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Gait and step training to reduce falls in Parkinson's disease

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Abstract. *Introduction:* Frequent falls and risk of injury are evident in individuals with Parkinson's disease (PD) as the disease progresses. There have been no reports of any interventions that reduce the incidence of falls in idiopathic PD.
Purpose: Assess the benefit of gait and step perturbation training in individuals with PD.
Design: Randomized, controlled trial.
Setting: Outpatient research, education and clinical center in a tertiary care Veterans Affairs Medical Center.
Outcome measures: Gait parameters, 5-step test, report of falls
Subjects: Eighteen men with idiopathic PD in stage 2 or 3 of the Hoehn and Yahr staging
Methods: Subjects were randomly assigned to a trained or control group. They were asked about any falls 2 weeks prior to and after an 8 week period. Gait speed, cadence, and step length were tested on an instrumented walkway. Subjects were timed while stepping onto and back down from an 8.8 cm step for 5 consecutive steps. Gait training consisted of walking on a treadmill at a speed greater than over ground walking speed while walking in 4 directions and while supported in a harness for safety. Step training consisted of suddenly turning the treadmill on and off while the subject stood in the safety harness facing either forwards, backwards, or sideways. Training occurred 1 hour per day, three times per week for 8 weeks. A two-factor (time and group) analysis of variance with repeated measures was used to compare the groups.
Results: Substantial reduction occurred in falls in the trained group, but not in the control group. Gait speed increased in the trained group from 1.28 ± 0.33 meters/sec to 1.45 ± 0.37 meters/sec, but not in the control group (from 1.26 to 1.27 m/s). The cadence increased for both groups: from 112.8 to 120.3 steps/min for the trained group and 117.7 to 124.3 steps/min for the control group. Stride lengths increased for the trained group, but not the control group. The 5-step test speed increased in the trained group from 0.40 ± 0.08 steps/sec to 0.51 ± 0.12 steps/sec, and in the control group (0.36 ± 0.11 steps/sec to 0.42 ± 0.11 steps/sec).
Conclusion: Gait and step perturbation training resulted in a reduction in falls and improvements in gait and dynamic balance. This is a promising approach to reduce falls for patients with PD.

Keywords: Parkinson's disease, falls, gait training, rehabilitation

1. Introduction

Gait abnormalities are one of the most common disabling conditions in Parkinson's disease (PD) [31]. Individuals with PD have a gait pattern characterized by hesitant, shuffling steps that are short and quick. Difficulties in gait initiation and changes in postural control

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are also problematic [2]. Turning is difficult because it requires a series of gait initiations [3]. Freezing and motor blocks, balance deficits, and frequent falls occur during latter stages of PD. Although antiparkisonian medications improve gait, their effectiveness decreases as the disease progresses. Other forms of interventions have limited impact on gait and balance over time. Therefore, there is a need to explore alternative, rehabilitation interventions to improve gait and balance impairments.

Few studies have tried to isolate different components of rehabilitation interventions. Several studies examined the efficacy of using motor control strategies in patients with PD. Stefaniwsky and Bilowit [38] comparing 10 patients with PD and 5 healthy subjects found that movement initiation was significantly slower in the patients with PD compared to healthy subjects. After daily in-home exercises using sensory stimuli to facilitate movement initiation for a 3 week period, the patients demonstrated comparable movement initiation speeds to the healthy individuals. In another study, standing weight shifting was compared in 34 people with stage I or II PD and 34 neurologically intact subjects [15]. Reduced ability to shift weight from one lower extremity to another was observed in both disability stages of PD when compared to the controls. All groups improved weight shifting responses using continuous video feedback when compared to end of trial feedback. Although this study only used a single session, and did not use a training strategy over several weeks, it supports the notion that sensory stimuli can influence movement control in individuals with PD when performing complex motor tasks. In a similar fashion, visual and auditory sensory cues as well as the anti-parkinsonian medication levodopa can modify gait movements and muscle activation in some patients with PD [21,28,41]. Schenkman et al. [34] reported that improved spinal flexibility improved measures of balance in individuals with PD. Similarly, posteroventral pallidotomy has been reported to influence postural control in PD [30].

Studies have been published demonstrating that humans with neurological conditions can improve gait by either training ambulation on a treadmill with no body weight support or with body weight support [6,7,10,17, 27,43,44,46–48]. The degree of locomotor recovery has been shown to be significantly related to the training used in patients with neurological conditions [10,29, 43]. Other studies comparing task-specific gait training with body-weight supported training report that similar gait outcomes occur with either training strategy in individuals with neurologic deficits [16,23]. Several recent reports suggest that ambulation training using body weight support for individuals with Parkinson's disease (PD) results in improvements in gait [12,19,20]. These reports were either case reports or of small sample sizes. The studies used varying training intervals, or used no balance or fall measures.

We previously demonstrated with a case report that a gait and step training strategy improved gait and balance, and reduced falls in an individual with a parkinsonian syndrome [40]. The purpose of this article is to report the results of a pilot controlled study of gait and step training in individuals with idiopathic PD who had reduced balance, and/or recent problems with falls.

2. Methodology

2.1. Sample

Eighteen men with idiopathic PD diagnosed at the Houston VA Parkinson's Disease Research, Education and Clinical Center (PADRECC) were recruited for this study. The demographic and clinical characteristics of the subjects are shown in Table 1. Inclusion criteria were: 1) postural instability-gait difficulty predominant PD, 2) experiences with freezing episodes, and/or a history of falls, 3) stable regimen of antiparkinsonian medications, 4) ability to stand and walk with or without assistance, 5) stage 2 or 3 of the Hoehn and Yahr staging [11], and 6) scores of moderate or higher on all scales of the Neurobehavioral Cognitive Status Examination (Cognistat) [24]. The subjects provided informed consent as approved by the Institutional Review Boards of Baylor College of Medicine and Texas Woman's University, and were randomly assigned to either the training or control groups.

2.2. Measurement

Subjects were tested in the morning, and were asked to take their morning dose of medications about 1 hour prior to the test in order to assure that subjects were at their best 'on' state. All testing except for the fall record was conducted by a physical therapist and a technician who were blinded to the subject's group assignment. A physical therapist who was not blinded to group assignment obtained fall records.

Table 1
Subject characteristics by group

Variable	Group			
	Trained ($n = 9$)		Control ($n = 9$)	
	Mean	SD	Mean	SD
Age	71.3	7.4	73.7	8.5
Height (m)	1.81	0.07	1.78	0.07
Weight (kg)	83.5	12.3	83.4	15.0
Years since Diagnosis	7.1	5.1	8.1	4.4
Hoehn & Yahr Stage	2.8	0.35	2.9	0.17
UPDRS Motor Score[a]	28.3	13.6	30.4	8.0
Activities of Daily Living	82.2	8.7	80.6	7.3

[a]Unified Parkinson's Disease Rating Scale.

2.2.1. Gait parameters

Gait was assessed by *gait speed, cadence, and stride length*. The patient was asked to walk as fast as possible with any assistive device necessary on an instrumented, 3-meter walkway (GAITRite, CIR Systems Inc., PO Box 4402, Clifton, NJ) while the subject was guarded by a physical therapist to prevent falls. The patient completed 2 trials on the walkway, and the average of the results from these 2 trials was used as data. Gait speed was calculated from the time to walk 3 meters as meters/second. Cadence was the number of steps/sec., and the stride length was the length (in centimeters) of two consecutive footfalls of the same extremity. Spatial and temporal parameters measured with the GAITRite have been reported to be reliable (ICC > 0.93) and valid (ICC > 0.93) [8,18]. Gait speed has also been reported to be a reliable measure for individuals with PD with intra-class correlation coefficients of 0.87 [33].

2.2.2. Freezing of gait

The provocative test for freezing and motor blocks was used to assess freezing [42]. The subject was asked to stand, walk 5 meters between two chairs that were placed 1 meter apart in the path, turn 180°, and walk back through the chairs, and sit back down. The rater scored start hesitation, sudden transient blocks that interrupt gait, motor blocks on turning, motor blocks on reaching a target (chairs), and motor blocks when walking through the chairs (narrow space). The tasks were rated as not observed ($0 =$ no) or observed ($1 =$ yes). The maximum score for freezing was 5.

2.2.3. Fall frequency

Each subject was contacted daily by telephone for a period of 2 weeks prior to starting the 8 week training or control sessions. The patient was asked if he fell that day, under what circumstances, and whether or not the fall resulted in any injuries. The number of falls and fall history for this two-week period was recorded. This was repeated for the two-week period after the completion of the training.

2.2.4. Balance parameters

Dynamic balance was assessed by timing 5 consecutive steps up and back down a 8.8 cm step (step test). The patient was asked to perform the steps as quickly and safely as possible while being guarded for safety. This test has been reported to be reliable in elderly subjects [22].

2.2.5. Patient characteristics

The investigators asked each patient for a history of the PD disease and medications. Cognitive status was determined by the Cognistat, a 10-item, reliable measure [24]. The Unified Parkinson's Disease Rating Scale (UPDRS), a standardized measure of PD impairment, was administered at baseline [9].

2.3. Procedures

After the subject gave informed consent, the subject was asked to provide demographic information, a history of his PD, and current medications. An investigator completed the Cognistat and the UPDRS. If the subject met the inclusion/exclusion criteria, he was randomly assigned to either the gait and step training intervention group or a control group who only received the pre- and post-testing. An investigator called the subject daily for 2 weeks to establish a falls history prior to completing the pre-testing and after the 8-week period for both groups.

2.3.1. Gait and step training

Subjects assigned to the training group received training 3 times per week for 8 weeks. The subject was fitted with a harness that was attached snugly around the trunk (Quinton Pneu-Weight harness, Seattle, WA). The harness was attached to a pneumatic support system po-

Table 2
Gait and step test results by group

Variable	Group			
	Trained ($n = 9$)		Control ($n = 9$)	
	Pre	Post	Pre	Post
Gait speed (m/s)	1.28 (0.33)	1.45 (0.37)	1.26 (0.19)	1.27 (0.25)
Cadence (steps/min)	112.8 (7.2)	120.3 (8.2)	117.7 (13.0)	124.3 (15.1)
Stride length right (cm)	66.5 (13.7)	71.1 (14.4)	60.2 (13.3)	60.4 (10.0)
Stride length left (cm)	68.7 (14.9)	72.9 (17.0)	61.0 (15.4)	60.8 (10.9)
Step test (steps/s)	0.40 (0.08)	0.51 (0.12)	0.36 (0.11)	0.42 (0.11)

sitioned over the treadmill (Quinton Pneu-Weight Support System, Seattle, WA). The harness and support system was used for safety in case the subject fell. No body-weight support was used. The subject was also guarded by a physical therapist during the training. Initially, the treadmill speed was set at the fastest overground speed noted on the pre-test while the subject walked in a forward direction on the treadmill. The patient walked forward in the support system for 5 to 7 minutes each session. The subject was then asked to walk at his fastest, self-selected speed that allowed a full step while walking backwards on the treadmill for 5 to 7 minutes. The subject then walked at his fastest, self-selected speed that allowed a full step sideways both right and left. The subject walked sideways for 2 to 3 minutes in each direction. The therapist cued the patient verbally, and assisted the patient stepping if necessary. The treadmill speed was reassessed at the end of every training week, with the goal of gradually increasing the treadmill speed and time as training progressed. The subject was allowed to rest if fatigue occurred during gait training.

After a 5 minute rest, the patient underwent step training while standing on the treadmill in the support system when the treadmill was suddenly turned on at a sufficiently fast speed to perturb the subject's standing balance, but not fall. The subject was asked to take several steps to recover balance in response to this sudden perturbation. The treadmill was then turned off, and the subject had to recover balance again. The step training occurred while the patient stood in four directions: forward, backwards, and sideways right and left. Initially, the subject was allowed to hold the handrail, but, as training progressed, the subject stood without holding the handrail during perturbations and the treadmill speed was gradually increased. The number of trials in each position varied, but generally consisted of 15–20 perturbations in the forward and backward direction and 10 to 15 for both right and left sideways directions. If the subject fatigued during step training, the subject was allowed to take a short rest. If a subject missed more than 3 training sessions in a row for medical reasons or inability to participate, the subject could be discontinued from the study. If an occasional session was missed, the subject was allowed to make up the session until a total of 24 training sessions had occurred before post-testing.

2.4. Data analysis

The data were analyzed descriptively in order to determine group means and standard deviations for the measures. Group means were compared with a multivariate analysis of variance for repeated measures with two factors (time and group). Post-hoc analysis was used for significant differences. The alpha level was set at < 0.05.

3. Results

3.1. Pre- and post-gait outcomes

There were no significant differences on the subject characteristics between the trained and control groups (Table 1). Overall, the subjects were moderately impaired from the PD. Descriptive statistics for gait speed, cadence, right and left stride length, and the step test are shown in Table 2. Significant differences occurred post-test compared to pre-test for the trained group for gait speed, cadence and the step test (Table 3). Significant differences occurred for the control group on post-testing compared to pre-testing on cadence and the step test. No significant differences occurred pre-

Table 3
Results of the analyses of the effects of time and group by time for each of the measures

Variable	Sum of squares	df	Mean square	F	Sig.	Power
Time						
Gait speed	7.86	1	7.86	8.81	0.009	0.80
Cadence	440.3	1	440.3	9.26	0.008	1.0
Stride Length Right	50.43	1	50.43	1.19	0.29	0.18
Stride Length Left	33.25	1	33.25	0.94	0.35	0.15
Step Test	6.82	1	6.82	20.2	0.000	0.99
Group by Time						
Gait Speed	4.95	1	4.95	5.55	0.032	0.60
Cadence	1.91	1	1.91	0.04	0.84	0.05
Stride Length Right	43.6	1	43.6	1.03	0.33	0.16
Stride Length Left	43.6	1	43.6	1.23	0.28	0.18
Step Test	5.21	1	5.21	1.54	0.23	0.22
Error						
Gait Speed	0.143	16	8.92			
Cadence	760.9	16	47.6			
Stride Length Right	676.8	16	42.3			
Stride Length Left	565.9	16	35.4			
Step Test	5.42	16	3.39			

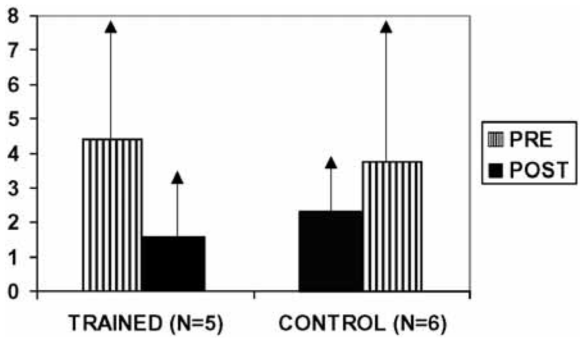

Fig. 1. Reported falls prior to and following an 8 week period for the trained and control groups.

to post-test for stride length, although the right and left stride length increased for the intervention group but not for the control. The only significant gait measure between the groups was for post-test gait speed. None of the subjects demonstrated freezing during our motor provocation testing.

3.2. Falls outcomes

Eleven subjects out of the 18 reported falling during the 2 week period prior to the start of the study. Those in the trained group experienced a significant decrease in reported falls after the intervention compared to before. However, the difference between the groups is not statistically significant although the trained group experienced half the falls during follow-up compared to the control group (Fig. 1).

4. Discussion

This is the first report of reduced falls in individuals with PD as a result of a physical training intervention. This is an important finding since falling is a serious problem as the disease progresses that can lead to injury and possibly death. This observation was accompanied by a statistically significant increase in gait speed, cadence, and the step test in the trained group. Although not significant, the stride length also increased in the trained group. We conclude that reduced falls were associated with improvements in gait speed and dynamic balance.

Ashburn and her group compared individuals with PD who were fallers and non-fallers and reported that 40% of the subjects had fallen within the last 12 months [1]. The fallers reported a median of 3 falls in 12 months. Furthermore, the fallers were more impaired and had poorer measures of mobility and balance than the non-fallers. Seventy-five percent of the fallers were either in Stage 2 or 3 of the Hoehn & Yahr staging, and, in contrast to our cohort, had lower UPDRS motor scores (22 for the fallers compared to 28.3 and 30.4 for our study). We only recorded falls for two 2 week periods before and after the 8 weeks of training; therefore, only 11 of our subjects experienced a fall during these times (5 in the trained group and 6 in the control group). The trained group had half the number of falls in the follow-up period compared to the control group. A longer period of time to observe falls is warranted in a follow-up study.

The gait speeds of our subjects were within normal limits for their age; however, we asked them to walk at their fastest, but safest speed during the tests. Our control group had similar speeds during the pre- and post-tests, but did not show an improvement. Several authors reported increased gait speeds after treadmill training [19,26] or repetitive training of compensatory stepping in individuals with PD [13]. Pohl and his group [26] reported increased gait speeds and stride length immediately after a single session of either speed-dependent treadmill training or limited progressive treadmill training compared to conventional gait training or a no-intervention waiting period. Miyai et al. [19] reported an increase in gait speed from 0.93 m/s to 1.18 m/s following gait training, using body-weight supported treadmill training 3 days/week for 1 month. In another study, patients with PD underwent training consisting of pull perturbations for 14 days and demonstrated an increase of gait speed from 0.64 m/s to 0.77 m/s [13]. This increase was accompanied by an increase in cadence (0.80 steps/s to 0.87 steps/s) and step length (0.80 m to 0.87 m), but there was no control group comparison.

We located only one study that used a dynamic balance test somewhat similar to the one used in this study before and after a physical therapy intervention [37]. Forty individuals with PD underwent a program consisting of exercise, cued walking, stepping, and motor function strategies for 30 days. The program resulted in improvements in static balance (timed tandem and single limb stance), as well as the number of single limb steps in 15 seconds for both groups of patients who fell and did not fall. The initial performance of our subjects on the 5-step test (0.40 steps/s for the intervention group and 0.36 steps/s for the control) is similar to values we have previously reported for elderly subjects 0.30 steps/s) [22]. Although the values do not suggest a deficiency in dynamic balance, the speed of performance of this activity was improved for the trained group.

Our study and others suggest that gait and balance can be improved for people with PD using a variety of motor learning strategies. It is difficult to determine the underlying mechanisms for these improvements. We used a multidirectional gait and step training strategy for training based on the outcomes of a single case study [40]. Morris suggests that visual and auditory cueing as well as attentional strategies can impact gait and balance in PD [21]. The treadmill could provide some visual cueing during walking, and auditory cues could have occurred during step training when the treadmill was turned on and off. Step perturbation training in community-dwelling older adults improved voluntary step initiation time [31]. Improved movement initiation could also be related to the outcomes we observed in our study.

Falls can be reduced in older adults with gait and balance training programs, and fall reduction is associated with improvements in gait and balance abilities in elder fallers [35]. Gait disturbances and instability are often linked to falls in individuals with PD. Our data suggests that improvements in fastest walking speed and dynamic balance may contribute to a reduction in falls in PD.

This study has a number of limitations. Our sample size was relatively small, especially given the variability in individuals with PD. We choose to randomly assign our subjects to the intervention as well as a no-treatment group in order to control for this variability. As a result, we saw no difference between groups in some of our measures before and after intervention (cadence and stride length) even though the measure changed for the trained group but not for the control group (stride length) or had a larger improvement for the trained group (step test). Interestingly, both groups increased cadence, while only the trained group had an increase in stride length. Increased stride length is frequently a desired outcome for physical therapy gait training with this population [21]. The power of our pre- and post-training measures were high for gait speed (0.80), cadence (1.0), and the step test (0.99). The power for our group comparisons were modest for gait speed (0.60), and low for all other measures. Despite this, these results are promising enough to expand this small study to a larger trial. Our fall record was a self-report from either the patient or a caregiver, and was collected by an investigator who was not blinded to group assignment, both of which could lead to some bias in the number of reported falls. One potential outcome of our training could be a reduced fear of falling; however, we did not have a measure for falls efficacy. Our training was task-specific to some of the challenges to balance experienced by these patients, such as difficulty stepping or walking backwards or sideways. Other approaches may produce different outcomes. We were not able to address the intensity, frequency, and duration of the training intervention in this study. Therefore, we do not know if the intervention we tested is most optimal.

5. Conclusion

Task-specific gait and step training resulted in a reduction in falls and improvement in gait speed and dynamic balance in individuals with postural instability gait difficulty pre-dominant PD and moderate disease symptoms. This is a promising approach that warrants further research.

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