating the width of a step PD may compromise medio-lateral stability and the force necessary to accelerate the center of mass toward the direction of the turn (Conradsson et al., 2017). Thus, the problems modulating the step width limit the performance during a turn and lead to instability, decrease balance and walking ability in people with PD during daily activity. Based on this, walking turns is a necessary component for improving the balance and walking ability in individuals with PD.

Participants in the EG reported a greater improvement in motor function than individuals in the CG group, with approximately 5-point change in the UPDRS- M, which is considered to be clinically meaningful (Ni et al., 2016). However, the CG did not meet this meaningful threshold. The higher changes of UPDRS-M achieved in the EG could be associated with greater improvement in BBS and TUG than those in the CG. The mean pre-to-post change in BBS of EG was from 5.92 to 10.05, compared to 2.40 to 7.76 in the CG. The minimal clinically important difference on the BBS is 4 points for individuals with balance disorders (Godi et al., 2013). For the TUG, the EG exerted a medium sized effect (d-value, 0.55). The possible mechanism of improved balance ability could be the increased functional connectivity between the cortical and sub-cortical areas of the brain that has been demonstrated during turning compared to walking straight in PD (Handojoseno et al., 2015).

Our study suggests that there is a positive effect of walking turns training on the walking capacity, speed (10MWT) and endurance (6MWT). For the 10MWT, the EG exerted a large effect size (d-value, 1.05). The mean pre-to-post change in 6MWT of the EG was 38.29 to 79.37 m, compared to 15.50 to 48.66 sec in the CG. For the 6MWT, the EG exerted a medium effect size (d-value, 0.62). In this study, both groups showed an increase in the walking speed and endurance, and the EG showed a more significant increase than the CG. We consider that the EG results impacted the qualitative aspect of gait (balance), as well as the quantitative aspect (walking speed and endurance). Walking turns training may increase the ability of individuals with PD by modulating the body segments. Segmental movements of the body in various directions have frequently been emphasized in walking training programs to improve balance and functional motor skills in individuals with neurological disorders (Conradsson et al., 2017). Thus, turning during walking may be an important factor to improve balance and walking ability by promoting the segmental movement of body and postural response (Conradsson et al., 2017). Turning while walking is a complex task incorporating balance and walking capacity, such as deceleration of forward progression and maintenance of the dynamic body stability, while continuing the gait cycle (Chen et al., 2016).

It is reported that the number of falls may be used as a method to validate postural instability (Cakit et al., 2007). The observed fall rate of our participants was approximately 88% at baseline. Cakit et al. (2007) suggested that patient with a history of falls had greater disease severity and significantly higher UPDRS scores than those who had not fallen. In our study, we found that the fall rate changed from 83% to 67% in EG. We thought that this was related to the improvement of balance (BBS and TUG).

A few limitations to this study warrant consideration. First, the small sample size is a major limiting factor that prevents the generalization of our results to the entire population with PD. Therefore, our results must be validated by further studies with a larger sample size. Based on a power analysis from the results of our study (d, 1.1; α, 0.05; 1- β, 0.95), 19 participants in each group would be necessary to statistically confirm our results. Secondly, the length of follow up prevents us from assessing the long-term impact of the observed effects. Thirdly, the analysis of trunk motion of participants is not conducted. Thus, the results should be considered with caution.

Ⅴ. Conclusion

The results of this study were that the walking turns plus treadmill training group showed significantly more improvement than the conventional training plus treadmill training group in the UPDRS- M, BBS, TUG, 10MWT, and 6MWT, over time. Our study indicates that a balance and walking disorder, which lead to immobility and disability in PD, can improve after walk turns training. The positive effects noted in our study support the need for rehabilitation in PD. The 4-week walk turning plus treadmill training, which focused on modulating the steps for turning, indicates an improvement in balance and walking in patients with PD. Therefore, the walk turning plus treadmill training could be incorporated into the exercise program of individuals with PD to improve the postural balance and walking performance.

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