Clinical Rehabilitation 2007; **21:** 698–705

The effects of incremental speed-dependent treadmill training on postural instability and fear of falling in Parkinson's disease

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Received 6th October 2006; returned for revisions 28th November 2006; revised manuscript accepted 15th December 2006.

Objective: To detect the effectiveness of incremental speed-dependent treadmill training on postural instability, dynamic balance and fear of falling in patients with idiopathic Parkinson's disease.
Design: Randomized controlled trial.
Setting: Ankara Education and Research Hospital, 2nd PM&R Clinic, Cardiopulmonary Rehabilitation Unit.
Subjects: Fifty-four patients with idiopathic Parkinson's disease in stage 2 or 3 of the Hoehn Yahr staging entered, and 31 patients (21 training, 10 control) had outcome data.
Interventions: Postural instability of patients with Parkinson's disease was assessed using the motor component of the Unified Parkinson's Disease Rating Scale (UPDRS), Berg Balance Test, Dynamic Gait Index and Falls Efficacy Scale. Twenty-one patients with Parkinson's disease participated in an eight-week exercise programme using incremental speed-dependent treadmill training. Before and after the training programme, balance, gait, fear of falling and walking distance and speed on treadmill were assessed in both Parkinson's disease groups.
Main measures: Walking distance and speed on treadmill, UPDRS, Berg Balance Test, Dynamic Gait Index and Falls Efficacy Scale.
Results: Initial total walking distance of the training group on treadmill was 266.45 ± 82.14 m and this was progressively increased to 726.36 ± 93.1 m after 16 training session ($P < 0.001$). Tolerated maximum speed of the training group on treadmill at baseline was 1.9 ± 0.75 km/h and improved to 2.61 ± 0.77 km/h ($P < 0.001$). Berg Balance Test, Dynamic Gait Index and Falls Efficacy Scale scores of the training group were improved significantly after the training programme ($P < 0.01$). There was no significant improvement in any of the outcome measurements in the control group ($P > 0.05$).
Conclusions: Specific exercise programmes using incremental speed-dependent treadmill training may improve mobility, reduce postural instability and fear of falling in patients with Parkinson's disease.

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10.1177/0269215507077269

Introduction

Parkinson's disease is a progressive, idiopathic, neurodegenerative disorder. Due to depletion of dopamine-producing neurons in the basal ganglia of the brain, patients with Parkinson's disease experience deterioration in balance and postural control, and progressive reduction in the speed and amplitude of movements.[1,2]

Movement disorders are the hallmark of Parkinson's disease and can severely compromise an individual's ability to perform well-learned motor skills such as walking, writing, turning around and transferring in and out of bed.[2,3] Due to neurotransmitter imbalances in the brain, people with Parkinson's disease progressively lose flexibility and adaptability in their locomotor responses and walk with a stereotypical short-stepped, narrow-based shuffling gait for a range of different tasks. They also experience difficulty in modulating gait parameters according to changing task demands.[2]

Postural instability, which is highly disabling and poorly treatable, is one of the cardinal symptoms of Parkinson's disease.[4–7] Alterations in postural control during standing, when responding to unexpected destabilizing events or voluntary movements[8] may increase the risk of falling, and evidence suggest that falls are very common for patients with Parkinson's disease.[4,6,8–10] Falls resulting from postural instability, freezing and involuntary movements[6] may lead to considerable morbidity and even mortality in patients with parkinsonism.[4]

Optimal management of Parkinson's disease involves both pharmacologic treatment (dopamine replacement therapy) and encouragement of physical activity.[11–13] Postural instability in Parkinson's disease is resistant to conventional pharmacotherapy.[10,14] Antiparkinson medication does not reduce balance problems, and two-thirds of falls occur when patients consider that their symptoms are well controlled. It is reported that development of improved therapeutic strategies to reduce postural instability are needed because conventional pharmacotherapy may paradoxically aggravate falls and thus increase the risk of falling by ameloriation of other symptoms, improving mobility without improving balance.[10]

Recent training techniques in neurologic rehabilitation include sport-physiologic approaches such as aerobic exercise and circuit training.[15,16] As a supplement to conventional therapies, treadmill training can significantly improve the results of other gait training therapies.[17] As a result of some studies, treadmill training with partial body-weight support and speed-dependent treadmill training in hemiparetic and Parkinson's disease patients seemed promising in the restoration of gait patterns.[15,17–19] In these studies, gait analysis, gait speed and Unified Parkinson's Disease Rating Scale (UPDRS) were used as outcome measurements before and after treadmill training. Only one study used a dynamic balance test (step test) and frequency of falling before and after gait and step training on a treadmill.[20]

The aim of the current study was to investigate postural instability and to detect the effectiveness of an incremental speed-dependent treadmill training programme on postural instability, dynamic balance and fear of falling in patients with idiopathic Parkinson's disease.

Methods

To be included in this study, subjects were required to be medically stable, able to walk a 10 m distance at least three times with or without an assistive device, and able to provide informed consent. Subjects were excluded if they had neurological conditions other than idiopathic Parkinson's disease, scored greater than 3 on the Hoehn and Yahr Disability Scale,[21] or scored less than 20 on the Mini-Mental State Examination.[21] Subjects were also excluded if they exhibited postural hypotension, cardiovascular disorders, class C or D exercise risk by the American College of Sports Medicine (ACSM) criteria[22] or musculoskeletal disorders, visual disturbance or vestibular dysfunction limiting locomotion or balance. Patients continued their normal schedule of medications, including levodopa and/or dopamine agonist drugs. Medications were not modified throughout the study.

The local medical ethics commitee approved this study and all patients gave informed consent before the assessment.

Between October 2004 and June 2005, a total of 62 patients with Parkinson's disease who fulfilled the UK Parkinson's Disease Society Brain Bank Criteria[23] were eligible and fulfilled the inclusion criteria. Six patients refused to participate and 54 subjects provided informed consent to participate in this study.

These 54 patients were randomly separated into treadmill training and control groups. Six of the 27 training group patients withdrew from the study. Nine of the 27 control group patients could not come to the final visit after eight weeks, the medications of four patients had been changed and four patients were unwilling to walk on the treadmill for the evaluation of walking distance and tolerated maximum speed (Figure 1).

All baseline assesssments were done by the same investigator who was blinded to the patients' group assignment approximately 1 hour after antiparkinson medication, with the patients in the *on* state when they were moving freely and easily without dystonia, excessive rigidity or tremor. The functional status of all Parkinson's disease patients was assessed using the motor component of UPDRS.[21] The UPDRS motor score is a qualitative functional subscoring system which is widely used to estimate postural instability and gait impairment associated with the disease process in Parkinson's disease.[21]

Balance was evaluated using the Berg Balance Test, which rates performance from 0 (cannot perform) to 4 (normal performance) on 14 different tasks, including ability to sit, stand, reach, lean over, turn and look over each shoulder, turn in a complete circle and step.

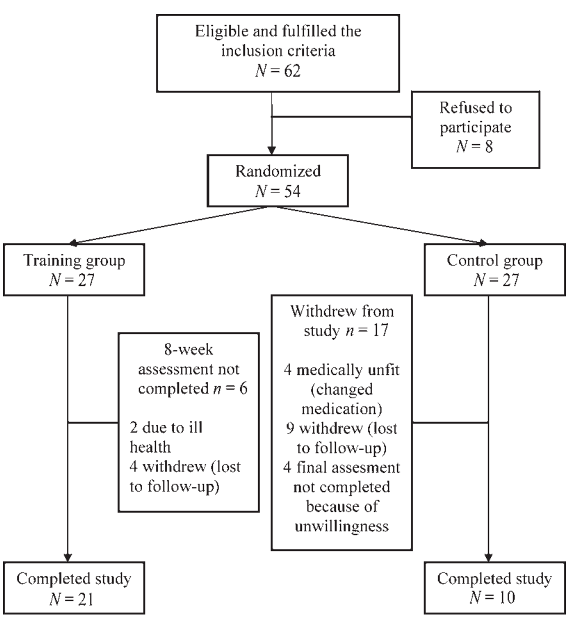

Figure 1 Study design – flow of participants through the study.

The total possible score is 56, indicating excellent balance. A score of 0 to 20 indicates a high risk, 21–40 indicates a medium risk, and 41–56 indicates a low risk of falling.[24,25]

The Dynamic Gait Index was used to evaluate the ability to adapt gait to changes in task demands. The Dynamic Gait Index rates performance from 0 (poor) to 3 (excellent) on eight gait tasks, including gait on even surfaces, gait when changing speeds, gait while performing head turns, stepping over or around obstacles, and pivoting during walking and stair-climbing. Scores on the Dynamic Gait Index range from 0 to 24. Scores of 16 or less indicate a high risk of falls, scores above 19 indicate a decreased risk of falls. The Dynamic Gait Index is a valid predictor of fall status among the elderly and patients with balance dysfunction and multiple sclerosis.[25–28]

Fear of falling was detected using the Falls Efficacy Scale.[29] The Falls Efficacy Scale is a 10-item rating scale to assess confidence in performing daily activities without falling. Each item is rated from 1 = extreme confidence to 10 = no confidence at all. Participants who reported avoiding activities because of fear of falling had higher Falls Efficacy Scale scores, representing lower self-efficacy or confidence, than those not reporting fear of falling.

The training group participated in an eight-week exercise programme including stretching, range-of-motion exercise and treadmill training. The history of falls and the use of assistive devices were noted. Before acceptance into the exercise programme, all subjects were administered stress tests to determine cardiovascular tolerance. Exercise tests were performed using Modified Bruce protocol.[22] During the exercise tests, electrocardiograms and vital signs were monitored continuously. Testing was discontinued according to the ACSM guideline indications for terminating exercise testing criteria., and such individuals were excluded from this study.

The patients were observed during treadmill training by a physiatrist, who gave no assistance in the actual performance of the movements. Maximum-tolerated walking speed was determined before the training session. This speed was then halved and used for a 5-minute warm-up period. After the warm-up period the belt speed was increased by increments of 0.6 km/h every 5 minutes. When the belt speed was increased to the highest speed at which the patient could walk safely and without stumbling. This maximum-achieved belt speed was maintained for

5 minutes and then followed by 0.6 km/h decrements. The patient maintained the rest of the treadmill session with this speed for 15 minutes. If the patient was unable to maintain this speed, it was reduced by 0.6 km/h in the next phase. If the patient successfully completed 5 minutes of walking at the maximum speed, the speed was increased during the next phase by 0.6 km/h. The treadmill was run at 0% incline. The treadmill training session lasted for 30 ± 5 minutes.

The walking distance and walking speed on treadmill, Berg Balance Test, Dynamic Gait Index and Falls Efficacy Scale scores were used as outcome measures, and all outcome measures were assessed by the same physician who was blinded for the pretraining test results.

Data were analysed with SPSS version 11.0 for Windows. The Mann–Whitney U-test was performed to compare Parkinson's disease groups. The Wilcoxon's test was used to compare the outcome parameters before and after treadmill training. Spearman's correlation test was used to detect correlations between UPDRS, Berg Balance Test, Dynamic Gait Index, Falls Efficacy Scale scores and history of falling, assistive device use and disease duration. Statistical significance was accepted at $P < 0.05$. Results are reported as mean ± standard deviation or error of the mean.

Table 1 Demographic features of patients with Parkinson's disease

	Patients (n = 31)
Sex (female/male)	15/16
Age (years)	71.8 ± 6.4
Duration of Parkinson's disease (years)	5.58 ± 2.9
UPDRS motor subscale	18.14 ± 9.32
Medications	
Levodopa monotherapy	n = 3
Dopamine agonist monotherapy	n = 5
Levodopa-dopamine agonist combined therapy	n = 13

UPDRS, Unified Parkinson's Disease Rating Scale.

Results

Descriptive subject information about 31 patients (21 training, 10 control) concerning age, sex, duration of disease, medications and mean UPDRS motor subscale is described in Table 1.

Initial total walking distance of the training group on treadmill was 266.45 ± 82.14 and this was progressively increased to 726.36 ± 93.1 m after 16 training session. Tolerated maximum speed of the training group on the treadmill at baseline was 1.9 ± 0.75 km/h and improved to 2.61 ± 0.77 km/h. The mean Berg Balance Test, Dynamic Gait Index and Falls Efficacy Scale scores of the training and control groups at baseline (0 week) are shown in Table 2 and outcome measures at eight weeks and the mean change of outcome measures before and after training period are shown in Table 3. There were significant changes for the outcome measures between the baseline and eight weeks values for the two groups. The baseline values of the control group were slightly better than those of the training group, but there was no statistical significant difference between the groups ($P > 0.05$). In the training group, walking distance and tolerated maximum speed on treadmill, Berg Balance Test, Dynamic Gait Index and Falls Efficacy Scale scores improved significantly after the training programme ($P < 0.01$). There was no significant improvement in any of the outcome measurements in the control group ($P > 0.05$) (Table 3).

Only two trained Parkinson's disease patients showed ventricular extrasystole as a cardiac symptom during the training session, but they were not dropped from the study. All 21 patients who underwent treadmill training completed the training programme. There were no side-effects from treadmill training requiring discontinuation of the therapy.

Seven of all 31 patients (22%) reported having fallen in the previous 12 months. Sixteen (51%) of all patients used assistive devices. Berg Balance Test scores of patients with Parkinson's disease were correlated negatively with history of falls and use of assistive device ($P < 0.001$, $r = -0.743$, $P < 0.05$, $r = -0.498$, respectively). UPDRS motor subscale scores were correlated negatively with Berg Balance Test and Dynamic Gait Index scores ($P < 0.001$, $r = -0.683$, $P < 0.05$, $r = -0.567$, respectively) and correlated positively with history of falls ($P < 0.01$, $r = 0{,}643$).

Discussion

Our study has shown that postural instability can be determined using qualitative measures in clinical

Table 2 Baseline measures of treadmill training group and Parkinson's disease control patients

	Training group (n = 21)	Control group (n = 10)	P-value
BBT score	37.0 ± 9.41	42.6 ± 9.37	>0.05
DGI score	11.81 ± 5.58	16.3 ± 5.2	>0.05
FES score	37.72 ± 9.29[a]	26.8 ± 8.06[a]	>0.05
Walking distance on treadmill (m)	266.45 ± 82.14[a]	348.2 ± 89.24[a]	>0.05
Tolerated maximum speed on treadmill (km/h)	1.9 ±0.75	1.92 ± 0.92	>0.05

[a]Mean ± standard error.
BBT, Berg Balance Test; DGI, Dynamic Gait Index; FES, Falls Efficacy Scale.

Table 3 Outcome measures of training group and control group

Group	Control group		Training group	
	At 8 weeks	Change	At 8 weeks	Change
Item	$N = 10$	$N = 10$	$N = 21$	$N = 21$
BBT score	41.4 ± 10.65	–1.42 ± 0.23[a]	44.09 ± 7.11[¥]	7.09 ± 1.27[a]
DGI score	16 ± 5.35	0.85 ± 0.04[a]	16.54 ± 3.35[¥]	4.72 ± 0.88[a]
FES score	29.2 ± 9.87[a]	4.23 ± 0.12[a]	25.45 ± 7.46[a¥]	–12.27 ± 6.56[a]
Walking distance on treadmill (m)	362 ± 90.70[a]	35.47 ± 6.32[a]	726.36 ± 93.18[a¥]	459.9 ± 32.99[a]
Tolerated maximum speed on treadmill (km/h)	1.86 ± 0.59	–0.4 ± 0.02[a]	2.61 ± 0.77[¥]	7.09 ± 0.73[a]

[a]Mean ± standard error.
[¥]$P < 0.01$.
BBT, Berg Balance Test; DGI, Dynamic Gait Index; FES, Falls Efficacy Scale.

practice and incremental speed-dependent treadmill training may produce improvement in mobility and reduce fear of falling in patients with Parkinson's disease.

The study by Protas *et al.* was the first to determine balance and fall measurements after gait and step training on a treadmill. They assessed gait speed, cadence, stride length, dynamic balance and fall frequency in nine trained and nine untrained Parkinson's disease patients. After two weeks of training, they found that task-specific gait and step training resulted in a reduction in falls and improvement in gait speed and dynamic balance.[20] In our study, which was similar to that of Protas *et al.*, we evaluated balance and gait parameters before and after treadmill training. Additionally, we used the Berg Balance Test and Dynamic Gait Index to evaluate balance and gait and we also used the Falls Efficacy Scale to detect fear of falling, which was not used before. Protas *et al.* gradually increased the speed and time on the treadmill at the end of every training week. We used an incrementally increased speed protocol in each training session.

In another study, Pohl *et al.* used a speed-dependent treadmill training method in early Parkinson's disease patients. They increased the belt-speed to the highest speed in a period of 1–2 minutes per session with recovery periods and they concluded that speed-dependent treadmill training and limited progressive treadmill training are more effective than conventional gait therapy in improving gait parameters after one training session. Their results also showed that the immediate effects of treadmill training with structured speed variation are comparable to the effects of training without speed increases.[15] In our study, treadmill belt-speed was incrementally increased without a recovery period.

Miyai *et al.*[18] and Pohl *et al.*[15] suggested that treadmill training in patients with Parkinson's disease may be more effective than gait training without the use of treadmill. Treadmill training forces the Parkinson's disease patients to lengthen their stride, which may be an important factor in their gait improvement. Several researchers reported that treadmill training with or without body-weight support is effective in improving the mobility in patients with stroke and spinal cord injury. Reduced energy expenditure and lowered cardiovascular demands were also observed in stroke patients who underwent treadmill training.[15,17–20,30] As in these studies, Miyai *et al.* showed that body-weight supported treadmill training produces greater improvement in activities of daily living, motor performance and ambulation than does physical therapy in Parkinsonian patients. They reported that cortical reorganization, especially in the supplementary motor area might also be a possible mechanism underlying the improvement.[18] Using a different method, we showed that incremental speed-dependent treadmill training markedly improved balance, walking speed and walking distance on treadmill in patients with Parkinson's disease.

Postural instability leads to gait disturbances and fear of falling. Accurate assesment of postural instability and prevention of falls are significant issues for patients with Parkinson's disease. Fear of falling should be considered as an important, independent risk factor in the assesment and treatment of postural instability in patients with Parkinson's disease.[8] Adkin *et al.* showed that an estimate of fear of falling might help to explain quantitative postural instability in Parkinson's disease.[8] The other consequence of a fall may be the development of fear of future falls, which may lead to a decrease in mobility and a decline in functional independence.[4,9] Adkin *et al.* also suggested that, if possible, restoring patient confidence in their ability to perform activities of daily living could be essential to avoid the negative consequences of activity restriction and reduced quality of life.[8]

It is reported that the number of falls in the previous six months may be used as a method for validation of postural instability.[6] The observed fall rates were almost 38–70% for Parkinson's disease patients during 1 year.[4,9] Ashburn *et al.* found that fallers had greater disease severity and significantly higher Hoehn and Yahr grades and UPDRS scores than non-fallers.[31] Several researchers stated that mobility and balance control were more impaired among fallers than non-fallers.[7,10,31] In our study, we found that 22% of our patients were fallers and we did not find significant difference between fallers and non-fallers regarding Berg Balance Test, Dynamic Gait Index and Falls Efficacy Scale values before and after treadmill training. We thought that this was due to our patients' good functional levels because we did not include late-stage and high-grade patients with Parkinson's disease for treadmill training. Most studies found no relation between disease duration and falls. This apparently paradoxical observation is explained by the fact that falls are initially absent early in the course of disease, then become progressively more frequent, but eventually disappear again when patients become increasingly immobilized in late-stage Parkinson's disease.[9] In our study, we found positive correlation between disease duration and history of falls. Although our findings seem to be different from other studies, this result may be because of the effects of pharmacotherapy, which is thought to increase the frequency of falls due to the amelioriation of other symptoms.[10]

It is thought that fear of falling is reported more often in patients with Parkinson's disease due to the altered control of posture and increased incidence of falls observed in this population.[8] A fear of future falls can lead to restriction of daily activities. The reduced mobility causes loss of independence and deprives patients of their social contacts, leaving some patients isolated.[10] Lack of mobility may lead to cerebrovascular disease, joint degeneration, muscle weakness and reduced tendon flexibility. All these factors can negatively affect postural control and increase morbidity and mortality.[9]

Not only Parkinson's disease patients, but also people over the age of 65 years experience balance problems and balance-related injuries.[6,7,9,10,24,25,31] Balance impairment in older adults with longer durations of Parkinson's disease usually does not respond to pharmacological treatment, and falls and freezing of gait often respond poorly and sometimes paradoxically to treatment with dopaminergic medication.[9,11,14] Dopaminergic medication can cause balance and gait deficits in Parkinson's disease. Dopaminergic medication can lead to orthostatic hypotension and thereby cause syncopal falls. Persons with Parkinson's disease are five times more likely than healthy older adults to suffer fall-related injuries, such as hip fractures.[11] Within 10 years after diagnosis of the disease, approximately 25% of patients will have developed a hip fracture.[9] The rehabilitation process after such fractures is slower and less successful among patients with Parkinson's disease.[4] Average survival is reduced to approximately seven years, once recurrent falls are present.[9]

Many experts recommend rehabilitation to prevent complications and to maintain or assist with function in patients with Parkinson's disease. Exercise is thought to be an important adjunctive therapy for parkinsonism.[13,18,32,33] Recent reports indicate that strength and balance training improve equilibrium and reduce falls for those with Parkinson's disease. Loss of balance has been shown to be reversible through exercise training in elderly subjects.[34,35] Aerobic walking produced improvements in balance for elderly subjects.[36] Li *et al.* suggested that improved functional balance through Tai Chi training is associated with subsequent reductions in fall frequency in older people.[37] Scandalis *et al.* showed that patients with Parkinson's disease had gains in strength with resistance training similar to normal elderly subjects.[38]

A guiding principle in the rehabilitation of neurologic patients is that a skill will be improved if it is practised. This method can be applied to improve gait speed in patients with Parkinson's disease.[15] For patients with reduced walking ability, increasing walking speed gives a patient a greater behavioural repertoire in everyday life, and it also helps to reduce the risk of falling and resultant morbidity in the general population and in patients with Parkinson's disease.[4,17]

As a result of drop-outs, the major drawback of our study is its small sample size. Further studies are necessary to compare different treatment alternatives with incremental speed-dependent treadmill training in patients with Parkinson's disease.

In conclusion, our results indicated that postural instability, which causes gait disturbances and fear of falling, can be determined using qualitative and quantitative measures. Specific exercise programmes including incremental speed-dependent treadmill training may improve mobility and reduce fear of falling in patients with Parkinson's disease.

Clinical messages

- Postural instability leads to gait disturbances and fear of falling.
- Assessment of postural instability and prevention of falls are important in patients with Parkinson's disease.
- Incremental speed-dependent treadmill training may improve mobility and fear of falling.

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