Six Weeks of Intensive Treadmill Training Improves Gait and Quality of Life in Patients With Parkinson’s Disease: A Pilot Study

Talia Herman, MSc, Nir Giladi, MD, Leor Gruendlinger, MSc, Jeffrey M. Hausdorff, PhD


Objective: To evaluate the effects of 6 weeks of intensive treadmill training on gait rhythmicity, functional mobility, and quality of life (QOL) in patients with Parkinson’s disease (PD).

Design: An open-label, before-after pilot study.

Setting: Outpatient movement disorders clinic.

Participants: Nine patients with PD who were able to ambulate independently and were not demented. Mean age was 70±6.8 years. Patients had mild to moderate PD (Hoehn and Yahr stage range, 1.5–3).

Interventions: Patients walked on a treadmill for 30 minutes during each training session, 4 training sessions a week, for 6 weeks. Once a week, usual overground walking speed was re-evaluated and the treadmill speed was adjusted accordingly.

Main Outcome Measures: The 39-item Parkinson’s Disease Questionnaire (PDQ-39), motor part of the Unified Parkinson’s Disease Rating Scale (UPDRS), gait speed, stride time variability, swing time variability, and the Short Physical Performance Battery (SPPB).

Results: A comparison of the measures taken before and after the treadmill intervention indicates general improvement. QOL, as measured by the PDQ-39, was reduced (improved) from 32 to 22 (P<.014). Parkinsonian symptoms, as measured by the UPDRS, decreased (improved) from 29 to 22 (P<.043). Usual gait speed increased from 1.11 to 1.26m/s (P<.014). Swing time variability was lower (better) in all but one patient, changing from 3.0% to 2.3% (P<.06). Scores on the SPPB also improved (P<.008). Interestingly, many of the improvements persisted even 4 months later.

Conclusions: These results show the potential to enhance gait rhythmicity in patients with PD and suggest that a progressive and intensive treadmill training program can be used to minimize impairments in gait, reduce fall risk, and increase QOL in these patients.

Key Words: Cues; Gait; Parkinson’s disease; Quality of life; Rehabilitation; Treadmill test.

© 2007 by the American Congress of Rehabilitation Medicine and the American Academy of Physical Medicine and Rehabilitation

Gait disturbances and instability are common among patients with Parkinson’s disease (PD). The most significant consequences of the dysrhythmic and disturbed gait include falls, often leading to functional dependence and markedly impinging on quality of life (QOL). The therapeutic options for treating these gait disturbances and reducing fall risk in PD are quite limited. Despite advances in pharmacologic therapy and surgical procedures, impairment in gait and balance remain common in PD patients. Development of adjunct therapy and rehabilitation-like approaches is important for the management and the welfare of these patients.

Treadmill training is widely used to enhance the gait of poststroke patients and patients with spinal cord injury, in part because it enables walking while allowing for partial body-weight support. Only a few studies have examined the effects of treadmill training on gait and motor performance in PD. In 2000, Miyai et al investigated the effects of body-weight supported treadmill training (BWSTT) on gait and parkinsonian symptoms of PD patients. In this 4-week crossover study, BWSTT produced greater improvement in motor performance compared with conventional physical therapy (PT), increasing stride length and gait speed and reducing parkinsonian symptoms. A follow-up randomized controlled trial showed a long-term effect of BWSTT on gait, beyond that of conventional PT, which lasted for about 4 months. Similarly, Toole et al studied the effects of 6 weeks of treadmill walking in 23 subjects with PD, who were divided into 3 intervention groups who trained with different amounts of weight bearing. Muscle strength did not change, but significant improvement in the motor portion of the Unified Parkinson’s Disease Rating Scale (UPDRS), balance and gait were seen in all 3 groups, regardless of the degree of weight bearing. These findings suggest that treadmill training is effective in PD, but that unlike in the stroke patient, body-weight support is apparently not critical for training patients with PD.

Three works have studied how the treadmill can be used to improve PD gait without body-weight support. Pohl et al examined the immediate effects of a single treadmill session in a crossover, 4-consecutive-day trial in 17 patients with early PD. Their results suggest that gait speed and stride length can be improved through a single intervention of treadmill training (even without body-weight support), but not through conventional gait training. Using a paradigm that focused on stepping rather than routine walking, Protas et al assessed the benefits of gait and step training in PD. They found that walking on a treadmill at a speed greater than overground walking speed while walking in 4 directions (back and forth and sideways) and step training (practicing starting and stopping) resulted in a reduction in falls and improvement in gait and dynamic balance in a small group of patients. Whereas these investiga-
tions examined gait parameters such as speed, cadence, and stride length, Frenkel-Toledo et al.\(^{19}\) assessed the influence of treadmill training on stride-to-stride variability. This aspect of gait reflects the consistency of the gait pattern and has been associated with fall risk and has been shown to be independent of stride length in PD.\(^{19-23}\) Frenkel-Toledo showed that when walking on a treadmill, patients with PD improve their gait and walk with reduced gait variability, even when walking at the same speed as on overground walking. These findings indicate that treadmill walking can promote a more stable walking pattern in patients with PD, and suggest that perhaps an intervention program that includes long-term treadmill walking—without using body-weight support—will be able to restore rhythmicity, reduce gait variability, and perhaps succeed at lowering fall risk. The objective of the present study, therefore, was to examine the effects of 6 weeks of intensive treadmill training on gait rhythmicity. In addition, we assessed the effects of this treadmill training program on functional mobility, gait, and QOL in patients with PD. To this end, patients were assessed before they participated in the training program, after, and 4 weeks later to evaluate post-training effects.

**METHODS**

**Participants**

In this study, we included 9 patients with idiopathic PD who were able to ambulate independently. Subjects who met the inclusion criteria were recruited from the Movement Disorders Unit at the Tel Aviv Sourasky Medical Center, using a convenience sample of mild to moderate PD patients. All patients were free of serious comorbidities, other than PD (eg, dementia, unstable cardiovascular disease [CVD], rheumatologic disease, orthopedic disturbances, or pain while walking) or acute illness that would make training inappropriate. Patients who had used a treadmill more than once a week, or were unwilling to commit to the training program and to the follow-up period, were excluded. Patients with any signs of CVD were asked to provide written medical clearance from their cardiologist. The study was approved by the Human Studies Committee of Tel-Aviv Sourasky Medical Center and all patients signed a consent form.

**Pre- and Post-Assessments**

After providing informed written consent, the patients underwent a comprehensive physical and neurologic assessment. Patients were studied 3 times: (1) before the treadmill training program started; (2) 2 to 3 days after they completed the 6 weeks program; and (3) about 4 to 5 weeks after they completed the training program. The pre- and postassessments included a full medical history, history of falls, Mini-Mental Status Examination (MMSE),\(^{24}\) and the motor part (part III) of the UPDRS.\(^{25}\) The 39-item Parkinson’s Disease Questionnaire (PDQ-39)\(^{26}\) was used to assess QOL. The Short Physical Performance Battery (SPPB) was used to assess balance and lower-extremity capabilities.\(^{27}\) We also administered the Activities-specific Balance Confidence (ABC) scale\(^{28,29}\) and the Geriatric Depression Scale (GDS)\(^{30-32}\) to assess fear of falling and mental well-being, respectively. To measure and quantify stride-to-stride variability, we placed force-sensitive insoles in the subject’s shoe while the subject walked on a level surface for 2 minutes at comfortable walking speed. Overground comfortable walking speed was measured using a stop watch, and average stride length was calculated. In addition, we used a modified visual analog scale (VAS) to quantify the subject’s subjective perceptions of his/her gait performance.\(^{33}\)

We determined average stride time, swing time (in percent), stride time variability, and swing time variability from the force record using previously described methods.\(^{20,21,34}\) Variability measures were quantified using the coefficient of variation (CV); for example, stride time variability equals $100 \times (\text{average stride time/standard deviation [SD]})$.

**Treadmill Training Protocol**

Patients walked on a motorized medical treadmill,\(^{8}\) under the close supervision of a physical therapist. The patients walked in all sessions while wearing a safety harness to prevent falls, but no patient used the weight-support option. The training program consisted of sessions of 30 minutes each, 4 sessions a week, for 6 weeks (a total of 24 sessions). Once a week, overground walking speed was re-evaluated and the treadmill speed was adjusted accordingly, in order to enable a progressive increase in gait speed as detailed below.

A unique aspect of this study was the application of an intensive and progressive gait training program. Because walking on the treadmill is different than overground walking, we started the program of each patient by setting the treadmill speed to 80% of his/her overground comfortable walking speed, increasing to 90% of the comfortable walking speed after a week. Thus, by the third week of training, all patients reached the overground measured comfortable walking speed (on the treadmill). From the third week, the treadmill speed was gradually increased to reach a goal of 5% to 10% above that week’s overground comfortable walking speed. Because the overground comfortable walking speed improved each week, patients ended up walking on the treadmill at speeds higher than those measured at baseline. Each session of the training program was designed to be a rehabilitation-like treatment with positive feedback and re-enforcement of the patient’s performance by the physical therapist who conducted the treatment. During the sessions, the physical therapist encouraged the patients to devote effort to their gait by walking with large strides and correct posture.

**Statistical Analysis**

Descriptive statistics are reported as mean ± SD. The Mann-Whitney $U$ test (nonparametric equivalent of the paired $t$ test) was used to compare the pre- and postmeasurements. All statistical analyses were performed using SPSS.\(^{35}\) A $P$ value of .05 or less was considered statistically significant.

**RESULTS**

**Patient Characteristics**

Demographic and clinical characteristics of the 9 patients at baseline are summarized in table 1. Disease severity of the patients was mild to moderate, and the Hoehn and Yahr stages ranged from 1.5 to 3. Two patients experienced motor response fluctuations. Eight patients were on levodopa or dopamine

---

**Table 1: Characteristics of the Study Participants (N=9)**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>PD Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>70±6.8</td>
</tr>
<tr>
<td>Sex (men)</td>
<td>6(66.7)</td>
</tr>
<tr>
<td>Height (m)</td>
<td>168.5±6.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>72.1±9.6</td>
</tr>
<tr>
<td>Disease duration (y)</td>
<td>5.0±2.6</td>
</tr>
<tr>
<td>MMSE score</td>
<td>28.9±0.6</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD or n (%).
agonist therapy, and 1 patient was treated with amantadine and selegiline.

**Short-Term Effects**

Table 2 compares baseline values with those measured a few days after completion of 6 weeks of intensive treadmill training. There was no significant change in the level of fear of falling (as measured by the ABC score) or mental well-being (as measured by the GDS). There was a tendency for reduced swing time variability, as can be seen in the change in swing percentage CV. Mobility, as measured by gait speed, stride length, VAS, and the SPPB, significantly improved in response to the training. Scores on the PDQ-39 also significantly improved. Consistent with the observed improvements in many of the objective measures, all participants expressed enthusiasm for the protocol and a desire to continue with it.

**Longer-Term Effects**

Seven patients were retested 4 to 5 weeks after they completed the 6 weeks of treadmill training. Many variables remained significantly improved compared with baseline values (pretreatment). Gait speed (longer-term speed, 1.16 vs 0.24 m/s; 
P = .028), VAS gait (longer-term score, 8.14 vs 2.3; 
P = .043) and stride length (longer term stride length, 1.26 vs 0.21; 
P = .043) were significantly increased compared with baseline values 4 weeks after the training was stopped. Parkinsonian motor signs, as measured by part III of the UPDRS, remained significantly lower (19.7 vs 6.4, 
P = .027) 4 weeks later compared with the value seen at baseline. Compared with baseline values, even functional performance, as measured by the SPPB, tended to be improved 4 weeks after the intervention was completed (11.2 vs 1.2, 
P = .06). Other measures were now similar to baseline values.

**DISCUSSION**

This study examined the possibility that a treadmill may be used as an adjunct treatment to complement PT, to improve QOL, physical performance, and enhance gait stability in PD patients. We focused on these issues because PD is a classic example of a motor disorder that impacts on QOL. With this intervention, not only were positive effects seen immediately, but a carryover effect was observed 4 weeks later for many measures. Furthermore, positive effects beyond gait were seen in the patients’ perspective of their general well-being and QOL.

In this pilot study, the rationale to choose an intensive and progressive training derived from studies using progressive resistance strength training and high-intensity voice treatment. For example, Fiatarone et al35 showed that high-intensity, progressive resistance training is highly efficacious, even among frail adults. Additional justification that a progressive and intensive training program may improve gait rhythmicity in PD, despite the presence of neurodegeneration, comes from work on voice treatment in PD. There are at least 3 features that underlie the voice disorders common in PD: (1) reduction in amplitude; (2) a problem with the sensory perception of effort; and (3) deficient internal cueing causes difficulty in generation of appropriate effort. To some extent, parallel deficiencies can be found in gait (eg, shortened stride length as an expression of small amplitude; impaired rhythmicity as a deficient internal cueing). Ramig et al36-38 have shown that patients with PD can be trained to work around these deficits in speech, and that the training effects can last at least 2 years after cessation of an initial intensive training period. The parallels between voice and gait suggest that retraining of gait (rhythmicity) may also be achievable. Increasing the walking demand and challenging the patient by setting gait speed is one way to adapt progressive training. With the treadmill, there is no getting around it, the patient must match his/her pace to the treadmill.

The mechanism whereby treadmill training works in PD remains to be fully determined. One possibility is that the treadmill acts as an external cue by setting the walking pattern, reinforcing neuronal circuits that contribute to gait pacing. This explanation is supported by earlier findings which showed that external cues improve gait in PD.39-46 Perhaps a treadmill provides an external rhythm that compensates for the defective internal rhythm of the basal ganglia in the same way that rhythmic auditory stimulation or visual cues work in PD. Another possibility is that treadmill training works as a form of motor learning. Recently van Hedel et al47 evaluated the acquisition and performance of a high-precision locomotor task in patients with PD compared with healthy subjects. Initially, PD patients performed poorer and improved foot clearance more slowly. However, after task repetition, the groups performed similarly, indicating that adequate training can improve locomotor behavior in PD patients.47 The treadmill protocol described here may achieve its short-term and longer-term, carryover effects by inducing gradual implicit motor learning of rhythmic walking. Like voice training,36-38 the treadmill training used here was intensive, repetitive, and involved ongoing feedback. The patient learns to adapt to progressively increasing demands—a process that may enhance the automaticity of motor control. Motor learning may explain the carryover effect, because the treadmill trains a steady gait speed and paces gait on a more subconscious level, but the pacing cannot be ignored. In this respect, it is important to note that in our group of patients, treadmill walking began as a novel task because subjects did not have a history of using a treadmill.

In reviews of the literature,48-50 we find calls for additional study of rhythmic stimulation and training and for outcome measures with particular relevance to patients, caregivers, physical therapists, and physicians. Here, in the present intervention, we tried to meet these needs, and enhance the main and secondary outcomes from motor performance (eg, speed, stride length) to QOL and mental well-being.
Study Limitations
The study has a number of limitations. This was an open trial with a relatively small number of participants. Nonetheless, the results of this pilot study are quite promising. After only 6 weeks, improvements were seen in a number of key areas including stride length, parkinsonian symptoms (as measured by the UPDRS), and QOL (as measured by the PDQ-39, probably the most widely used measure of QOL in patients with PD). It is possible that all of these gains are merely the result of a placebo effect. It is, however, somewhat surprising that such an effect would last even 5 weeks after the intervention was stopped. We suggest, instead, that these preliminary findings support the idea that treadmill training has an effect greater than a placebo and that some of its influence continues even weeks after completion of the intervention. Consistent with the work of Toole et al., the present findings suggest that body-weight support is apparently not critical in achieving positive treadmill effects in PD. Nonetheless, larger scale, randomized controlled studies are needed to definitively establish efficacy and long-term carryover effects, to explain why certain aspects of gait and mobility appear to be more sensitive to the intervention, and to directly measure the effects of treadmill training on fall risk. The present findings should be useful in guiding the design of such studies.

Potential Clinical Implications
The present findings indicate that walking on a treadmill improves gait, mobility, and QOL of patients with PD. Treadmill training may promote a more stable walking pattern in patients with PD and an intervention program that includes long-term treadmill walking apparently is able to restore rhythmicity and impact fall risk, even when the patient is off the treadmill. In the presence of PD, many see the goal as maintenance care, but do not see the feasibility or opportunity for rehabilitation. This pilot study contributes to a growing body of evidence that shows that “rehabilitation” may be achievable even in the presence of a neurodegenerative disease like PD.

Recent studies suggest that treadmill training is more effective than conventional approaches to improve gait characteristics associated with PD. We suggest combining conventional PT with intensive treadmill training using a protocol of at least 3 sessions a week, 20 to 30 minutes each. It is probably important that the physical therapist ensures a “normal” gait pattern while the patient walks on the treadmill. However, if any gait deviations occur or if there are signs of pain or fatigue complaints, treadmill speed should be adjusted accordingly.

CONCLUSIONS
In PD, there appears to be no need to unload the patient, unless specific safety issues arise. Based on our experience, we also suggest conducting all training sessions when the PD patient is in the “on” state. Still, one has to remember that due to the relatively high cost of this apparatus, the need for a relatively large facility and increased time commitment, a treadmill training program based on a medical treadmill (with a safety harness) may not be practical for everyone or for everyday use in the clinic. Important safety issues arise when treadmill training might be prescribed in the home setting for patients with PD.

Acknowledgment: We thank Shelli Ehrlich for her invaluable assistance in data collection.

References


30. Brink TL. Brief psychiatric screening of institutionalized aged: a review. Long Term Care Health Serv Adm Q 1980;4:253-60.


