

An Analysis of Functional Outcome Measures After Treadmill Training in Older Adults With Parkinson's Disease

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Abstract

Changes in functional outcome measures were compared before and after four weeks of training each on a land, aquatic, and anti-gravity treadmill. Ten elderly adults, ages 64 to 80 years, with Parkinson's disease exercised for four weeks, twice per week, on each treadmill. Functional measures of balance and gait using the Tinetti Performance-Oriented Mobility Assessment, postural sway using the Limits of Stability Test, and fine motor performance using the Purdue Pegboard Test were assessed. Gait scores on the Performance Oriented Mobility Assessment were significantly increased after the land treadmill exercise intervention versus scores immediately pre-intervention (11.7 ± 1.5 vs. 9.2 ± 3.1 , respectively; $p = .028$). All other functional measures, including balance, postural sway, and fine motor performance, were not different across time points. Aerobic exercise training on various treadmills had little effect on functional measures in adults with Parkinson's disease.

Key words: *Balance in the elderly, Parkinson's disease, stability, treadmill training*

Introduction

Parkinson's disease (PD) is a chronic, neurological disorder that currently affects approximately 500,000 individuals in the United States (National Institutes of Health, 2017). The disease arises due to a progressive destruction of dopaminergic neurons in the brain (Gibb & Lees, 1994). This neurotransmitter imbalance may lead to both nonmo-

tor and motor symptoms exhibited by those diagnosed with PD (Moore, Durstine, & Painter, 2016). Nonmotor symptoms can include sleep difficulties, sensory disturbances, or abnormal psychosocial behavior (Myers & Nieman, 2010). These symptoms are correlated with increased morbidity and mortality, decreased independence, and an increased cost of care (Snyder & Adler, 2007).

The primary motor symptoms of PD are associated with abnormal movements of the body, and include resting tremors, bradykinesia, muscular rigidity, and abnormalities associated with posture and gait (Myers & Nieman, 2010). It is known that proper gait requires dynamic balance and postural control by maintaining the body's center of gravity (COG) within its base of support while walking (Dicharry, 2010; Farley & Ferris, 1998; Kuo & Donelan, 2010). Decreased step length and foot clearance, an increased prevalence of shuffling, and a loss of proper stance and swing phase times contribute to abnormal gait in those with PD (Morris, Ianseck, Matyas, & Summers, 1996). Stability is compromised as the line of gravity is often displaced outside of the base-of-support, causing an increased cadence and decreased stride length with an inability to stop (Bloem, Hausdorff, Visser, & Giladi, 2004; Morris et al., 1996). Postural reflexes are eventually lost, making it more difficult to recover if displaced outside of the base-of-support (LeMura & von Duvillard, 2004). Posture can also be negatively affected by the presence of rigidity in the muscles and tissues surrounding the vertebrae, thereby further limiting movement if the individual is perturbed outside of the base-of-support (Myers & Nieman, 2010). These intrinsic factors, particularly when combined with extrinsic factors (e.g., environmental hazards), increase the likelihood of future falls (Rubenstein, 2006). As falls are the leading cause of death from injury and the leading cause of trauma-related hospitalizations in the elderly (National Council on Aging, 2017), the analysis of balance, gait and postural sway is therefore an appropriate, functional outcome measure in older adults diagnosed with PD.

Other motor symptoms include difficulties with fine motor skills, including fastening buttons, writing, and grasping and handling objects. This dexterous impairment may lead to difficulties performing activities of daily living (ADLs; Pohar & Jones, 2009; Vanbellingen et al., 2017). While the exact cause is unknown, the loss of fine motor skills is thought to be related to other motor symptoms inherent with the pathophysiology of PD including bradykinesia (Vanbellingen et al., 2011) and reduced muscular strength and torque at the hands and fingers (Oliveira, Rodrigues, Caballero, Petersen, & Shim, 2008). To treat the motor symptoms associated with PD, medications and surgeries are often used, but are expensive, dangerous, and can have adverse cardiovascular side effects (Bloem et al., 2004). Exercise may therefore be a useful and safe alternative to improve symptoms in this population.

Most existing research that includes using exercise as an intervention to treat the motor symptoms of PD have included range-of-motion and flexibility exercises, balance training, and coordination exercises (e.g., Banks & Caird, 1989; Comella, Stebbins, Brown-Toms, & Goetz, 1994; Pedersen &

Oberg, 1993). The impact of aerobic exercise training, using a treadmill, on functional abilities of those with PD has been limited. Significant improvements were found, however, after six weeks of moderate-intensity aerobic exercise on a treadmill in 20-m walking time, timed U-turn task, turning around a chair, climbing up and down a flight of stairs, and arising from an armless chair in adults with PD (Kurtais, Kutlay, Tur, Gok, & Akbostanci, 2008).

Based on these findings, there is a need to assess clinical and functional measures of balance, gait, posture, and fine motor skill performance following an aerobic exercise intervention on a traditional land treadmill (LTM) in older adults diagnosed with PD. However, the movement abnormalities associated with PD, including tremors, akinesia, bradykinesia, and an abnormal coordination between limbs, may cause inherent safety issues (Bloem et al., 2014; Borrione, Tranchita, Sansone, & Parisi, 2014; Moore et al., 2016). Therefore, it may be necessary to prescribe aerobic exercise using different modalities that reduce the risk of musculoskeletal injury and falls (Michalowska, Fiszer, Krygowska-Wajs, & Owczarek, 2005; Rubenstein, Giladi, & Hausdorff, 2002; Wielinski, Erickson-Davis, Wichmann, Walde-Douglas, & Parashos, 2005). Exercise on an aquatic treadmill (ATM) may be a safe alternative due to the natural buoyancy of the water which creates the unloading of stress and compressive forces at the submerged joints (Pendergast, Moon, Krasney, Held, & Zamparo, 2015). Another alternative that creates an unloading of forces at the lower-body joints is an anti-gravity treadmill (AGTM), which requires the participant to be attached to the treadmill with their body weight displaced by air, thereby reducing the risk of falling (Raffalt, Hovgaard-Hansen, & Jensen, 2013).

Understanding how functional outcome measures are influenced by traditional and alternative modes of treadmill exercise could be very useful for the health care practitioner or caregiver of those with PD. To date, a comparison of these measures following multi-week treadmill training interventions on an LTM, ATM, and AGTM are not known. The purpose of this study was to compare changes in functional outcomes, including balance, gait, postural sway, and fine motor skill performance, before and after four weeks of training each on a land treadmill, aquatic treadmill, and anti-gravity treadmill in older adults diagnosed with Parkinson's disease.

Method

Participants

Ten participants, aged 64 to 80 years, diagnosed with PD were recruited through various local, community, and university organizations. Participants were screened to include those (a) with a classification of 2 (i.e., both sides of the body affected with normal balance) to 3 (i.e., mild to moderate symptoms with balance impairment but physically independent) on the modified Hoehn and Yahr scale (Hoehn & Yahr, 1967); (b) whose height allowed for the water level to be between the xiphoid process and navel while exercising on the ATM; (c) whose height and weight fit within the limits of the AGTM; (d) without a known cardiovascular or pulmonary

disease; (e) free of any surgical procedures performed within the past six months; and (f) without an allergy to chlorine or neoprene. Given the lack of access to a large population and the required inclusion criteria, only 10 participants could be recruited. All participants completed a university-approved informed consent, medical history questionnaire, and photo and video release form prior to data collection. The participants were asked not to alter the schedule of their medications during the study.

Experimental Procedures

An entry session was scheduled before any testing occurred. During this session, participants were familiarized with the study protocol and were presented with the necessary questionnaires and forms for entry. Once all forms were completed and signed, height and weight were measured. Height was measured using a stadiometer (Detecto Scale Company, Webb City, MO) and weight was measured on a digital scale. Body mass index (BMI) was calculated from these measures. Next, the participants briefly walked on the LTM, ATM, and AGTM to determine the necessary speed and incline that corresponded to a moderate intensity of exertion, as measured using the modified rating of perceived exertion (RPE) scale.

Data collection was performed over a period of 20 weeks. The protocol was divided into four, 4-week blocks: (a) a control period, (b) exercise on the LTM, (c) exercise on the ATM, and (d) exercise on the AGTM. During the control period, no structured exercise on any treadmill was performed. The control period was the first block completed for all participants. While on the ATM, the water level was between the navel and xiphoid process for all participants. The mean water temperature during training was 83°F. During exercise on the AGTM, the treadmill was unloaded to 50% of the participant's body weight. There is a small, 3% error difference between the measured and predicted weight on the AGTM at 50% of weight unloading (McNeill, de Heer, Bounds, & Coast, 2015).

The exercise blocks were presented in a random order. Each 4-week exercise block consisted of exercise on the respective treadmill twice per week for 30-45 min. Each participant maintained a moderate intensity, as measured by a 5 or 6 on the modified RPE scale throughout the exercise (Moore et al., 2016). During exercise on the AGTM, the treadmill was unloaded to 50% of the participant's body weight. Two weeks separated the first and second exercise blocks, and the second and third exercise blocks. During this time, the participants were instructed to refrain from any aerobic exercise on a treadmill.

Before and after each block, balance, gait, and fine motor skill performance were assessed. There were five total testing periods: (a) pre-control; (b) post-control and pre-block 2; (c) post-block 2 and pre-block 3; (d) post-block 3 and pre-block 4; and (e) post-block 4. The testing sessions at (b), (c), and (d) served as a concurrent post-test for one block and a pre-test for the next block. Dynamic balance, gait, and fine motor skill performance were assessed at all five testing periods. Postural instability was assessed during the final four testing periods, as the investigators were concerned with the

fatigue levels among the participants during the pre-control testing period. The order of the assessments during the pre-control testing period was as follows: (a) fine motor skill performance and (b) dynamic balance and gait. The order of the assessments during all other testing periods was as follows: (a) fine motor skill performance, (b) dynamic balance and gait, and (c) postural instability.

Dynamic balance and gait performance was measured using the Tinetti Performance-Oriented Mobility Assessment (POMA). The POMA included Balance and Gait subtests. The Balance subtests consisted of a series of assessments with the participant in sitting and standing postures. The Gait subtest consisted of recording gait abnormalities while walking in a straight line. The POMA has been validated in older adults diagnosed with PD (Kegelmeyer, Kloos, Thomas, & Kostyk, 2007).

Postural sway performance was measured using the Limits of Stability (LOS) test. The LOS test was performed on the Neurocom Balance Master System (Natus Medical Inc., Pleasanton, CA). This system provides visual feedback using a force plate. During the LOS assessment, the participant was instructed to stand on a force plate and voluntarily sway to various locations in space (i.e., forward-right, backward-right, backward-left, forward-left) while maintaining a static foot placement with the arms at the sides. Constant visual feedback on a screen in front of the participant allowed the participant to view his/her COG, which was provided via video by the force plate output. The participant was given 8s to initiate the movement and to reach, and maintain position at, the target. Reaction time and average sway velocity were measured. Directional control, a comparison of the amount of movement in the intended direction to the amount of extraneous movement, was calculated as a percentage by the following:

| | |
|--------------------------------|------------------------------------------------------------------------------------------------------------------------------|
| Directional Control (%) | $\frac{(\text{amount of intended movement}) - (\text{amount of extraneous movement})}{(\text{amount of intended movement})}$ |
| | |

The results for each variable measured in each direction during the LOS test were averaged for a composite score. The LOS test on the Neurocom Balance Master System has been validated for use in older adults (Clark, Rose, & Fujimoto, 1997).

The fine motor skill assessment consisted of four separate tasks using the Purdue Pegboard (Lafayette Systems, Lafayette, IN). The right-hand (RH) task involved using the right hand to retrieve pins from a bin one at a time, and place them in consecutive holes on the pegboard. This test was timed for 30 seconds, and the total number of pins placed was recorded. The left-hand (LH) task and the both-hands (BH) tasks differed from the RH task only in that the left hand or both hands simultaneously were used to retrieve and place pins in the pegboard, respectively. The final task was an assembly task, which involved several subtasks in the following order using the: (a) dominant hand to place a pin in the board, (b) non-dominant hand to place a washer over the placed pin, (c) dominant hand to place a collar on the washer-pin complex, and (d) non-dominant hand to place a washer on

the collar-washer-pin complex. The sequence of these four pieces represented one assembly. Participants were allotted 60s to complete as many assemblies as possible, and the total number of components (four components per assembly) was recorded. After arriving for testing, a researcher introduced the task and apparatus to the participant. The participants were asked to practice two to three trials prior to the test. During this time, the researcher provided corrections if the task was not completed correctly. For each test, the researcher timed the participant with a stopwatch. The Purdue Pegboard test has been shown to have excellent test-retest reliability among adults diagnosed with mild to moderate PD (Metman et al., 2004).

Statistical Analysis

The independent variable was block (i.e., pre-control, post-control, post-block 2, post-block 3, post-block 4). The following were dependent variables: (a) POMA Balance score, (b) POMA Gait score, the (c) reaction time (s), (d) average velocity (deg/s), and (e) directional control (%) during the postural sway test, and scores using (f) the right hand, (g) the left hand, (h) both hands, and (i) the general assembly using the Purdue Pegboard Test. An analysis of variance (ANOVA) with repeated measures for block was performed to compare functional outcomes between testing periods. Bonferroni post-hoc tests were used to follow up any significant differences. Results were analyzed using SPSS v.24 (IBM Inc., Armonk, NY) with a significance level of .05. To avoid further reductions in power and to address the small sample size obtained, no correction to the significance level was made despite the use of multiple ANOVAs.

Results

Participant demographics can be found in Table 1. Four participants were classified as a 2 or 2.5 and 6 participants were classified as a 3 on the modified Hoehn and Yahr scale. Every participant completed at least 30 min of exercise on each treadmill at a moderate intensity, and most progressed up to 45 min of continuous exercise on each treadmill. Each participant also attempted every assessment during the testing sessions.

Table 1
Participant Characteristics

| Variable | Mean \pm SD | Minimum | Maximum | Range |
|-------------------------------|------------------|---------|---------|-------|
| Age (yrs) | 70.0 \pm 5.3 | 64 | 80 | 16 |
| Height (cm) | 175.4 \pm 12.4 | 162.0 | 197.5 | 35.5 |
| Weight (kg) | 83.1 \pm 13.4 | 62 | 99 | 37 |
| BMI (kg/m ²) | 27.2 \pm 4.7 | 21.4 | 36.1 | 14.7 |
| Hoehn and Yahr classification | 2.7 \pm 0.4 | 2 | 3 | 1 |
| Time since diagnosis (yrs) | 6.7 \pm 5.7 | 0.7 | 21.8 | 21.1 |

Note. Data were obtained from 10 adults diagnosed with Parkinson's disease (7 men, 3 women). BMI = body mass index.

Scores using clinical measures of balance and gait at the start of the study and following each block can be found in Table 2. There were no differences across blocks for the scores on the Balance subtest of the POMA ($p > .05$ for all). There was a significant difference in the scores on the Gait subtest of the POMA ($p = .028$), and scores increased 17 to 27% from post-control to the treadmill blocks. Post-hoc analyses revealed that the score on the Gait subtest was significantly lower at the start of the study ($p = .016$) and post-control ($p = .019$) when compared to scores after the 4-week block of LTM exercise. Effect sizes (omega squared) were small, ranging from .04 to .21, indicating that exercise explained only a small percentage of the variance in these clinical measures.

Table 2
Clinical Balance and Gait Performance Scores for All Participants Before and After Each Block

| | Pre-Control | Post-Control | Post-LTM | Post-ATM | Post-AGTM |
|--------------|-------------------------|------------------------|------------|------------|------------|
| POMA Balance | 13.5 ± 3.0 | 14.3 ± 1.2 | 13.5 ± 2.3 | 14.3 ± 2.0 | 14.0 ± 1.6 |
| POMA Gait | 10.3 ± 1.6 [†] | 9.2 ± 3.1 [†] | 11.7 ± 1.5 | 10.8 ± 2.3 | 10.8 ± 0.9 |

Note. Values are mean ± SD. [†] Significantly less than post-LTM ($p < .05$); AGTM—anti-gravity treadmill; ATM—aquatic treadmill; LTM—land treadmill; POMA—Performance Oriented Mobility Assessment; TUG—Timed-Up-and-Go.

Postural sway performance and fine motor skill performance scores at each block can be found in Table 3 and Table 4, respectively. Although differences did not reach statistical significance in any postural sway variable across blocks ($p > .05$ for all), there was an observable decrease in reaction time (a decrease of 17 to 28% from post-control to all treadmill blocks) and increase in mean velocity of sway (an increase of 4 to 9% from post-control to all treadmill blocks) after each treadmill exercise block when compared to baseline values. There were also no significant differences across blocks for any fine motor performance variable ($p > .05$ for all). The largest trends observed were an increase in the scores during the RH task (a 7 to 17% increase from post-control to all treadmill blocks) and the assembly task (a 3 to 19% increase from post-control to all treadmill blocks). Omega squared effect sizes were also small for these measures, ranging from .02 to .11.

Table 3
Postural Sway Performance Scores for All Participants Before and After Each Block

| | Post-Control | Post-LTM | Post-ATM | Post-AGTM |
|--------------------------|--------------|-------------|-------------|-------------|
| Reaction time (s) | 1.17 ± 0.66 | 0.97 ± 0.72 | 0.96 ± 0.48 | 0.84 ± 0.39 |
| Average velocity (deg/s) | 3.23 ± 1.68 | 3.37 ± 2.17 | 3.51 ± 2.25 | 3.52 ± 1.85 |
| Directional control (%) | 66.1 ± 25.9 | 66.1 ± 25.9 | 69.3 ± 21.9 | 67.3 ± 26.3 |

Note. Values are mean ± SD and represent composite scores. AGTM—anti-gravity treadmill; ATM—aquatic treadmill; LTM—land treadmill.

Table 4
Fine Motor Performance Scores for All Participants Before and After Each Block

| | Pre-Control | Post-Control | Post-LTM | Post-ATM | Post-AGTM |
|--------------|-------------|--------------|------------|------------|------------|
| FMS RH | 8.4 ± 3.3 | 8.6 ± 3.0 | 9.2 ± 2.7 | 10.1 ± 2.8 | 9.8 ± 2.6 |
| FMS LH | 8.7 ± 3.2 | 9.1 ± 2.8 | 9.0 ± 3.4 | 8.8 ± 2.8 | 9.0 ± 3.2 |
| FMS BH | 6.1 ± 2.4 | 6.6 ± 2.7 | 7.3 ± 2.9 | 6.8 ± 2.2 | 6.2 ± 1.9 |
| FMS Assembly | 15.9 ± 6.8 | 15.9 ± 6.3 | 17.6 ± 7.2 | 18.9 ± 6.7 | 16.3 ± 5.0 |

Note. Values are mean ± SD. AGTM—anti-gravity treadmill; ATM—aquatic treadmill; LTM—land treadmill; FMS—fine motor skill; BH—both hands; LH—left hand; RH—right hand.

Discussion

The purpose of this study was to compare changes in functional outcomes, including balance, gait, postural sway, and fine motor skills, before and after four weeks of training each on an LTM, ATM, and AGTM in older adults diagnosed with Parkinson’s disease. The primary finding from this study was that scores on the Gait subtest of the POMA were significantly increased when compared to scores obtained before and after the control block in which the participants did not perform any structured aerobic exercise. All other functional measures were not different across blocks. Based on these findings, there is limited evidence to suggest that functional measures of balance, gait, posture, and fine motor skills are improved with aerobic exercise training using various treadmill modalities.

With regard to scores on the Gait subtest of the POMA, the results of this study are similar to those reported by Ganesan, Sathyaprabha, Gupta, and Pal (2014). In the study by Ganesan et al. (2014), a noticeable trend was observed with the POMA Gait subtest scores, which increased after four weeks of gait training on a body-weight supported treadmill in one group and increased after four weeks of training while free-walking in another group when compared to baseline measures. However, this increase was not statistically significant. In this study, POMA Gait subtest scores were improved after all three treadmill training blocks, but only reached statistical significance after the LTM exercise block when compared to post-control measures.

The statistically significant increase in scores on the Gait subtest of the POMA after four weeks of exercise on the LTM may be due to the specificity of the exercise training modality. Although walking economy is negatively affected by a diagnosis of PD (Christiansen, Schenkman, McFann, Wolfe, & Kohrt, 2009), gait training on a traditional treadmill may improve spatiotemporal parameters of gait, including velocity, cadence, and stride length (Protas et al., 2005), scores on clinical measures of gait, including the gait variability index (Cakit, Saracoglu, Genc, Erdem, & Inan, 2007), and performance during timed walking tasks (Shulman et al., 2013) and walking tasks with a set distance (Kurtais et al., 2008). Functional outcome measures may be improved most if the training is specific to the assessment of these measures, particularly in older adults (Liu, Shiroy, Jones, & Clark, 2014).

Another potential reason why scores on the Gait subtest of the POMA were changed following exercise on the LTM may be related to the physiological responses during each mode. In a recent study, higher levels of acute cardiovascular stress (e.g., heart rate) were observed at submaximal speeds (up to 3 mph) on an LTM when compared to exercise on an ATM and AGTM at similar speeds in older adults diagnosed with PD (Rigby et al., in press). An elevated heart rate response during LTM exercise may increase cardiac output, thus allowing for more oxygen and nutrients to be delivered to the working muscle during exercise (Powers & Howley, 2015)

The participants in this study were classified as mild-to-moderate severity, according to their scores on the Hoehn and Yahr Scale (Hoehn & Yahr, 1967). The functional status of all participants therefore allowed for exercise on the LTM. Locomotion on an LTM may not be possible for those who are more severely affected with PD, particularly those who exhibit abnormal balance, postural instability, and gait dysfunction. The ATM and AGTM may be more appropriate modalities to meet the guidelines for aerobic exercise established by the American College of Sports Medicine (ACSM) for individuals with moderate-to-severe PD, primarily due to the added safety these devices, and their environment, provide.

Although there were no statistically significant differences between blocks for any other functional measure, there were some noticeable trends. Following exercise on the ATM, there was a noticeable trend as most of the remaining variables were improved when compared to other blocks. These included: (a) an increased score on the Balance subtest of the POMA, (b) an increased directional control score on the postural sway assessment, (c) an increased score using the RH on the fine motor performance assessment, and (d) an improved score on the assembly portion of the fine motor performance assessment. These interesting findings should be explored further with a larger population of individuals diagnosed with PD. In a protocol of similar duration (45 min per day), frequency (twice per week for four weeks), and participants (mostly males, right-handed, with a similar age, time since diagnosis, and Hoehn and Yahr classification), aquatic therapy (i.e., a combination of walking, trunk mobility exercises), transfers, and postural stability training) was effective at improving clinical measures of balance and postural stability in adults with PD (Vivas, Arias, & Cu-deiro, 2011).

Limitations

There were several limitations in this study. Medications, the most commonly prescribed treatment for those with PD, were taken by all participants in this study. Both dopaminergics and dopamine agonists can interfere with the cardiovascular response to exercise. These medications can also induce motor disturbances and ataxia in addition to the symptoms already experienced from a diagnosis of PD (Myers & Nieman, 2010). A combination of these factors may prevent adequate oxygen delivery to the working muscles and thus produce a deficit in energy production. This even-

tual effect on the metabolic system may have affected exercise training and testing sessions. An attempt was made to control for other environmental influences by testing under standardized conditions and at the same time of day.

The study was also not sufficiently powered to examine variations in functional outcome measures that may be, at least partially, explained by sex, body composition, and disease severity. Some participants were more mildly affected than others, and functional abilities differed among participants. Results from this study therefore cannot be extrapolated to those who are more severely affected with PD. Indeed, with such a small sample size ($n = 10$), results (e.g., mean differences, effect sizes) may not be reflective of actual population parameters. Third, the amount of time between exercise blocks was two weeks, which may not have been an adequate amount of time for any improvements in functional measures to return to a baseline value. The participants in this study also did not perform a graded exercise test to maximum exertion. Therefore, the intensity of exercise could not be prescribed as a relative percentage of VO_{2max} . Finally, while the sample population corresponds to the most prevalent age range for the onset of symptoms (i.e., 50 to 79 years) in those diagnosed with PD (Myers & Nieman, 2010), this sample may not be reflective of those diagnosed with PD as a whole, particularly with those diagnosed with juvenile PD (i.e., onset of symptoms occurring before the age of 40 years).

Conclusion

It may be of tremendous value to clinicians to understand how exercise can improve functional outcomes in adults with PD. According to the results of this study, the benefits of aerobic exercise with regard to these functional measures (i.e., balance, gait, posture, fine motor performance) are limited. Additional research with varying protocols using alternative modes of treadmill exercise is needed with this population.

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