Effect of Partial Weight—Supported Treadmill Gait Training on Balance in Patients With Parkinson Disease

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Objective: To investigate the role of conventional gait training and partial weight—supported treadmill gait training (PWSTT) in improving the balance of patients with Parkinson disease (PD).

Design: Prospective randomized controlled design.

Setting: National-level university tertiary hospital for mental health and neurosciences.

Patients: Sixty patients with PD fulfilling the United Kingdom Brain Bank PD diagnostic criteria were recruited from the neurology outpatient department and movement disorder clinic.

Methodology: The patients were randomly assigned into 3 equal groups: (1) a control group that only received a stable dosage of dopaminomimetic drugs; (2) a conventional gait training (CGT) group that received a stable dosage of dopaminomimetic drugs and conventional gait training; and (3) a PWSTT group that received a stable dosage of dopaminomimetic drugs and PWSTT with unloading of 20% of body weight. The sessions for the CGT and PWSTT groups were provided for 30 minutes per day, 4 days per week, for 4 weeks (16 sessions).

Outcome measures: The Unified Parkinson Disease Rating Scale (UPDRS) motor score, dynamic posturography, Berg Balance Scale, and Tinetti performance-oriented mobility assessment (POMA) were used as main outcome measures.

Results: A significant interaction effect was observed in the UPDRS motor score, mediolateral index, Berg Balance Scale, limits of stability (LOS) total score, POMA gait score, and balance score. Post-hoc analysis showed that in comparison with the control group, the PWSTT group had a significantly better UPDRS motor score, balance indices, LOS in 8 directions, POMA gait, and balance score. The CGT group had a significantly better POMA gait score compared with control subjects. Compared with the CGT group, the PWSTT group had a significantly better UPDRS motor score, mediolateral index, POMA gait score, and LOS total score.

Conclusion: PWSTT may be a better interventional choice than CGT for gait and balance rehabilitation in patients with PD.

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INTRODUCTION

Parkinson disease (PD) is characterized by deteriorating motor function due to degeneration of the dopaminergic nigrostriatal pathways. Gait and balance abnormalities observed in persons with PD are important components of the disability [1]. Despite the use of levodopa, mobility deficits related to gait and balance are very difficult to treat [2,3]. Adjuvant physiotherapy has shown promise in addressing this crucial aspect of management of PD. Partial weight—supported treadmill gait training (PWSTT) is a promising therapeutic approach to help retrain patients with PD to walk [4-6]. The authors of a meta-analysis on treadmill training in patients with PD identified 8 trials in which investigators assessed the utility of variants of treadmill training and PWSTT in improving mobility in patients with PD [7]. Only a few studies have addressed the effect of treadmill training on balance in persons with PD [6,8,9]. The Berg Balance Scale (BBS), fall efficacy scale, and step test were used as outcome measures for balance control.
Only one study has addressed the sensory orientation test with use of dynamic posturography as an outcome measure after PWSTT [6]. A knowledge gap exists with regard to the effect of PWSTT on the limits of stability (LOS) and direction-specific balance components in persons with PD. Visintin et al [10] reported a significant improvement in functional balance, motor recovery, and gait after PWSTT in patients who had a stroke compared with patients undergoing treadmill training alone. PWSTT is considered to be a safer method of training, provides a sense of security regarding falls, and facilitates free leg movements compared with treadmill training alone. In addition, persons with neurologic conditions were able to walk for a longer duration and with minimally increased heart rates when partial weight support was provided [11]. Therefore the current study was planned to assess the effects of PWSTT on the dynamic balance indices, LOS in all directions, and clinical balance measures in persons with PD.

**METHODS**

This study was a prospective randomized controlled trial. The schematic flow of the research study is depicted in Figure 1. Sixty patients with PD were randomly assigned into 3 equal groups (n = 20/group): (1) a control group that only received a stable dosage of dopaminomimetic drugs; (2) a conventional gait training (CGT) group that received a stable dosage of dopaminomimetic drugs and conventional gait training; and (3) a PWSTT group that received a stable dosage of dopaminomimetic drugs and PWSTT with 20% unloading of weight. Patients were recruited from the neurology outpatient department and movement disorders clinic at the National Institute of Mental Health & Neurosciences. The diagnosis of PD was confirmed by a movement disorders specialist as per the United Kingdom Brain Bank Criteria [12]. The ethics committee at the National Institute of Mental Health and Neurosciences approved the study, and written informed consent was obtained from all participants.

**Figure 1.** A flow chart of the study. CGT = conventional gait training; PWSTT = partial weight—supported treadmill training, UPDRS = Unified Parkinson’s diseases rating scale; OBI = overall balance index; API = anteroposterior index; MLI = mediolateral index; BBS = Berg balance scale; POMA = Tinetti Performance-Oriented Mobility Assessment.
participants. Patients with cognitive deficits (ie, a mini-
mental status examination score ≤24), moderate to severe
depression (Beck Depression Inventory score ≥17), severe
dyskinesia (Goetz score >3), advanced PD (Hoehn and Yahr
[H&Y] stage >3), unpredictable motor fluctuations, and
orthopedic problems affecting gait training, as well as sub-
jects who had undergone previous formal gait training or
balance training, were excluded from the study.

The severity of PD was assessed with use of the motor
section of the Unified Parkinson’s Disease Rating Scale
(UPDRS-III). The hand and leg dominance of subjects were
assessed with use of the Edinburgh inventory. All partici-
pants took a stable dosage of dopaminomimetic drugs
throughout the study period. The assessment and training
were performed during the best “on” period after the regular
medications were taken. All assessments were performed at
baseline, after 2 weeks (W2), and after 4 weeks (W4). The
balance assessment and gait training were conducted in
the Gait and Balance Laboratory at the Department of
Neurorehabilitation.

Balance Assessment

**Dynamic Posturography.** Balance was tested with dy-
namic posturography (Stability System [model 945-302];
Biodex Medical Systems, software version 3.12, New York,
NY), the details of which have been published elsewhere
[13,14]. In brief, this system consists of a circular platform
supported so that it can tilt 20° in all directions from the
horizontal. The system’s microprocessor-based actuator
controls the extent of the surface instability of the platform.
The surface instability can be adjusted from level 8 (mini-
mally unstable) to level 1 (very unstable). Level 8 was used
for examination of balance in all the subjects.

The subjects were tested for dynamic stability in all
directions (overall balance index [OBI]), front to back sta-
bility (anteroposterior index [API]), and side to side stability
(medialateral index [MLI]). Each subject was asked to
maintain the center of his or her mass in the middle of a
concentric circle that appeared on the screen placed in front
of the subject. The instrument records the actual postural
sway and calculates the variance from the center, which is
expressed as a balance index. More postural sway is re-
flected as a large variance that is quantified as a greater score
of the balance index. The test consisted of 3 trials, each of
which were 20 seconds in duration with a 25-second inter-
trial rest period. The average value of the 3 trials was
taken as the final balance index and was used for further
analysis.

The subjects also were tested for LOS in 8 directions,
including forward (FW), backward (BW), right (RT),
left (LT), forward-right (FW-RT), forward-left (FW-LT),
backward-right (BW-RT), and backward-left (BW-LT). For
the LOS test, each subject had to move his or her center of
mass, without changing foot position, into 8 targets, the
perimeter of which corresponded to 50% of the theoretical
LOS. The target is displayed on the screen by a blinking
square, which appeared randomly in different directions
only once. The postural sway required to reach the target
from the center by the shortest vertical or horizontal path is
recorded by the instrument and given as a score. In a
particular direction, the maximum achievable perfect score is
100. A lower score indicated greater sway. The maximum
time allowed to perform the movements to complete the
LOS test was 300 seconds. The balance indices and the LOS
scores as computed and obtained from the system were used
for further analysis.

**Clinical Measures of Balance**

Clinically, balance was assessed with the BBS [15] and
the Tinetti Performance-Oriented Mobility Assessment
(POMA) [16]. The clinical measures of balance performed
by the BBS contain 14 items; each item is scored from 4
(normal) to 0 (unable to perform task). The maximum score
is 56. Each item in the POMA scale was scored on a 3-
point ordinal scale ranging from 0 to 2 (0 = maximum
impairment; 2 = normal). The POMA has a gait component
and a balance component. The total balance score was 16,
and the gait score was 12. The balance score was based on
testing of the following 9 items: balance while sitting, arising
from a chair, attempts to arise, immediate standing balance,
standing balance, response to a nudge, eyes closed, turning
360 degrees, and sitting down. The gait score was obtained
by testing the following 7 items: initiation of gait, step length
and clearance, step symmetry, step continuity, walking path,
trunk sway, and walking stance. The balance measures were
performed by a qualified physiotherapist. The same rater
performed all the repeated measurements.

**Training Groups**

The control group received only a stable dosage of dop-
aminomimetic drugs for the entire study period, whereas the
CGT and PWSTTT groups received gait training along with
medications. All 3 groups were encouraged to perform their
regular activities of daily living. The control group was
instructed not to undergo any specific gait, balance, or
exercise training until the end of the study period.

CGT included walking in a straight path, training to
turn, and incorporating arm swinging strategies while
walking. In addition, verbal auditory cues were given to
encourage longer steps. The first 2 sessions of CGT were
performed with the subject inside parallel bars, and then
sessions were performed outside parallel bars. Each session
of CGT consisted of 3 sets of 10-minute continuous
training with 2 minutes of rest between the sets of training.
The 10-minute walking training sessions included walking
in straight path and turning strategies such as step and
pivot turnings with the help of floor markings in the
walking path. Arm swinging was taught and encouraged during walking.

The PWSTT unit (Gait trainer [model 945-397]; Biodex Medical Systems, software version 2.01, Shirley, NY) consisted of a treadmill with visual biofeedback of step length and step speed and an unweighing support system. The support system was set to unload 20% of body weight while the subject was training on the treadmill. The percentage of body weight unloaded was chosen on the basis of previous studies [4,5]. The unweighing support system (model 945-473; Biodex Medical Systems) provides continuous monitoring of unweighed weight. In the CGT and PWSTT groups, the progression and speed of the training were individualized to the subject’s own comfortable ground walking speed and fast walking speed. In the initial 2 sessions, the subjects were encouraged to perform the walking training at a comfortable ground walking speed. After 2 sessions, the subjects were encouraged to perform the walking at a self-selected comfortable fast walking speed. The CGT and PWSTT groups received four 30-minute training sessions, excluding a 5-minute warm-up and cooldown period for each session, for 4 weeks (a total of 16 sessions).

**Data Analysis**

A 3×3 mixed factorial analysis of variance (with repeated measures) was used to assess the significant changes in the study parameters. SPSS 15.0 statistical software was used for data analysis. The 2 independent factors included in the analysis were (1) group (between-subjects factor) with 3 levels—control, CGT, and PWSTT; and (2) time (within-subjects factor) with 3 levels—baseline, W2, and W4. A Bonferroni adjustment was performed for post-hoc comparison. Two-sided tests were performed, the alpha was set at 5%, and the effect size was calculated by the partial eta squared (η²) value. Partial η² interpretation for effect size is as follows: >0.2, large-effect size; >0.1, medium-effect size; and >0.05, small-effect size.

### RESULTS

Clinical details for the patients are provided in Table 1. Demographic variables such as age, gender, height, and weight were comparable for the 3 study groups. No significant differences were found in the mean duration of the disease, the mean age of onset of symptoms, H&Y stage, UPDRS-III scores, Beck Depression Inventory scores, mini-mental status examination scores, and the levodopa equivalent dosage between the 3 groups of patients. All the subjects completed the study, and no adverse effects were reported in any of the treatment groups.

#### UPDRS-III Motor Scores

Table 2 shows the comparison of UPDRS-III (motor) scores. The UPDRS-III score showed significant group with time interaction (F2,114 = 27.01; P < .001). Significant improvement from baseline to W4 was noted in both the CGT and PWSTT groups (CGT group, P = .014; PWSTT group, P < .001). In addition, the PWSTT group showed significant improvement from W2 compared with the control group. No significant changes were seen in the control group (P = .999). In group comparison, the PWSTT group showed a significant improvement compared with the control group (P = .001) and the CGT group (P = .040) at W4. However, the CGT group did not differ significantly from the control group.

### Clinical Measures of Balance

**BBS.** A significant group with time interaction was observed in the clinical balance measures of BBS (F = 27.09; P < .001). The BBS score significantly increased in both the CGT and PWSTT groups after 4 weeks of treatment compared with baseline. Adjusted post-hoc group comparison did not show any significant difference between the groups (Table 2). Effect sizes (partial eta value) were as follows: PWSTT, 0.666; CGT, 0.221; and control group, 0.20.

### Table 1. Clinical details of the patients with Parkinson disease

<table>
<thead>
<tr>
<th></th>
<th>CT</th>
<th>CGT</th>
<th>PWSTT</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>59.1 ± 6.8</td>
<td>57.7 ± 10.3</td>
<td>57.6 ± 9.1</td>
<td>.841</td>
</tr>
<tr>
<td>Women/men ratio</td>
<td>4.16</td>
<td>5.15</td>
<td>5.15</td>
<td>.999</td>
</tr>
<tr>
<td>Height, cm</td>
<td>162.4 ± 5.4</td>
<td>158.3 ± 7.0</td>
<td>159.4 ± 7.8</td>
<td>.156</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>61.3 ± 10.9</td>
<td>58.8 ± 12.4</td>
<td>61.05 ± 8.4</td>
<td>.720</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>23.2 ± 3.8</td>
<td>23.4 ± 4.4</td>
<td>24.1 ± 3.5</td>
<td>.743</td>
</tr>
<tr>
<td>Mean age of onset, y</td>
<td>53.6 ± 7.5</td>
<td>52.8 ± 9.1</td>
<td>51.9 ± 10.6</td>
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</tr>
<tr>
<td>Duration of disease, y</td>
<td>5.5 ± 3.4</td>
<td>4.9 ± 3.1</td>
<td>5.7 ± 3.9</td>
<td>.728</td>
</tr>
<tr>
<td>Hoehn and Yahr stage, 2/2.5</td>
<td>16.4</td>
<td>17.3</td>
<td>17.3</td>
<td>.999</td>
</tr>
<tr>
<td>Levodopa equivalent dosage, mg</td>
<td>698.3 ± 227.1</td>
<td>577.1 ± 299.8</td>
<td>625.7 ± 315.1</td>
<td>.394</td>
</tr>
<tr>
<td>BDI</td>
<td>6.9 ± 2.6</td>
<td>5.8 ± 1.8</td>
<td>6.3 ± 2.3</td>
<td>.287</td>
</tr>
<tr>
<td>MMSE</td>
<td>28.7 ± 0.8</td>
<td>28.8 ± 1.0</td>
<td>29.3 ± 0.9</td>
<td>.106</td>
</tr>
</tbody>
</table>

The Fisher exact test was used for gender distribution and Hoehn and Yahr Stage; analysis of variance was used for other variables.

CT = control; CGT = conventional gait training; PWSTT = partial weight–supported treadmill training; BMI = body mass index; BDI = Beck Depression Inventory; MMSE = mini-mental status examination.
Clinical balance measures

Berg Balance Score; POMA = Tinetti Performance-Oriented Mobility Assessment; RMANOVA = repeated-measures analysis of variance.

F and P values were expressed after RMANOVA with Bonferroni adjustment; group-specific and time-specific comparisons are adjusted for multiple comparisons. Degree of freedom for group effects = 2.57, interaction effects = 4.114, and time effect = 2.114.

**Tinetti POMA.** Table 2 provides a comparison of POMA components. A significant interaction effect was observed in the POMA gait component (F = 32.813; P < .001) and balance component (F = 12.679; P < .001).

At W2, only the PWSTT group showed a significant improvement in gait score (P = .001) and balance score (P = .015) compared with baseline. At W4, the CGT group and PWSTT group had a significant increase in the POMA gait score (suggesting improvement) compared with baseline. At the same time, an improvement in the POMA balance score, compared with the baseline, was seen only in the PWSTT group. At W4, the control group did not show any significant change compared with baseline.

In the group comparison, the POMA gait score significantly improved at W4 in the CGT and PWSTT groups compared with the control group. In addition, the gait score was significantly better in the PWSTT group compared with the CGT group at W4. At W4, the POMA balance score significantly improved only in the PWSTT group compared with the control group (P = .001).

The effect size for PWSTT (partial $\eta^2$ value for gait score = 0.737 and balance score = 0.505) was greater. The effect size for CGT on gait score (partial $\eta^2$ = 0.245) was greater, and no effect was found on the balance score (partial $\eta^2$ = 0.063). The control group did not show any effect on gait score (partial $\eta^2$ = 0.007) and balance score (partial $\eta^2$ = 0.001). A good test-retest value was found for both the BBS (intraclass correlation coefficient [ICC] = 0.98) and the Tinetti POMA (ICC = 0.98).

**Dynamic Posturography**

**Balance Indices.** The balance indices are given in Figure 2 and Table 2. The OBI showed a significant group effect (F_{2,114} = 3.059; P = .039) and time effect (F_{2,114} = 4.359; P = .015). Similarly, API also showed significant group effect (F_{2,114} = 4.271; P = .009) and time effect (F_{2,114} = 3.716; P = .027). MLI showed a significant group with time interaction (F_{4,114} = 5.557; P = .002).
At W2, none of the groups showed significant changes in any of the balance indices compared with the baseline. At W4, significant changes were noted only in the PWSTT group. In this group, only the OBI and MLI showed a significant decrease in score from baseline (suggesting improvement). In group comparison, a significant improvement in the PWSTT group was found compared with the control group at W4 (OBI, P = .002; API, P = .003; MLI, P < .001). In addition, the MLI was significantly better in the PWSTT group than in the CGT group (P = .020) at W4.

The effect size for PWSTT was larger for OBI (partial $\eta^2 = 0.229$) and MLI (partial $\eta^2 = 0.274$) and medium for API (partial $\eta^2 = 0.103$). The control group (partial $\eta^2$ value for OBI = 0.001, API = 0.054, and MLI = 0.027) and CGT group (partial $\eta^2$ value for OBI = 0.022, API = 0.029, and MLI = 0.006) showed minimum or no effect on balance.

**LOS (Table 3).** The time to complete the LOS task showed a significant group (F = 4.914, P = .011) and time effect (F = 6.494, P = .008). A significant group with time interaction was found in the total LOS scores (F = 3.781, P = .017), as well as in the following subscores: FW (F = 3.064, P = .023); LT (F = 3.879, P = .010); BW-RT (F = 4.012, P = .004); and BW-LT (F = 2.996, P = .022). A significant time effect was noted in the following LOS subscores: RT (F = 5.485, P = .007); FW-RT (F = 4.492, P = .015); and FW-LT (F = 3.849, P = .034). Similarly, a few subscores also showed significant group effect: RT (F = 7.721, P < .001); FW-RT (F = 5.721, P = .005); FW-LT (F = 9.009, P < .001); and BW (F = 12.431, P < .001). The comparisons of LOS subscores are provided in Figure 3.

At W2, none of the groups showed any significant changes in direction-wise analysis of LOS scores compared with baseline. At W4, only the PWSTT group had a significant increase in all the LOS subscores (Figure 3) and a significant reduction in the time to complete the LOS task (Table 3).

In group comparisons, the PWSTT group showed a significant improvement in the total LOS score and the LT and BW-RT subscores compared with the control group at W2.
In addition, the PWSTT group also demonstrated significant improvement of the total LOS scores and all the subscores compared with control subjects at W4. The total LOS score and FW, BW, RT, BW-RT, and BW-LT scores were better than the CGT group scores at W4. The CGT group did not show any significant change compared with the control group at either W2 or W4.

The effect size for PWSTT (partial \( \eta^2 \) value for FW = 0.245; BW = 0.122; RT = 0.242; LT = 0.280; FW-RT = 0.155, FW-LT = 0.207; BW-RT = 0.392, and BW-LT = 0.307) was medium to large. The control group (partial \( \eta^2 \) value for FW = 0.012; BW = 0.008; RT = 0.021; LT = 0.011; FW-RT = 0.012, FW-LT = 0.002; BW-RT = 0.004; and BW-LT = 0.001) and CGT group (partial \( \eta^2 \) value for FW = 0.051; BW = 0.022; RT = 0.034; LT = 0.067; FW-RT = 0.021, FW-LT = 0.022; BW-RT = 0.061; and BW-LT = 0.015) showed minimum or no effect on balance.

The ICC values for the balance indices OBI (0.96), API (0.86), MLI (0.86), and the direction-specific LOS scores, that is, FW (0.93), BW (0.93), RT (0.94), LT (0.95), FW-RT (0.94), FW-LT (0.95), BW-RT (0.94), and BW-LT (0.91), showed good inter-rater reliability.

The dynamic posturography measure did not have any correlation with the clinical severity UPDRS-III motor score and the Tinetti POMA gait component score. BBS showed a significant positive correlation with FW (r = 0.327, P = .011), BW-RT (r = 0.334, P = .009), and BW-LT (r = 0.293, P = .23) direction LOS scores. The Tinetti POMA balance component had a significant positive correlation with BW (r = 0.267, P = .039) and BW-LT (r = 0.392, P = .002) direction LOS scores.

In brief, the study showed that 4 weeks of PWSTT significantly improved the UPDRS-III motor score, balance indices (OBI, API, and MLI), LOS in 8 directions, Tinetti POMA gait score, and balance component scores. The CGT group showed significant improvement in motor score and the gait component of POMA (but not in the balance component). BBS showed significant improvement in the PWSTT and CGT groups compared with baseline; however, no group differences were observed. No significant changes were observed in dynamic posturography parameters in control subjects and the CGT group.

**DISCUSSION**

The results of the present study show that improvement in the UPDRS-III motor score, MLI, POMA gait score, and LOS total score was significantly better in the PWSTT group than in the CGT group. Although the gait score improved in the CGT group, improvement in balance was seen only in the PWSTT group. Various techniques have been used to assess balance control in persons with PD, such as posturography, force platforms, kinematics, electromyography techniques, and clinical scales [17,18]. Dynamic posturography is used to evaluate 2 components of balance: dynamic balance indices and LOS. Dynamic balance indices reflect the integral control of proprioceptive reflexes required to produce timely coordinated movement to retain balance and equilibrium [19]. Poor neuromuscular control was indicated by a large variance quantified as an increased dynamic balance indices score [13,14]. Although a number of studies have addressed the effects of therapeutic interventions on balance in persons with PD, limited randomized controlled trials have been reported [6,20-22].

The PWSTT group showed significant improvement in all the balance indices compared with the control group. However, only the MLI is significantly better compared with the CGT group at W4. API did not show significant changes compared with the CGT group, which points to the difficulty in balance training in the anteroposterior direction. Improvement of MLI at W2 compared to control explains the early trainability of balance in the mediolateral direction rather than the anteroposterior direction. In addition, we speculate that this phenomenon also may contribute to the increased frequency of falls in the anteroposterior direction in patients with PD.

Although both CGT and PWSTT groups were instructed to perform the training at a self-selected comfortable fast
walking speed, the subjects in the PWSTT group preferred a relatively faster walking speed compared with the subjects in the CGT group. When subjects are trained with CGT, they may use a wider walking base of support (BOS) than subjects trained with a treadmill. Using a smaller walking BOS is a more demanding task that could have contributed to a greater balance control after PWSTT training. However, CGT could be associated with walking with a relatively larger walking BOS, which is a less demanding task in terms of balance control, and therefore they showed improvement in gait only. It is likely that training the subjects with a treadmill (with a relatively smaller walking BOS) results in more demand on weight transfer in the mediolateral direction. In addition, the anteroposterior direction translation is easily obtained through treadmill motion. These factors probably resulted in improved balance in the mediolateral direction than in the anteroposterior direction in the PWSTT group.

Although the PWSTT reduces trunk motion, the dose of walking, the walking speed, and training in a relatively small walking BOS may contribute to the improvement of balance measures in the PWSTT group compared with the CGT group. However, it is also possible that similar benefits can be obtained through treadmill training without partial weight support. No conclusions can be drawn about this possibility based on the current study because of a lack of a group undergoing treadmill training without partial weight support. However, the results favor the beneficial effects of PWSTT on balance compared with CGT.

LOS reflects the interlimb coordination based on different task requirements in different directions, and the increase in LOS scores suggests a good control of balance toward the specific directions [13,14]. A significant improvement was found in the overall LOS scores and in the 8 direction-wise LOS components in the PWSTT group after 4 weeks of training, which suggests that PWSTT increases the LOS whereas CGT does not influence the LOS component after 4 weeks of training. Reduced LOS scores have been reported earlier in persons with PD [14,23], which might be the result of abnormal temporal features in balancing strategy during implementation of the vision-dependent behavior in persons with PD and impaired anticipatory motor strategies [24]. The present study is probably the first to report the influence of PWSTT on the LOS in patients with PD. Studies have reported direction-specific postural instability in patients with PD [14,17,25]. By using posturography in patients with early-stage PD, Horak et al [25] reported impairment of balance in backward directions and different diagonal directions in patients with PD. Our study has demonstrated significant improvement in LOS scores in patients in all 8 directions after 4 weeks of PWSTT. In contrast, CGT does not have significant benefit in direction-specific balance improvement after 4 weeks of training.

On the clinical measures, the UPDRS-III motor score showed significant improvement in the PWSTT group compared with the control group and significantly better improvement than the CGT group at W4. Similarly, the PWSTT group gait score improvement at W4 was significantly better than that of the CGT group, which probably indicates that PWSTT is better than CGT in improving motor scores and gait in patients with PD.

On the clinical balance measurement scale (POMA), a significant improvement in the gait score and balance score was found in the PWSTT group compared with the control group after 4 weeks of training. Although the CGT group had significant improvements in the gait score, the balance score did not show any significant changes after 4 weeks of training, which indicates that although the gait component can be improved by either CGT or PWSTT, the balance component requires PWSTT training.

Although BBS demonstrated a significant group with time interaction effect, adjusted pair-wise group comparison did not reveal significant group differences, which suggests that physical training–induced improvement in balance as assessed by BBS may not be sensitive enough to detect differences between PWSTT, CGT, and control subjects in a 4-week period. Consistent with these findings, Toole et al [6] and Ashburn et al [20] did not find any improvement in BBS but reported improvement in the functional reach test.

The exact pathogenesis of postural instability in persons with PD is still unknown. The underlying mechanisms are complex, with involvement of different neural structures [2,3]. Blin et al [2] reported levodopa (L-DOPA)–sensitive and L-DOPA–resistant components of walking and other postural tasks. Bloem et al [3] concluded that balance impairment in persons with PD is related to a combination of both dopaminergic and nondopaminergic lesions. We speculate that the improvement of balance observed in the present study was a result of improvement of both L-DOPA–sensitive and L-DOPA–resistant components of balance. However, the exact mechanism of improvement is unknown.

A better functional outcome with body weight support than without weight support has been reported in patients who have had a stroke [10]. This finding supports our observation that partial weight support in treadmill training may contribute to the improvement of balance in the PWSTT group. Among the tests of dynamic posturography measures, LOS produced noticeable changes as mentioned previously compared with the balance indices, which indicates that LOS may serve as an early predictor outcome measure in evaluating short-term rehabilitation in persons with PD. Hence among the various parameters that assess balance, dynamic posturography may predict the small changes in balance. PWSTT can be an intervention of choice, especially in persons with PD who have direction-specific balance impairment.

Using a similar methodology in patients with PD, Miyai et al [4] reported greater improvement in activities of daily
living, motor performance, and ambulation after PWSTT with 20% unloading of weight than with conventional physio-
therapy. A follow-up study by the same group showed the
beneficial effects lasting for 6 months [5]. However, unlike
us, Miyai et al [4,5] did not address any balance parameters.
Toole et al [26] reported improved balance in patients with
PD (H&Y stages 1-3) concluded that treadmill training
improved speed of gait and walking distance [7]. However,
the dynamic balance and the components of LOS that we
addressed in our study have not been addressed in previous
studies. The meta-analysis reported the absence of adverse
events in treadmill training, an observation with which we
agree based on the results of our study.

The added advantage of PWSTT may also result from (1)
symmetrical continuous sensory stimuli from the moving
treadmill, enhancing locomotor pattern generators [27];
(2) partial weight support, providing a sense of security
regarding falling and facilitating free leg movements [4,5];
and (3) getting positive feedback from every step, which

### Table 3. Direction-wise analysis of limits of stability components in all the 3 groups

<table>
<thead>
<tr>
<th>LOS</th>
<th>Group</th>
<th>BL</th>
<th>After 2 Weeks (W2), Mean ± SD</th>
<th>After 4 Weeks (W4), Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to complete LOS test</td>
<td>CT</td>
<td>187.7 ± 46.2</td>
<td>180.9 ± 41.2</td>
<td>178.1 ± 36.6</td>
</tr>
<tr>
<td></td>
<td>CGT</td>
<td>167.3 ± 32.7</td>
<td>165.2 ± 36.9</td>
<td>155.9 ± 31.1</td>
</tr>
<tr>
<td></td>
<td>PWSTT</td>
<td>175.9 ± 42.1</td>
<td>152.90 ± 46.4</td>
<td>131.3 ± 45.1</td>
</tr>
<tr>
<td>Total LOS score</td>
<td>CT</td>
<td>20.9 ± 9.0</td>
<td>22.6 ± 8.5</td>
<td>21.8 ± 9</td>
</tr>
<tr>
<td></td>
<td>CGT</td>
<td>25.4 ± 8.8</td>
<td>27.0 ± 8.7</td>
<td>29.9 ± 7.8</td>
</tr>
<tr>
<td></td>
<td>PWSTT</td>
<td>26.8 ± 9.2</td>
<td>31.9 ± 10.6</td>
<td>42.2 ± 14.7</td>
</tr>
<tr>
<td>FW</td>
<td>CT</td>
<td>27 ± 13.2</td>
<td>29.5 ± 15.7</td>
<td>26.9 ± 11.1</td>
</tr>
<tr>
<td></td>
<td>CGT</td>
<td>27.1 ± 12.9</td>
<td>29.6 ± 10.8</td>
<td>34.9 ± 12.7</td>
</tr>
<tr>
<td></td>
<td>PWSTT</td>
<td>28.6 ± 12.4</td>
<td>37.4 ± 12.6</td>
<td>48.9 ± 20.6</td>
</tr>
<tr>
<td>BW</td>
<td>CT</td>
<td>15.6 ± 11.4</td>
<td>14.7 ± 7.9</td>
<td>13.1 ± 6.7</td>
</tr>
<tr>
<td></td>
<td>CGT</td>
<td>18.2 ± 12.2</td>
<td>23.1 ± 17.6</td>
<td>20.6 ± 7.5</td>
</tr>
<tr>
<td></td>
<td>PWSTT</td>
<td>19.7 ± 9.5</td>
<td>22.8 ± 14.9</td>
<td>30.2 ± 16.3</td>
</tr>
<tr>
<td>RT</td>
<td>CT</td>
<td>23.9 ± 10.5</td>
<td>28.8 ± 16.8</td>
<td>26.4 ± 12.7</td>
</tr>
<tr>
<td></td>
<td>CGT</td>
<td>27.6 ± 11.9</td>
<td>32.3 ± 13.2</td>
<td>35 ± 16.8</td>
</tr>
<tr>
<td></td>
<td>PWSTT</td>
<td>32.8 ± 17.3</td>
<td>33.1 ± 13.9</td>
<td>49.3 ± 22</td>
</tr>
<tr>
<td>LT</td>
<td>CT</td>
<td>18.9 ± 11.5</td>
<td>20.3 ± 10.9</td>
<td>18.4 ± 9.5</td>
</tr>
<tr>
<td></td>
<td>CGT</td>
<td>26.1 ± 12.2</td>
<td>23.7 ± 7.1</td>
<td>28.7 ± 10.9</td>
</tr>
<tr>
<td></td>
<td>PWSTT</td>
<td>21.3 ± 9.7</td>
<td>28.4 ± 11.6</td>
<td>37.8 ± 18.4</td>
</tr>
<tr>
<td>FW-LT</td>
<td>CT</td>
<td>22.7 ± 10.9</td>
<td>25.1 ± 16.5</td>
<td>26.3 ± 15.5</td>
</tr>
<tr>
<td></td>
<td>CGT</td>
<td>26.6 ± 8.4</td>
<td>27.6 ± 10.9</td>
<td>31.2 ± 17.8</td>
</tr>
<tr>
<td></td>
<td>PWSTT</td>
<td>27.2 ± 8.8</td>
<td>37.9 ± 16.4</td>
<td>39.4 ± 18.6</td>
</tr>
<tr>
<td>FW-LT</td>
<td>CT</td>
<td>24.3 ± 16.1</td>
<td>25.7 ± 11</td>
<td>24.5 ± 11.3</td>
</tr>
<tr>
<td></td>
<td>CGT</td>
<td>31.7 ± 15.1</td>
<td>32.3 ± 15.8</td>
<td>35.9 ± 10.8</td>
</tr>
<tr>
<td></td>
<td>PWSTT</td>
<td>30.2 ± 14.5</td>
<td>36.2 ± 16.6</td>
<td>47.1 ± 23.6</td>
</tr>
<tr>
<td>BW-LT</td>
<td>CT</td>
<td>18.5 ± 11.4</td>
<td>19.9 ± 11.9</td>
<td>20.8 ± 11.5</td>
</tr>
<tr>
<td></td>
<td>CGT</td>
<td>23.9 ± 9.3</td>
<td>26.0 ± 13.4</td>
<td>31.0 ± 12.4</td>
</tr>
<tr>
<td></td>
<td>PWSTT</td>
<td>25.2 ± 12.1</td>
<td>33.2 ± 17.3</td>
<td>48.4 ± 19.9</td>
</tr>
</tbody>
</table>

LOS = limits of stability; BL = baseline; W2 = week 2; W4 = week 4; CT = control; CGT= conventional gait training; PWSTT = partial weight–supported treadmill training; FW = forward; BW = backward; RT = right; LT = left; RMANOVA = repeated-measures analysis of variance.

F and P values were expressed after RMANOVA with Bonferroni adjustment; group-specific and time-specific comparisons are adjusted for multiple comparisons. Degree of freedom for group effects = 2.57, interaction effects = 4.114, and time effect = 2.114.
helps in autocorrection of step length and enhances motor learning [28]. It has been also postulated that these cueing strategies help bypass the defective basal ganglia by using alternative pathways unaffected by PD [29]. Attention strategies offer an alternative to external cues because they rely more on cognitive mechanisms of motor control and are internally generated, which help improve motor performance [29]. Other possible explanations include task-specific motor learning or improvement in postural reflexes [30], exercise-induced and activity-dependent neural plasticity (ie, neurogenesis, synaptogenesis, and molecular adaptation) [31,32], and normalization of corticomotor excitability/cortical reorganization, especially in the supplementary motor area in persons with PD [33].

The limitations of our study include the lack of a patient group subjected to training on a treadmill without partial weight support, lack of follow-up, and lack of blinding of the participants to the assessment. It is possible that the “Hawthorne effect” can influence the subject’s performance while performing the outcome measures. In the current study, all three groups received a similar level of attention. However, no significant improvement was observed in the measures of balance outcome in the control and CGT groups, which implies that the influence of attention on balance would have

<table>
<thead>
<tr>
<th>Group, Time and Interaction Effects</th>
<th>Groups</th>
<th>BL</th>
<th>W2</th>
<th>W4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group effect: F = 4.914; P = .011</td>
<td>CT-CGT</td>
<td>.354</td>
<td>.725</td>
<td>.214</td>
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<tr>
<td>Time effect: F = 6.494; P = .008</td>
<td>CT-PWSTT</td>
<td>.999</td>
<td>.115</td>
<td>.001</td>
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<tr>
<td>Interaction: F = 1.816; P = .161</td>
<td>CGT-PWSTT</td>
<td>.999</td>
<td>.999</td>
<td>.135</td>
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<tr>
<td>Group effect: F = 16.767; P &lt; .001</td>
<td>CT-CGT</td>
<td>.371</td>
<td>.413</td>
<td>.071</td>
</tr>
<tr>
<td>Time effect: F = 9.062; P = .001</td>
<td>CT-PWSTT</td>
<td>.129</td>
<td>.008</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Interaction: F = 3.781; P = .017</td>
<td>CGT-PWSTT</td>
<td>.999</td>
<td>.319</td>
<td>.002</td>
</tr>
<tr>
<td>Group effect: F = 8.566; P = .001</td>
<td>CT-CGT</td>
<td>.999</td>
<td>.999</td>
<td>.309</td>
</tr>
<tr>
<td>Time effect: F = 7.092; P = .002</td>
<td>CT-PWSTT</td>
<td>.999</td>
<td>.194</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Interaction: F = 3.064; P = .023</td>
<td>CGT-PWSTT</td>
<td>.999</td>
<td>.209</td>
<td>.017</td>
</tr>
<tr>
<td>Group effect: F = 12.431; P &lt; .001</td>
<td>CT-CGT</td>
<td>.999</td>
<td>.194</td>
<td>.106</td>
</tr>
<tr>
<td>Time effect: F = 1.140; P = .322</td>
<td>CT-PWSTT</td>
<td>.726</td>
<td>.229</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Interaction: F = 1.694; P = .160</td>
<td>CGT-PWSTT</td>
<td>.999</td>
<td>.999</td>
<td>.024</td>
</tr>
<tr>
<td>Group effect: F = 7.721; P = .001</td>
<td>CT-CGT</td>
<td>.999</td>
<td>.999</td>
<td>.383</td>
</tr>
<tr>
<td>Time effect: F = 5.485; P = .007</td>
<td>CT-PWSTT</td>
<td>.133</td>
<td>.999</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Interaction: F = 2.278; P = .073</td>
<td>CGT-PWSTT</td>
<td>.688</td>
<td>.999</td>
<td>.041</td>
</tr>
<tr>
<td>Group effect: F = 9.120; P &lt; .001</td>
<td>CT-CGT</td>
<td>.148</td>
<td>.894</td>
<td>.056</td>
</tr>
<tr>
<td>Time effect: F = 5.026; P = .013</td>
<td>CT-PWSTT</td>
<td>.999</td>
<td>.043</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Interaction: F = 3.879; P = .010</td>
<td>CGT-PWSTT</td>
<td>.540</td>
<td>.438</td>
<td>.113</td>
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<tr>
<td>Group effect: F = 5.721; P = .005</td>
<td>CT-CGT</td>
<td>.506</td>
<td>.999</td>
<td>.999</td>
</tr>
<tr>
<td>Time effect: F = 4.492; P = .015</td>
<td>CT-PWSTT</td>
<td>.593</td>
<td>.061</td>
<td>.025</td>
</tr>
<tr>
<td>Interaction: F = 1.017; P = .381</td>
<td>CGT-PWSTT</td>
<td>.999</td>
<td>.096</td>
<td>.436</td>
</tr>
<tr>
<td>Group effect: F = 9.009; P &lt; .001</td>
<td>CT-CGT</td>
<td>.447</td>
<td>.484</td>
<td>.094</td>
</tr>
<tr>
<td>Time effect: F = 3.489; P = .034</td>
<td>CT-PWSTT</td>
<td>.765</td>
<td>.083</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Interaction: F = 1.159; P = .107</td>
<td>CGT-PWSTT</td>
<td>.999</td>
<td>.999</td>
<td>.102</td>
</tr>
<tr>
<td>Group effect: F = 15.498; P &lt; .001</td>
<td>CT-CGT</td>
<td>.376</td>
<td>.568</td>
<td>.108</td>
</tr>
<tr>
<td>Time effect: F = 11.615; P &lt; .001</td>
<td>CT-PWSTT</td>
<td>.181</td>
<td>.016</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Interaction: F = 4.012; P = .004</td>
<td>CGT-PWSTT</td>
<td>.999</td>
<td>.366</td>
<td>.002</td>
</tr>
<tr>
<td>Group effect: F = 10.112; P &lt; .001</td>
<td>CT-CGT</td>
<td>.999</td>
<td>.978</td>
<td>.999</td>
</tr>
<tr>
<td>Time effect: F = 4.990; P = .008</td>
<td>CT-PWSTT</td>
<td>.857</td>
<td>.104</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Interaction: F = 2.996; P = .022</td>
<td>CGT-PWSTT</td>
<td>.999</td>
<td>.736</td>
<td>.001</td>
</tr>
</tbody>
</table>
achieved a ceiling effect during the pretraining assessment. The posttraining assessment results were possibly due to training effect.

CONCLUSIONS

Four weeks of CGT and PWSTT improved gait in patients with PD. The UPDRS-III motor score and balance (both the balance indices and the LOS in 8 directions) improved only in the PWSTT group. Improvement of the UPDRS-motor score, MLI score, and LOS total score was significantly better in the PWSTT group compared with the CGT group. Therefore we conclude that PWSTT can be a recommended as an intervention of choice in patients with PD, especially in patients with balance impairment.

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REFERENCES


