Effect of Balance Training on Postural Instability in Patients With Idiopathic Parkinson's Disease

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Abstract

Background. Postural instability (PI) is a disabling sign of Parkinson's disease (PD) not easily amenable to treatment with medication. *Objective*. To evaluate the effects of balance training on PI in patients with PD. *Methods*. A total of 64 patients with PI were randomly assigned to the experimental group (n = 33) for balance training or to the control group (n = 31) for general physical exercises. Each patient received 21 treatment sessions of 50 minutes each. Patients were evaluated by a blinded rater before and after treatment as well as 1 month posttreatment using the Berg Balance Scale (BBS), Activities-Specific Balance Confidence Scale (ABC), postural transfer test, self-destabilization of the center of foot pressure test, number of falls, Unified Parkinson's Disease Rating Scale (UPDRS), modified Hoehn and Yahr (H&Y) Staging Scale, and Geriatric Depression Scale (GDS). *Results*. At the end of treatment, the experimental group showed significant improvements in all outcome measures, except for the UPDRS and the H&Y scale. Improvement was maintained at the 1-month follow-up in all outcome measures except for the GDS. No significant changes in performance were observed in the control group. *Conclusions*. A program of balance training can improve PI in patients with PD.

Keywords

equilibrium, postural control, randomized controlled trial, falls, rehabilitation

Introduction

Postural instability (PI) is a common feature of Parkinson's disease (PD), becoming a clinical concern in the middle stage of the progressive illness. PI consists of alterations in postural control strategies during standing tasks, when responding to an unexpected destabilizing perturbation, or when performing voluntary movements.[1] This is a highly disabling disturbance that is difficult to treat and predisposes patients with PD to a loss of equilibrium and unexpected falls.[2]

The mechanisms of PI in PD may involve dysfunction at the level of several neural subsystems. Studies on the pathophysiology of postural control in PD have found abnormalities in the processing of afferent inputs from vestibular, proprioceptive, and visual systems.[3-5] Deficiencies in postural control have also been found to be related to an abnormal choice of postural strategies under different surface conditions.[6] Overall, PI in PD may involve changes in both anticipatory (feedforward) and compensatory (feedback) postural reactions.[7,8]

In regard to the neural subsystems involved in PI pathogenesis, studies of automatic leg responses to sudden platform movements have partially clarified that PD postural abnormalities may not be related to dysfunction of dopamine systems.[9-14] Thus, unlike the situation in bradikinesia, dopaminergic medications may produce a limited improvement in PI.[11,15] In particular, the velocity of postural movements is not improved by drugs,[16,17] and early automatic postural responses are only partially corrected while later occurring postural corrections do not improve at all.[18]

Physiotherapy is perhaps the most commonly used procedure as an adjunct to drug therapy to treat PD movement disorders. However, 2 Cochrane reviews have highlighted the need for more randomized controlled trials to support or

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refute its efficacy.[19,20] Most rehabilitation studies in PD address the treatment of bradykinesia.[21-23] Only recently have a number of studies assessed the effect of balance rehabilitation.[24-29] Although the results seem promising, most studies include a small sample size and methodological limitations such as a limited set of relevant outcome measures.

The main aim of the present study was to evaluate whether training aimed at improving balance control can positively influence postural stability, improve the level of confidence perceived during daily life balance activities, and reduce the frequency of falls in patients with PD. The secondary aim was to assess whether balance training can also have a positive impact on severity of disease and depression in patients with PD. The study was carried out as a randomized controlled trial.

Participants and Methods

Patients

A total of 64 patients suffering from idiopathic PD and PI (Hoehn and Yahr [H&Y] stage 3-4) were recruited from 130 patients attending the PD outpatient department of the G.B. Rossi University Hospital Neurological Rehabilitation Unit (Verona, Italy) from June 2003 to February 2004. Patients' demographic and clinical characteristics are detailed in Table 1.

Before being tested, participants were divided into 2 groups (experimental and control) according to a simple randomization scheme[30] using a randomization list locked in a desk drawer accessible only to the principal investigator (NS).

All participants were outpatients, did not require assistance to rise from chairs or beds, and were not affected by unstable cardiovascular disease or other chronic conditions that could interfere with their safety during testing or training procedures. Patients had no other neurological conditions or mental deterioration[31] (Mini Mental State Examination score >23). With their PD, these participants did not have severe dyskinesias or "on-off" phases. During the study, participants were instructed to take their Parkinson's medications regularly and were tested and trained during the on phase, 1 to 2.5 hours after taking their morning dose. Their Parkinson's medications were not changed during the study.

Prior to the start of the study, the authors designed the experimental and control group treatment protocols and instructed the treating physiotherapists in their implementation. All patients were informed as to the experimental nature of the study and gave their consent for participation. The study was approved by the Ethics Committee of the Verona University, Department of Neurological and Vision Sciences. During treatment and follow-up, patients did not undergo any form of physiotherapy other than that scheduled in the study protocol.

Table 1. Demographic Features and Disease Duration in the Patient Groups

	Experimental Group (n = 28)	Control Group (n = 27)
Age (years)		
Mean (SD)	67.64 (7.41)	67.26 (7.18)
Range	53-79	50-79
Sex		
Male/Female	14/14	15/12
Education (years)		
Mean (SD)	7.89 (3.61)	8.52 (3.59)
Range	2-18	3-15
Disease duration (years)		
Mean (SD)	10.39 (4.76)	8.63 (5.39)
Range	2-19	0-19

Abbreviation: SD, standard deviation.

Treatment Procedures

Two therapists, unaware of the aim of the study, treated patients. One therapist performed the experimental group training and the other performed the control group training. Both therapists knew that they were participating in a study, but neither knew if they were carrying out the experimental or the control treatment, nor were they aware of the type of treatment performed by the other group.

Patients in each group received 21 treatment sessions of 50 minutes each, 3 days a week (Monday, Wednesday, Friday) for 7 consecutive weeks. Both the experimental and the control group training were performed through individual treatment in an outpatient setting in the rehabilitative gym of the G.B. Rossi University Hospital Neurological Rehabilitation Unit.

Experimental group training. Each patient was submitted to a balance training consisting of exercises aimed at improving both feedforward and feedback postural reactions. Patients were required to repeat exercises belonging to 3 different predetermined groups of exercises. The first group consisted of exercises of self-destabilization of the center-of-body mass. The patients performed voluntary motor actions in static or dynamic conditions (eg, transferring their body weight onto the tips of the toes and onto the heels; bouncing a ball during gait with the 2 hands alternating to the right and left side). These tasks mainly involved feedforward postural control. The second group of exercises included tasks that externally induced destabilization of the center-of-body mass. The patient was required to maintain balance while standing on foam support bases of different consistency, on moveable platforms with different degrees of stability, or while the therapist was disturbing the patient's stability by sternal or dorsal pulling in order to induce perturbations in the anterior and posterior direction. These tasks mainly involved feedback postural control. The third group of exercises emphasized

coordination between leg and arm movements during walking as well as locomotor dexterity over an obstacle course and other potentially destabilizing activities. These types of tasks require continuous feedback and feedforward postural adjustments. During each treatment session, the patient was challenged with 10 exercises: 4 from the first group of exercises, 4 from the second group, and 2 from the third group. Each single exercise was repeated several times (from 5 to 10 times according to the patient's clinical condition) in 5 minutes. Each exercise was individualized to the patient's balance ability. During the course of the therapy sessions, the complexity of the tasks was progressively increased as the patient improved. The therapist gave verbal instructions and, when required, assisted the patient in maintaining balance by providing support at the pelvis or chest.

Control group training. Each patient was required to perform exercises not specifically aimed at improving postural reactions. The training consisted of active joint mobilization, muscle stretching, and motor coordination exercises. Active joint mobilization was carried out with the patient in the supine, prone (if possible), or sitting positions. Muscle stretching was carried out mainly in the supine, prone (if possible), and standing positions (with the participants' arms stretched out against the wall). Motor coordination exercises were carried out in a supine position (ie, bending the left upper limb while simultaneously extending the right lower limb) while sitting on a bench (ie, touching the left shoulder with the right hand while straightening out the left arm at the shoulder level and then touching the right shoulder with the left hand straightening out the right arm) and in the standing position while leaning on a front support or with the back against a wall (eg, the patient had to perform a standing march, tapping alternatively the right and the left foot on the ground). During each session, the patient started by lying on a carpet; then, treatment continued in the sitting and standing positions. The patient was required to perform a total of 10 exercises in the following sequence: 6 exercises in the supine position (stretching, joint mobilization, and motor coordination exercises), 2 exercises in the sitting position (joint mobilization and motor coordination exercises), and 2 in the standing position (stretching and motor coordination exercises). Each exercise was repeated with the same frequency and duration as those of the experimental group. Tasks were chosen based on the patient's clinical impairment, and their complexity progressively increased as the patient showed improvement. The therapist assisted the patients by demonstrating exercises and providing verbal instructions.

Testing Procedures

Patients were evaluated before and immediately after treatment, and 1 month after the end of treatment by means of a battery of tests, including primary and secondary outcome measures. All patients were evaluated by the same examiner who was blinded with regard to the treatment received by the patients.

Primary outcomes. The Berg Balance Scale (BBS) is a 14-item (0-4 points per task; high=best performance) validated scale that evaluates balance abilities during sitting, standing, and positional changes.[32] A score of 43.5 or below suggests risk of falls.[33] The Activities-Specific Balance Confidence Scale (ABC) is an interview assessment that examines the patient's perceived level of balance confidence while performing 16 daily living activities rated 0 to 100 each.[34] Patients with a score below 75.6 are at risk for falls.[33] In addition, a digital stopwatch was used to measure the time of execution of postural transfers using a 70-cm-high bed (postural tranfer 1) and a 45-cm-high chair with armrests (postural tranfer 2). Participants were required to transfer from lying to sitting, first to the left side of the bed and then to the right (the score of this item was the average of these 2 trials) and from sit to stand (scored as the time required to perform 1 single transfer). Patients were asked to perform the postural transfers at their usual speed and were allowed to take a 1-minute rest between trials. Also, participants stood barefoot on a balance platform (Cosmogamma, Bologna, Italy) with the feet positioned symmetrically with respect to the longitudinal axis of the platform (tibial malleoli 70 mm apart) and arms along the sides of the body. In front of the patient, a computer monitor displayed a visual point that moved parallel to the online displacement of the center of foot pressure (CFP). Immediately before the start of the test (CFP self-destabilization and control test), the patient was required to keep the visual point at the center of a Cartesian axis system (dividing the monitor space into 4 equal quadrants) by controlling the CFP. At the start of the test, a bright square target appeared on the screen in one of the quadrants. Through voluntary displacements of the CFP and without moving the foot support base, the patient had to place the visual point over the target. Once the target was reached, it disappeared, and another target appeared in a different spatial position. Targets appeared in pseudorandom order, and the sequence was the same for all the patients and throughout all the test sessions. The test lasted 60 s. The outcome variable for this testing was the number of targets reached over the 60 s. Test-retest and interobserver reliability of CFP self-destabilization and the control test were evaluated in a sample of 10 patients with PD (H&Y score 3-4) by means of the Kendall t statistic correlation. Significant and high correlation was observed in the test-retest reliability ($K = 0.92$; $P < .001$) and in the interobserver reliability ($K = 0.71$; $P = .01$).

Data regarding the number of falls reported in the previous month, the circumstances of the falls, and the consequences on the participant's physical condition were

collected for each patient by self-report. Each participant was requested to record any falls in a diary for 1 month prior to the start of each evaluation session. A fall was defined as an unexpected event in which the person inadvertently came to rest on the ground or another lower level, not due to a major intrinsic or extrinsic event.

Secondary outcomes. The Unified Parkinson's Disease Rating Scale (UPDRS) with 4 subsections[35] (I. Mentation, behavior and mood; II. Activities of daily living; III. Motor examination; IV. Complications of therapy) is scored from 0 to 147 (high = worst performance). Patients with a score of 36.50 or above are at higher risk of falling.[33] The Modified H&Y Scale was used for staging the disease.[36] The Geriatric Depression Scale (GDS) is a 30-item self-report assessment to identify depression in older people[37] and in PD patients.[38] Scores range from 0 to 30 with higher scores equated to greater symptoms.

Sample Calculation and Statistical Analysis

Sample calculation took into account that in a similar study,[28] a difference in the BBS of –4.9 was detected between the experimental and control groups (standard deviation of 6,1) because of experimental rehabilitation. According to this study, a sample of at least 20 patients (ie, 10 patients for each group) was required in order to achieve 90% power.[39,40] We used the Mann-Whitney test to assess the homogeneity of the groups before the study. The Friedman test was used to analyze changes in performance in the different evaluation sessions within each patient group. Wilcoxon signed rank tests on the pretreatment/posttreatment scores and on the pretreatment/follow-up scores for the different outcome measures were carried out in each group of patients. Descriptive analysis was used to evaluate the effect size measures between the 2 independent groups (Cohen's *d* calculation)[41] and the confidence intervals. The Mann-Whitney test was used to compare the effect of treatment in the 2 patient groups. For this purpose, we computed the differences between posttreatment and pretreatment performance and between follow-up and pretreatment performance for all outcome measures. The α level for significance was set at $P < .05$. The Bonferroni correction[42] was used in multiple comparisons ($P < .025$). Statistical analysis was carried out using the SPSS for Windows statistical package, version 13.0 (SPSS Inc, Chicago, IL).

Results

In all, 5 patients in the experimental group and 4 patients in the control group withdrew from the study because of medical complications or lack of cooperation (Figure 1). Age, length of illness, BBS score, ABC Scale score, postural transfer test score, self-destabilization of CFP test score, number of falls, UPDRS score, H&Y staging, and GDS score were not statistically different between groups (age: $Z = –0.51$, $P = .60$; length of illness: $Z = –1.41$, $P = .158$; BBS: $Z = –1.06$, $P = .28$; ABC: $Z = –1.07$, $P = .28$; postural transfer 1: $Z = –0.96$, $P = .33$; postural transfer 2: $Z = –0.86$, $P = .386$; self-destabilization of CFP: $Z = –0.74$, $P = .45$; number of falls: $Z = –0.66$, $P = .51$; UPDRS: $Z = –0.96$, $P = .33$; H&Y: $Z = –1.06$, $P = .28$; and GDS: $Z = –0.59$, $P = .54$).

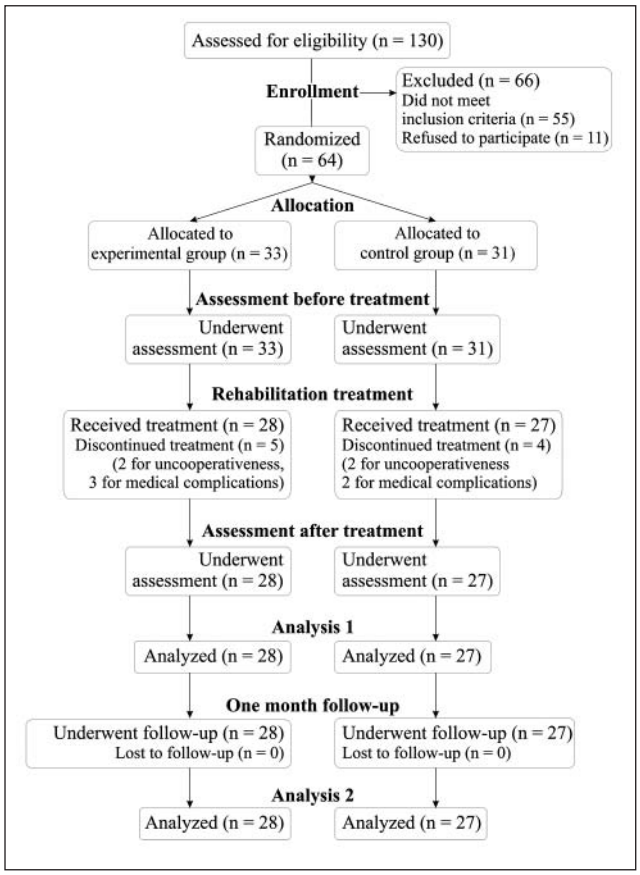

Figure 1. Profile of the clinical trial

Primary Outcomes

In the experimental group, overall significant changes in performance in the different evaluation sessions were found in regard to all primary outcome measures (BBS: $X = 27.41$, $P = .000$; ABC Scale: $X = 16.97$, $P = .000$; postural transfer 1: $X = 25.63$, $P = .000$; postural transfer 2: $X = 33.90$, $P = .000$; test of self-destabilization: $X = 23.08$, $P = .000$; number of falls: $X = 34.81$, $P = .000$). Within-group comparisons showed that changes in performance were significant at both the posttreatment and follow-up evaluation (see Table 2 for details). In the control group, no significant changes in the primary outcome measures were found during any of the evaluation sessions (statistics in Table 2).

A between-group comparison showed that the effects of the experimental and the control group treatment were significantly different in all primary outcome measures (statistics in Table 3).

Table 2. Patients' Performance and Treatment Effects in All Outcome Measures

					Before–After			Before–1-Month Follow-up		
	Group	Before Mean (SD)	After Mean (SD)	1-Month Follow-up, Mean (SD)	95% CI Mean (LB; UB)	Effect Size (BG)	*P* Value (*Z*)	95% CI Mean (LB; UB)	Effect Size (BG)	*P* Value (*Z*)
	Experimental	44.5 (6.6)	49.8 (4.3)	49.9 (4.7)	5.2 (3.4;7.1)		.000 (–4.34)[a]	5.4 (3.2;7.5)		.000 (–3.84)[a]
BBS (0-56)						1.2			1.0	
	Control	41.8 (8.2)	41.0 (8.9)	40.85 (8.88)	–0.8 (–2.1;0.50)		.062 (–1.86)	–1.0 (–2.4;0.3)		.038 (–2.07)
	Experimental	54.3 (18.4)	61.3 (17.0)	62.3 (17.3)	6.9 (4.5;9.3)		.000 (–4.09)[a]	7.9 (2.9;12.8)		.001 (–3.10)[a]
ABC scale (0-100)						0.79			0.9	
	Control	49.5 (16.1)	48.2 (16.1)	47.0 (17.2)	–1.3 (–2.6; –0.0)		.03 (–2.18)	–2.5 (–4.4; –0.6)		.73 (–1.79)
	Experimental	14.4 (14.0)	9.6 (10.3)	8.2 (7.1)	–4.7 (–7.7;–1.7)		.000 (–3.89)[a]	–6.2 (–9.8;–2.6)		.000 (–4.14)[a]
Postural transfers 1						–0.45			–0.7	
	Control	18.2 (22.0)	17.6 (22.4)	18.4 (23.3)	–0.6 (–4.4;3.2)		.325 (–0.98)	0.2 (–2.5;3.0)		.476 (–0.71)
	Experimental	4.2 (3.1)	2.9 (2.0)	2.6 (1.6)	–1.3 (–1.9;–0.6)		.000 (–4.38)[a]	–1.6 (–2.3;–0.9)		.000 (–4.15)[a]
Postural transfers 2						–0.51			–0.47	
	Control	4.5 (4.2)	4.9 (5.1)	5.2 (5.1)	0.4 (–0.4;1.3)		.184 (–1.33)	0.7 (–0.1;1.5)		.31 (–1.01)
	Experimental	10.0 (6.5)	14.2 (6.9)	15.3 (7.8)	3.5 (1.9;5.2)		.000 (–3.62)[a]	4.4 (2.4;6.4)		.000 (–3.83)[a]
CFP self-destabilization						0.65			0.6	
	Control	9.3 (7.9)	9.5 (7.3)	9.7 (8.9)	0.2 (–0.8;1.2)		.821 (–0.22)	0.3 (–0.8;1.6)		.986 (–0.01)
	Experimental	4.3 (9.1)	1.3 (4.7)	1.3 (4.7)	–2.9 (–5.3;–0.6)		.000 (–3.86)[a]	–3.0 (–5.3;–0.6)		.000 (–3.75)[a]
Number of falls						–0.45			–0.4	
	Control	4.6 (8.0)	4.1 (7.3)	4.1 (7.0)	–0.5 (–1.3;0.2)		.142 (–1.46)	–0.5 (–1.3;0.2)		.142 (–1.46)
	Experimental	46.1 (11.5)	43.5 (14.6)	43.8 (14.4)	–2.5 (–5.3;0.2)		.031 (–2.15)	–2.4 (–5.1;0.1)		.063 (–1.85)
UPDRS (0-147)						–0.02			–0.1	
	Control	43 (16.9)	43.9 (18.3)	45.7 (18.5)	0.9 (–1.5;3.4)		.387 (–0.88)	2.7 (–0.1;5.6)		.046 (–1.99)
	Experimental	3.0 (0.1)	3.0 (0.1)	3.0 (0.1)	0.0 (–0.1;0.1)		1.000 (0.00)	0.0 (–0.1;0.1)		1.000 (0.00)
H&Y stage (0-5)						–0.3			–0.25	
	Control	3.1 (0.3)	3.1 (0.3)	3.1 (0.3)	0.0 (–0.1;0.1)		1.000 (0.00)	0.0 (–0.1;0.1)		1.000 (0.00)
	Experimental	14.6 (5.9)	12.7 (5.2)	13.1 (5.9)	–1.8 (–3.5;–0.9)		.002 (–3.07)[a]	–1.5 (–3.5;0.4)		.068 (–1.82)
GDS (0-30)						–0.54			–0.34	
	Control	15.4 (6.2)	15.9 (6.3)	15.8 (6.3)	0.5 (0.0;1.0)		.04 (–2.05)	0.4 (–0.3;1.3)		.247 (–1.158)

Abbreviations: SD, standard deviation; CI, confidence interval; LB, lower bound; UB, upper bound; BBS, Berg Balance Scale; ABC, Activities-Specific Balance Confidence Scale; CFP, center of foot pressure; UPDRS, Unified Parkinson's Disease Rating Scale; H&Y, Hoehn and Yahr; GDS, Geriatric Depression Scale; BG, between-groups; *P* value (*Z*) = *P* value and corresponding *Z* value identified from the Wilcoxon test.

[a]Statistically significant.

Table 3. Comparison of Treatment Effects Between the Experimental and Control Groups

	Before–After	Before–1-Month Follow-up
	P Value (*Z*)	*P* Value (*Z*)
BBS (0-56)	.000 (–4.94)[a]	.000 (–4.65)[a]
ABC scale (0-100)	.000 (–4.71)[a]	.000 (–4.11)[a]
Postural transfers 1	.000 (–3.62)[a]	.000 (–3.98)[a]
Postural transfers 2	.000 (–4.20)[a]	.000 (–4.12)[a]
CFP self-destabilization	.000 (–4.06)[a]	.000 (–4.15)[a]
Number of falls	.001 (–3.46)[a]	.001 (–3.31)[a]
UPDRS (0-147)	.011 (–2.53)[a]	.002 (–3.02)[a]
H&Y stage (0-5)	1.000 (0.00)	1.000 (0.00)
GDS (0-30)	.000 (–4.21)[a]	.004 (–2.86)[a]

Abbreviations: BBS, Berg Balance Scale; ABC, Activities-Specific Balance Confidence Scale; CFP, center of foot pressure; UPDRS, Unified Parkinson's Disease Rating Scale; H&Y, Hoehn and Yahr; GDS, Geriatric Depression Scale; *P* value (*Z*) = *P* value and corresponding *Z* value identified from the Mann-Whitney test.
[a]Statistically significant.

Secondary Outcomes

In the experimental group, overall significant changes in performance in the different evaluation sessions were found in the UPDRS and GDS (UPDRS: $X = 9.84$, $P = .007$; GDS: $X = 14.73$, $P = .001$). The before–after and before–follow-up comparisons revealed a significant improvement only in the GDS after treatment, which was not maintained at follow-up (statistics in Table 2).

Discussion

In regard to the main objective of the study, the results showed that the experimental balance training could improve postural stability, improve the level of confidence perceived while performing daily activities that require balance, and reduce the frequency of falls in patients with PD. The training effects were maintained for at least 1 month after the end of treatment. In contrast, patients undergoing the nonspecific rehabilitation training (control group) showed no significant changes in any of these parameters. The magnitude of the differences between the experimental and the control treatment effects (see effect size calculation) further support the value of our experimental approach. With regard to the secondary aim, no treatment effects were found, except for a significant improvement of depression in the experimental group after training, which was not maintained at follow-up.

The most important outcome in our study was that a specific rehabilitative training led to an improvement of postural stability in patients with PD. This result was strengthened by the fact that the study was a randomized controlled trial conducted on a considerable sample of patients and that the methods used for balance assessment incorporated a number of tests that provided a comprehensive picture of the different aspects of PI. In particular, the issue of balance assessment methods is very relevant in PD rehabilitation studies.[26,43,44] Indeed, PI in PD has a complex pathophysiology and induces various disabling conditions such as difficulty with transfers, gait disorders, inability to live independently at home, and falls. On this basis, recent studies recommend the use of multiple tests to improve the assessment of PI in PD.[26,43,44] In addition, they underline the limited validity of some of the most frequently used clinical assessment tools for PI in PD.[26,43,44]

In addition, we used a new instrumental test, the CFP self-destabilization and control test, which is a reliable tool for assessment of balance control ability in PD. To maintain balance during this task, the patient should rely on both feedback and feedforward control. Furthermore, while controlling and planning the most appropriate postural strategies, the patient has to simultaneously perform a visual exploration activity, thus also stressing visual and dual tasking cognitive control. The test could be suitable to evaluate postural "corrective" responses. This motor strategy, frequently impaired in PD,[45-48] consists of maintaining balance by activation of the leg, trunk, and neck muscles while the position of the feet (base of support) is constant.[45,49] Other important balance strategies, also frequently impaired in PD,[45,50,51] are "protective" responses, which are featured by changes in the base of support (ie, one or both feet leave their original position in an attempt to maintain balance).

A few recent reports have assessed the effect of specific balance rehabilitation programs[24-29,45,52] for PD. Participants received a wide variety of treatment approaches, including balance exercises,[24,26,29,45] strengthening,[29] gait[27,52] and step training,[27] computerized dynamic posturography,[28] and whole body vibration.[25] The dosage of the rehabilitation therapy was a inconsistent parameter among the various studies. In particular, frequency of treatment ranged from 2 to 5 sessions/wk, with sessions lasting from 30 to 150 min/d and the length of the programs ranging from 10 days to 10 weeks.[24-29,45,52] As in the present research, most previous studies were carried out using an individual treatment approach in an outpatient regimen.[24,26-29,45] Due to the differences in sample and methods issue, comparison between our study and previous researches cannot be performed.

An important outcome of our study was a significant reduction in falls during daily life in the experimental group. This is particularly relevant because people with PD experience frequent falls and suffer fall-related injuries, including fractures.[53,54] Fear of falling is also frequent in community-dwelling people with PD, resulting in a restriction of activities, compromising their quality of life and

predisposing them to secondary reductions in muscle strength and cardiovascular fitness. Because our training was not specifically designed to teach strategies to prevent falls, the balance abilities acquired after treatment can possibly extend to untrained activities also.

To date, only a few randomized controlled trials have investigated the effect of an exercise intervention to reduce falls in PD. One study assessed the benefit of a fully supervised 8-week program of treadmill gait and step perturbation training in patients with PD. Patients in the experimental group showed a substantial reduction in the rate of falling and an improvement in gait and dynamic balance parameters.[27] The other study investigated a 6-week program in which patients were trained at home to learn strategies to prevent falls and performed muscle strengthening, range of movement, balance training, and walking exercises, whereas a control group received usual care, consisting of contact with a local PD nurse.[24] Results showed a consistent trend toward lower rates of falling and significantly lower rates of repeated near falls. Cost-effective, evidence-based interventions for preventing and reducing falls and related injuries are still needed.[55]

In our trial, the patients in the control group performed general physical therapy exercises but failed to show any significant improvement in balance. Two recent studies have evaluated the effect of rehabilitative treatment not specifically based on balance exercises. In one of these trials,[56] patients with PD received a rehabilitative program based on movement strategy, fall prevention, regular physical activity, and aerobic strength. In the other trial,[52] patients participated in an exercise program using incremental speed-dependent treadmill training. In contrast to our study, both of these studies showed a significant improvement in balance after treatment. A possible explanation of the lack of treatment effects in our control group is that exercises were performed mainly in the sitting or supine position, and therefore, patients received very little input suitable for stimulating postural adjustments.

As for the secondary aim of our study, the main result was that after the experimental training, patients showed an improvement in symptoms of depression, which was not maintained 1 month later. We hypothesize that the initial improvement is from increased confidence in balance related to daily-life activities and the decrease in falls, with a related increase in perceived quality of life. A similar improvement was not recorded in any other PD rehabilitation study.[57-60]

Limitations of the study are the lack of a follow-up assessment at 3 or more months after training and the lack of assessment of some important parameters related to PI, such as fear of falling, quality of life, and efficiency of patient's "protective" reactions. Future studies dealing with balance rehabilitation in PD should also take these issues into account. Furthermore, future studies should also determine the frequency and duration of treatment and other components that might be the most effective and optimal strategies for learning motor skills.[61]

In conclusion, the results of this properly powered randomized controlled trial show that balance training in patients suffering from PD can improve performance in highly relevant outcomes related to better postural control.

Authors' Note

EC and MG contributed equally to the work.

Declaration of Conflicting Interests

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References

1. Adkin AL, Frank JS, Jog MS. Fear of falling and postural control in Parkinson's disease. *Mov Disord.* 2003;18:496-502.
2. Marchese R, Bove M, Abbruzzese G. Effect of cognitive and motor tasks on postural stability in Parkinson's disease: a posturographic study. *Mov Disord.* 2003;18:652-658.
3. Pastor MA, Day BL, Marsden CD. Vestibular induced postural responses in Parkinson's disease. *Brain*. 1993;116:1177-1190.
4. Bronstein AM, Hood JD, Gresty MA, Panagi C. Visual control of balance in cerebellar and Parkinsonian syndromes. *Brain*. 1990;113:767-779.
5. Traub MM, Rothwell JC, Marsden CD. Anticipatory postural reflexes in Parkinson's disease and other akinetic-rigid syndromes and in cerebellar ataxia. *Brain*. 1980;103:393-412.
6. Horak FB, Nutt JG, Nashner LM. Postural inflexibility in Parkinsonian subjects. *J Neurol Sci.* 1992;111:46-58.
7. Lee RG, Tonolli I, Viallet F, Aurenty R, Massion J. Preparatory postural adjustments in Parkinsonian patients with postural instability. *Can J Neurol Sci.* 1995;22:126-135.
8. Schieppati M, Nardone A. Free and supported stance in Parkinson's disease: the effect of posture and "postural set" on leg muscle responses to perturbation, and its relation to the severity of the disease. *Brain*. 1991;114:1227-1244.
9. Beckley DJ, Bloem BR, Remler MP. Impaired scaling of long latency postural reflexes in patients with Parkinson's disease. *Electroencephalogr Clin Neurophysiol.* 1993;89:22-28.
10. Beckley DJ, Bloem BR, Singh J, Remler MP, Wolfe NS, Roos RA. Postural reflexes in patients on long-term neuroleptic medication. *Clin Neurol Neurosurg.* 1991;93:119-122.
11. Bloem BR, Beckley DJ, van Dijk JG, et al. Medium latency stretch reflexes in young-onset Parkinson's disease and MPTP-induced Parkinsonism. *J Neurol Sci.* 1994;123:52-58.

12. Bonnet AM, Loria Y, Saint-Hilaire MH, Lhermitte F, Agid Y. Does long-term aggravation of Parkinson's disease result from nondopaminergic lesions? *Neurology.* 1987;37:1539-1542.
13. Dietz V, Berger W, Horstmann GA. Posture in Parkinson's disease: impairment of reflexes and programming. *Ann Neurol.* 1988;24:660-669.
14. Scholz E, Diener HC, Noth J, Friedemann H, Dichgans J, Bacher M. Medium and long latency EMG responses in leg muscles: Parkinson's disease. *J Neurol Neurosurg Psychiatry.* 1987;50:66-70.
15. Visser JE, Allum JH, Carpenter MG, et al. Effect of subthalamic nucleus deep brain stimulation on axial motor control and protective arm responses in Parkinson's disease. *Neuroscience*. 2008;157:798-812.
16. Bronte-Stewart HM, Minn AY, Rodrigues K, Buckley EL, Nashner LM. Postural instability in idiopathic Parkinson's disease: the role of medication and unilateral pallidotomy. *Brain*. 2002;125:2100-2114.
17. Shivitz N, Koop MM, Fahimi J, Heit G, Bronte-Stewart HM. Bilateral subthalamic nucleus deep brain stimulation improves certain aspects of postural control in Parkinson's disease, whereas medication does not. *Mov Disord.* 2006;21:1088-1097.
18. Bloem BR, Beckley DJ, van Dijk JG, Zwinderman AH, Remler MP, Roos RA. Influence of dopaminergic medication on automatic postural responses and balance impairment in Parkinson's disease. *Mov Disord.* 1996;11:509-521.
19. Deane KHO, Jones D, Ellis-Hill C, Clarke CE, Playford ED, Ben-Shlomo Y. Physiotherapy for Parkinson's disease: a comparison of techniques. *Cochrane Database Syst Rev.* 2001;(1):CD002815.
20. Deane KHO, Jones D, Playford ED, Ben-Shlomo Y, Clarke CE. Physiotherapy versus placebo or no intervention in Parkinson's disease. *Cochrane Database Syst Rev.* 2001;(3):CD002817.
21. Bond JM, Morris M. Goal-directed secondary motor tasks: their effects on gait in subjects with Parkinson disease. *Arch Phys Med Rehabil.* 2000;81:110-116.
22. Morris ME, Iansek R, Matyas TA, Summers JJ. Stride length regulation in Parkinson's disease. Normalization strategies and underlying mechanisms. *Brain.* 1996;119:551-568.
23. Morris ME, Iansek R. Characteristics of motor disturbance in Parkinson's disease and strategies for movement rehabilitation. *Hum Mov Sci.* 1996;15:649-669.
24. Ashburn A, Fazakarley L, Ballinger C, Pickering R, McLellan LD, Fitton C. A randomised controlled trial of a home based exercise programme to reduce the risk of falling among people with Parkinson's disease. *J Neurol Neurosurg Psychiatry*. 2007;78:678-684.
25. Ebersbach G, Edler D, Kaufhold O, Wissel J. Whole body vibration versus conventional physiotherapy to improve balance and gait in Parkinson's disease. *Arch Phys Med Rehabil.* 2008;89:399-403.
26. Hirsch MA, Toole T, Maitland CG, Rider RA. The effects of balance training and high-intensity resistance training on persons with idiopathic Parkinson's disease. *Arch Phys Med Rehabil.* 2003;84:1109-1117.
27. Protas EJ, Mitchell K, Williams A, Qureshy H, Caroline K, Lai EC. Gait and step training to reduce falls in Parkinson's disease. *NeuroRehabilitation.* 2005;20:183-190.
28. Qutubuddin AA, Cifu DX, Armistead-Jehle P, Carne W, McGuirk TE, Baron MS. A comparison of computerized dynamic posturography therapy to standard balance physical therapy in individuals with Parkinson's disease: a pilot study. *NeuroRehabilitation.* 2007;22:261-265.
29. Toole T, Hirsch MA, Forkink A, Lehman DA, Maitland CG. The effects of a balance and strength training program on equilibrium in Parkinsonism: a preliminary study. *NeuroRehabilitation.* 2000;14:165-174.
30. Bryant TN, Machin D. Statistical methods. In: Wilson BA, McLellan DL, eds. *Rehabilitation Studies Handbook.* Cambridge, UK: Cambridge University Press; 1997:189-204.
31. Dick JP, Guiloff RJ, Stewart A, et al. Mini-mental state examination in neurological patients. *J Neurol Neurosurg Psychiatry.* 1984;47:496-499.
32. Berg K, Wood-Dauphinee S, Williams JI. The Balance Scale: reliability assessment with elderly residents and patients with an acute stroke. *Scand J Rehabil Med*. 1995;27:27-36.
33. Landers MR, Backlund A, Davenport J, Fortune J, Schuerman S, Altenburger P. Postural instability in idiopathic Parkinson's disease: discriminating fallers from nonfallers based on standardized clinical measures. *J Neurol Phys Ther.* 2008;32:56-61.
34. Powell LE, Myers AM. The Activities-specific Balance Confidence (ABC) Scale. *J Gerontol A Biol Sci Med Sci.* 1995;50:M28-M34.
35. Song J, Fisher BE, Petzinger G, Wu A, Gordon J, Salem GJ. The relationships between the UPDRS and lower extremity functional performance in persons with early Parkinson's disease. *Neurorehabil Neural Repair*. 2009;23:657-661.
36. Goetz CG, Poewe W, Rascol O, et al. Movement Disorder Society Task Force on Rating Scales for Parkinson's Disease. Movement Disorder Society Task Force report on the Hoehn and Yahr staging scale: status and recommendations. *Mov Disord.* 2004;19:1020-1028.
37. Yesavage JA, Brink TL, Rose TL, et al. Development and validation of a Geriatric Depression Screening Scale: a preliminary report. *J Psychiatr Res.* 1982;17:37-49.
38. McDonald WM, Holtzheimer PE, Haber M, Vitek JL, McWhorter K, Delong M. Validity of the 30-item Geriatric Depression Scale in patients with Parkinson's disease. *Mov Disord.* 2006;21:1618-1622.
39. Machin D, Campbell M, Fayers P, Pinol A. *Sample Size Tables for Clinical Studies.* 2nd ed. Malden, MA: Blackwell Science; 1997.
40. Zar JH. *Biostatistical Analysis*. 2nd ed. Englewood Cliffs, NJ: Prentice Hall; 1984.

41. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum; 1988.
42. Benjamini Y, Hochberg Y. Controlling the false discovery rate: a practical and powerful approach to multiple testing. *J R Stat Soc Ser B.* 1995;57:289-300.
43. Visser M, Marinus J, Bloem BR, Kisjes H, van den Berg BM, van Hilten JJ. Clinical tests for the evaluation of postural instability in patients with Parkinson's disease. *Arch Phys Med Rehabil.* 2003;84:1669-1674.
44. Jacobs JV, Horak FB, Tran VK, Nutt JG. Multiple balance tests improve the assessment of postural stability in subjects with Parkinson's disease. *J Neurol Neurosurg Psychiatry.* 2006;77:322-326.
45. Jobges M, Heuschkel G, Pretzel C, Illhardt C, Renner C, Hummelsheim H. Repetitive training of compensatory steps: a therapeutic approach for postural instability in Parkinson's disease. *J Neurol Neurosurg Psychiatry.* 2004;75:1682-1687.
46. Horak FB, Nutt JG, Nashner LM. Postural inflexibility in Parkinsonian subjects. *J Neurol Sci.* 1992;111:46-58.
47. Stelmach GE, Worringham CJ. Sensorimotor deficits related to postural stability: implications for falling in the elderly. *Clin Geriatr Med.* 1985;1:679-694.
48. Horak FB, Frank J, Nutt J. Effects of dopamine on postural control in Parkinsonian subjects: scaling, set, and tone. *J Neurophysiol.* 1996;75:2380-2396.
49. Rogers MW. Disorders of posture, balance, and gait in Parkinson's disease. *Clin Geriatr Med.* 1996;12:825-845.
50. Martin JP. *Basal Ganglia and Posture*. London, UK: Pitman; 1976.
51. Bloem BR, Beckley DJ, van Hilten BJ, Roos RA. Clinimetrics of postural instability in Parkinson's disease. *J Neurol.* 1998;245:669-673.
52. Cakit BD, Saracoglu M, Genc H, Erdem HR, Inan L. The effects of incremental speed-dependent treadmill training on postural instability and fear of falling in Parkinson's disease. *Clin Rehabil.* 2007;21:698-705.
53. Hely MA, Morris JG, Traficante R, Reid WG, O'Sullivan DJ, Williamson PM. The Sydney multicentre study of Parkinson's disease: progression and mortality at 10 years. *J Neurol Neurosurg Psychiatry.* 1999;67:300-307.
54. Johnell O, Melton LJ III, Atkinson EJ, O'Fallon WM, Kurland LT. Fracture risk in patients with Parkinsonism: a population-based study in Olmsted County, Minnesota. *Age Ageing*. 1992;21:32-38.
55. Canning CG, Sherrington C, Lord SR, et al. Exercise therapy for prevention of falls in people with Parkinson's disease: a protocol for a randomised controlled trial and economic evaluation. *BMC Neurol.* 2009;9:4.
56. Stankovic I. The effect of physical therapy on balance of patients with Parkinson's disease. *Int J Rehabil Res.* 2004;27:53-57.
57. Comella CL, Stebbins GT, Brown-Toms N, Goetz CG. Physical therapy and Parkinson's disease: a controlled clinical trial. *Neurology.* 1994;44:376-378.
58. Nieuwboer A, De Weerdt W, Dom R, Truyen M, Janssens L, Kamsma Y. The effect of a home physiotherapy program for persons with Parkinson's disease. *J Rehabil Med*. 2001;33:266-272.
59. Stallibrass C, Sissons P, Chalmers C. Randomized controlled trial of the Alexander technique for idiopathic Parkinson's disease. *Clin Rehabil.* 2002;16:695-708.
60. Wade DT, Gage H, Owen C, Trend P, Grossmith C, Kaye J. Multidisciplinary rehabilitation for people with Parkinson's disease: a randomised controlled study. *J Neurol Neurosurg Psychiatry.* 2003;74:158-162.
61. Onla-or S, Winstein CJ. Determining the optimal challenge point for motor skill learning in adults with moderately severe Parkinson's disease. *Neurorehabil Neural Repair*. 2008;22:385-395.