A Tandem Cycling Program: Feasibility and Physical Performance Outcomes in People With Parkinson Disease

Ellen L. McGough, PT, PhD, Cynthia A. Robinson, PT, PhD, Mark D. Nelson, MPT, Raymond Houle, BA, Gabriell Fraser, BS, Leslie Handley, PT, MS, Emilie R. Jones, PT, DPT, Dagmar Amtmann, PhD, and Valerie E. Kelly, PT, PhD

Background and Purpose: Individuals with Parkinson disease (PD) have motor and nonmotor impairments that interfere with exercise participation. The purpose of this study was to examine the feasibility and physical performance outcomes of a community-based indoor tandem cycling program that was designed to facilitate a higher cadence, consistency, and intensity of training.

Methods: Forty-one participants with mild to moderate PD were enrolled. A high-cadence cycling protocol using mechanically augmented (or forced) exercise on a tandem bicycle was adapted for our program. Participants cycled 3 times per week for 10 weeks. Feasibility measures included program retention, attendance, and adverse events, as well as the ability to reach training goals for heart rate (HR) and cadence. Physical performance outcomes included the Berg Balance Scale (BBS), Short Physical Performance Battery (SPPB), Five-Times-Sit-to-Stand (FTSTS) Test, Timed Up and Go (TUG), and gait parameters during usual and fast-paced walking.

Results: Program feasibility was demonstrated with a high attendance rate (96%) and retention rate (100%). There were no adverse events. The majority of participants reached their exercise training goals for target HR (87%) and cadence (95%). Statistically significant physical performance improvement ($P < 0.05$) was observed across domains of gait, balance, and mobility, suggesting a slowing or reversal of functional decline as a result of this cycling program.

Discussion and Conclusion: Program feasibility and improved physical performance outcomes were demonstrated in individuals with mild to moderate PD participating in a community-based indoor tandem cycling program.

Video Abstract available for more insights from the authors (see supplemental digital content 1, http://links.lww.com/JNPT/A146).

Key words: *community-based exercise, human movement system, mechanically augmented exercise, tandem cycling*

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INTRODUCTION

Approximately 630 000 people in the United States are currently diagnosed with Parkinson disease (PD) and prevalence is projected to exceed 1 million by 2030, with a national economic burden exceeding $14.4 billion.[1] For individuals with PD, participation in regular exercise is paramount for maintaining health and reducing disability. However, in a study of community-dwelling adults, individuals with PD were less active and expended 29% fewer kilocalories during daily physical activities compared with individuals without PD.[2] Among individuals with PD, reduced walking performance, greater disease severity, and age were important determinants of lower physical activity levels. Even people with mild PD symptom severity participated in significantly less physical activity than individuals without PD, possibly due to disease-related barriers.

Motor and nonmotor impairments[3] impede participation in regular exercise in individuals with PD, contributing to lower levels of fitness and health, and to increased risk for disability.[4] Motor impairments including bradykinesia and rigidity are common in PD,[5] and can make participation in an exercise program difficult. Balance and gait impairments are associated with reduced participation in mobility-related activities,[6] and are predictive of falls in individuals with PD.[7] Further interference with activities results from nonmotor impairments including reduced cognitive and emotional functioning.[3] Among individuals with disabilities, a wide range of barriers impacts one's ability to achieve and sustain beneficial levels of exercise including physical, emotional, and psychological barriers; lack of adaptive equipment; and difficulty accessing community programs.[8,9] Thus, exercise programs specifically designed to overcome common barriers may help individuals with PD to attain exercise levels that improve fitness and function.

Department of Rehabilitation Medicine, University of Washington, Seattle.

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Correspondence: Ellen L. McGough, PT, PhD, Assistant Professor, University of Washington, Department of Rehabilitation Medicine, 1959 NE Pacific St., Box 356490, Seattle, WA 98195 (emcg@uw.edu)

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Mechanically augmented (or forced) aerobic exercise, as defined by Alberts et al,[10] assists the participant in achieving and maintaining an exercise rate that is greater than their preferred voluntary rate. Forced exercise on a tandem bicycle has been described as a mode of aerobic exercise in which the rate of pedaling is facilitated at a higher cadence and consistency than would typically be performed voluntarily.[10,11] A standard tandem bicycle has a drive train that mechanically links the pedals through a timing chain and forces the 2 riders to pedal at the same rate.[10] In an 8-week pilot study of indoor tandem versus solo cycling, greater improvements in upper extremity motor control and gait were reported in individuals with PD who were paced by a healthy cycling partner to ride at a cadence of 80 to 90 revolutions per minute (RPMs), approximately 30% faster than solo riders with PD cycled.[11] In addition to mechanical facilitation, tandem cycling within a community-based program may facilitate reaching a higher exercise dose, especially in the face of barriers to participation.[12]

The purpose of this study was to examine the feasibility and physical performance outcomes of a community-based indoor tandem cycling program that was designed to facilitate a higher cadence, consistency, and intensity of training than voluntary exercise. For people with mild to moderate PD, we hypothesized that (1) our 10-week tandem cycling program would be feasible in terms of program processes, program adherence, exercise intensity, and safety, and (2) participants with PD would demonstrate improved physical performance as a result of participating in the tandem cycling program.

METHODS

Participants

Adults with a diagnosis of PD ($n = 41$) were recruited to participate in our community-based tandem cycling study. *Inclusion criteria* included a diagnosis of PD, age 45 to 75 years, able to walk 100 m (assistive device allowed), and physician approval. *Exclusion criteria* included a serious cardiac or pulmonary condition, diabetes mellitus, musculoskeletal contraindications, or a history of central nervous system disease other than PD. The University of Washington Institutional Review Board approved all study procedures. All participants provided written, informed consent.

Recruitment of Individuals With PD

Participants were recruited through newsletter and website postings by local Parkinson disease organizations, and through the Washington State Parkinson Disease Registry. All eligible individuals were enrolled, and the 10-week program was offered 3 times per year from January 2012 through March 2014. As a community-based program, it was important to allow all interested and eligible individuals to participate.

Recruitment of Cycling Partners

Physically fit adults were recruited to ride as cycling partners on the tandem bicycles. Recruitment was completed through advertisement in a community Parks and Recreation brochure, Parkinson disease organizations, and local cycling organizations. Volunteer cycling partners included members of the local community, family members, and University of Washington students. Inclusion and exclusion criteria for cycling partners were the same as for study participants, with the exception of age (range 20-70 years) and PD diagnosis.

Tandem Cycling Program Operations

Community Stakeholders and Resources

To establish this program within a community setting, we partnered with several community stakeholders. Our key partners in the day-to-day operations of the program were Seattle Parks and Recreation and the Outdoors for All Foundation, a not-for-profit organization specializing in recreational programs for individuals with disabilities. Seattle Parks and Recreation provided a well-ventilated room for the cycling class. Outdoors for All Foundation loaned 4 or 5 tandem bicycles for each cycling session. Local PD organizations were also instrumental in providing financial support and recruitment advertising. Volunteers and cycling partners assisted with class set-up/take-down and bike repair.

Cycling Equipment

Standard and recumbent tandem bicycles were mounted on Kreitler Fork Stands and CyclOps Magnetic Trainers. Low-level constant resistance was set on the bicycle trainers, allowing for adjustment of pedaling resistance by shifting the bicycle gears. The majority of the tandem bicycles had a lower rear cross bar and a telescoping seat post mast (Co-Motion Cycles, Eugene, Oregon). One recumbent bicycle was available (Sun EZ Tandem, Easy Racers, Watsonville, California) for participants needing more balance support or seating comfort. Three options for handlebars were available (drop bars, flat bars, or custom U-shaped bars with adjustable hand placement). Bike pedal cages (toe clips) with straps were used to allow easy fitting and ease of getting on and off the bicycle.

Program Orientation and Bicycle Fitting

A 1-hour orientation for participants with PD and cycling partners provided a description of the program. Bike fitting was initiated at the orientation session using general guidelines for road bicycle fit[13]; additional adjustments to improve comfort and pedaling efficiency were made on an individual basis.

Program Infrastructure and Environment

Program development took place over an 18-month period and included planning, pilot cycling sessions, and participant focus groups. In response to focus group input, the program infrastructure and environment were designed to be welcoming and enjoyable, to provide a safe exercise program, to facilitate self-efficacy, and to promote a sense of accomplishment. Before and after each cycling session, participants with PD met with their cycling partner to measure blood pressure (BP) and heart rate (HR) and to complete a checklist with exercise readiness questions. Participants also discussed weekly goals with their cycling partners, which contributed to the team dynamic.

Training Sessions

Cycling sessions were 60 minutes, three times per week for 10 weeks. The total number of sessions offered varied slightly, averaging 25 sessions/10-week class, due to facility closures for holidays and inclement weather. Four or 5 teams cycled simultaneously during each session (Figure). From the front seat of the tandem, the cycling partner set the pace, shifted the gears, and provided encouragement for the rider with PD. A high cadence-forced exercise protocol[11] was tailored to our program. Each session consisted of a 10-minute warm-up at 50 to 70 RPMs, a high-intensity training period of 40 minutes at 80 to 90 RPMs, and a 5-minute cool-down at 50 to 70 RPMs. The class instructor played music with a beat that matched the desired cadence. Five minutes of gentle stretching was completed after each cycling session.

Training Parameters

Training parameters were monitored continuously including (1) pre- and post-session vital signs: resting and recovery HR and BP; (2) training HR with Polar FT1 HR monitor and display (Polar Electro Oy, Kempele, Finland); (3) RPM via a CatEye Strada Cadence Meter (CatEye, Osaka, Japan); and (4) Perceived Rating of Exertion (PRE; 1-10 scale): a self-report rating of exertion on the 10-point modified Borg scale (taken every 10 minutes). HR and BP were taken twice during each session for volunteer cycling partners.

Individual Adjustment of Parameters

The class instructor provided training guidance to each team of riders to facilitate a pedaling cadence of 80 to 90 RPMs, a PRE of 3 to 4, equivalent to “moderate” or “somewhat hard,” and a target HR of 60% to 75% of their age-adjusted estimated maximum HR. Each cycling team focused first on reaching and maintaining the target cadence of 80 to 90 RPMs. Once cadence was sustained, the cycling partner adjusted the bicycle gears and their own personal pedaling efforts to facilitate training within target HR range and exertion levels.

Tandem Cycling Program Outcomes

Baseline Demographic and Health Measures

Demographic and health information included age, years since diagnosis of PD, medications, height, weight, vital signs (HR, BP, respiratory rate [RR]), and medical conditions. The Hoehn & Yahr (H&Y)[14] scale was used to stage motor symptom severity ranging from 0 to 4. A fall history questionnaire was completed. A brief physical examination by a licensed physical therapist was completed to ensure readiness for the cycling program.

Program Feasibility Measures

Adherence was assessed through retention and attendance rates. The *retention rate* was the percentage of participants completing the 10-week program. *Attendance rate* was calculated for each participant as the percentage of total cycling sessions completed divided by the number of sessions offered during the 10-week program. The feasibility of meeting training intensity goals (cadence, PRE, and target HR) and the number of adverse events were also measured. *Training intensity feasibility* was measured during the 40 minutes of higher intensity training via (1) the percentage of participants who trained at a cadence of 80 to 90 RPMs, (2) the percentage who trained at a PRE of 3 to 4, and (3) the percentage who trained at their target HR. Training intensity was assessed during weeks 3 to 10, as training intensity was gradually increased during weeks 1 to 2. *Adverse events* were defined as incidents of injuries or exercise intolerance.

Physical Performance Measures

Assessments were conducted within 1 week before and after the 10-week tandem cycling program. For each participant, pre- and post-program assessments were scheduled at the same time of day during the on-medication state (within 2 hours of taking Parkinson medications) to minimize changes due to medication fluctuations. All of the physical performance measures were completed by the same researcher (EM), who was not blinded to pre- versus post-program status.

Figure. Participants in a tandem cycling class.

Physical Performance Outcomes

The *Berg Balance Scale (BBS)*[15] is predictive of fall risk in PD[7] and demonstrates high test-retest reliability (intraclass correlation coefficient [ICC] = 0.94) in PD.[16] Scores range from 0 to 56, with higher scores indicating better balance. The *Short Physical Performance Battery (SPPB)*[17] is a widely used test of lower extremity function in older adults and consists of 3 tasks: static standing balance, comfortable walking speed (4 m), and a timed 5-times-sit-to-stand test. Lower extremity function, as measured by the SPPB, is predictive of subsequent disability in older adults.[18] The *Five-Times-Sit-to-Stand Test (FTSTS)*,[19] a measure of lower extremity function and fall risk, involves repeated sitting to standing performed quickly without upper extremity assistance. High interrater and test-retest reliability (ICC = 0.99 and 0.76, respectively), and utility for discriminating between fallers and nonfallers, has been reported in individuals with PD.[6] The *Timed Up and Go Test (TUG)*[20] was used to test functional mobility. Good interrater and intrarater reliability and high test-retest reliability (ICC = 0.85) have been demonstrated in people with PD.[16,21] *Quantitative spatiotemporal gait measures* were collected with the GAITRite Walkway System (MAP/CIR Inc, Havertown, Pennsylvania), a portable, instrumented mat that forms a 4.3-m walkway with pressure sensors that detect foot contacts. To ensure that steady-state walking was attained, participants started 2 m before the edge of the mat and continued walking 2 m beyond the mat. Gait speed (m/s), cadence (steps/min), and stride length (m) were averaged over 4 trials of usual pace walking and over 4 trials of fast pace walking. Good reliability of GAITRite measures has been reported in older adults with PD.[22] Short-distance walking tests at comfortable and fast speeds are highly reliable and responsive to change in older adults with PD.[23]

Data Analysis

SPSS Version 19 statistical software (SPSS, Inc, Chicago, Illinois) was used for data analysis. The distribution of scores on continuous variables was examined for normality and outliers using histograms and box plots. Descriptive statistics were used to assess feasibility of the tandem cycling program. Paired samples *t* tests were used to examine mean changes in the BBS, SPPB, TUG, and quantitative gait parameters during usual and fast-paced walking. Effect size of physical performance change was calculated as the absolute difference between the pre- and post-tandem cycling program measures divided by the standard deviation.[24]

RESULTS

Forty-one participants with PD ranging from 45 to 75 years old (mean age, 62.7 [standard deviation, 8.5]) were enrolled in the tandem cycling program. The average H&Y score was 1.85 (standard deviation, 0.18). Baseline characteristics and physical performance are described in Table 1. Three participants were dropped from the physical performance analysis, leaving a total of 38; 1 participant due to PD medication changes during the program, 1 had a knee injury after the last cycling session, and a third was unable to attend the post-tandem assessment due to personal reasons.

Table 1. Participant Baseline Characteristics and Physical Performance

	Mean (SD) or n (%)	Range
Characteristics (n = 41)		
Age, y	62.7 (8.5)	45-75
Duration of PD, y	5.4 (5.3)	0.5-19
Sex (% males)	25 (59.5%)	—
Fallen last 3 mo	16 (38.1%)	—
Using L-dopa medication	18 (42.9%)	—
Deep brain stimulator	5 (12%)	—
Performance-based tests (n = 38)		
Berg Balance Scale (0-56)	52.6 (5.7)	34-56
SPPB (0-12)	10.5 (1.6)	6-12
FTSTS, s	12.4 (2.9)	8.3-20.4
TUG, s	8.6 (1.5)	6.0-12.0
Quantitative gait measures (n = 38)		
Usual pace gait speed, m/s	1.26 (0.18)	0.85-1.65
Usual pace cadence, steps/min	109.66 (7.67)	95.6-131.0
Usual pace stride length, m	1.37 (0.25)	0.55-1.75
Fast pace gait speed, m/s	1.80 (28.4)	1.12-2.49
Fast pace cadence, steps/min	131.25 (15.68)	102.3-177.8
Fast pace stride length, m	1.59 (0.21)	0.94-1.75

Abbreviations: FTSTS, Five-Times-Sit-to-Stand; PD, Parkinson disease; SD, standard deviation; SPPB, Short Physical Performance Battery; TUG, Timed Up and Go.

Feasibility

The retention rate for participants (n = 41) was 100%, indicating that all participants completed the program. The attendance rate was 96% for the 10-week program. Eighty-seven percent of participants reached and sustained their target HR range, and 95% reached and sustained their cadence goal from week 3 through week 10. Five participants did not reach or sustain their age-predicted HR goal, on a regular basis, during any part of the program. Five participants had a lower-than-expected HR during the 40-minute higher intensity training even though they had a self-reported rating of perceived exertion (RPE) of 3 or 4 on the modified Borg scale. Of these participants, one was on β-blocker medication, and 4 had an unknown reason for their low HR response to exercise. A sixth participant had a comorbid condition in which he did not feel comfortable exercising at moderate intensities, so we changed his target RPE to 2 on the modified Borg scale. There were no adverse events; however, as expected, individual exercise adjustments were needed. Although there were no emergent medical concerns, we recommended to a total of 5 participants (including 2 described previously) that they consult with their physician to address their personal concerns about medications in relation to increased exercise levels. All participants were cleared to continue with the program.

Physical Performance

The mean change on physical performance outcomes improved significantly from pre- to post-program (n = 38, Table 2) on the BBS (1.5 ± 3.4; $P = 0.01$), SPPB (0.8 ± 1.2; $P = < 0.001$), FTSTS (−1.25 seconds ± 2.63; $P = 0.005$), and TUG (−0.33 seconds ± 0.80; $P = 0.02$). Significant increases were demonstrated in usual gait speed (0.04 m/s ± 0.09; $P = 0.03$) and cadence (2.27 steps/min ± 4.14; $P = 0.002$), but increased stride length was not statistically significant (0.04 m ± 0.17; $P = 0.13$). In contrast

Table 2. Physical Performance: Pre- Versus Posttandem Cycling (n = 38)

Physical Performance Measures	Pretandem Mean (SD)	Post-tandem Mean (SD)	Change Mean (SD)	95% CI	Effect Size	*P* Value
Performance-based tests						
BBS	52.7 (5.6)	54.2 (3.0)	1.5 (3.4)	0.3 to 2.6	0.44	0.012[a]
SPPB	10.4 (1.7)	11.2 (1.0)	0.8 (1.2)	0.4 to 1.2	0.68	<0.001[a]
FTSTS, s	12.27 (2.75)	11.02 (2.17)	− 1.25 (2.63)	−0.39 to −2.12	0.48	0.005[a]
TUG, s	8.58 (1.37)	8.25 (1.57)	− 0.33 (0.80)	−0.07 to −0.60	0.41	0.016[a]
Quantitative gait measurements						
Usual pace walking						
Speed, m/s	1.27 (0.19)	1.31 (0.19)	0.04 (0.09)	0.002 to 0.06	0.44	0.03[a]
Cadence, steps/min	109.88 (7.65)	112.16 (7.99)	2.27 (4.14)	0.89 to 3.35	0.55	0.002
Stride length, m	1.37 (0.25)	1.41 (0.17)	0.04 (0.17)	−0.01 to 0.10	0.23	0.13
Fast-pace walking						
Gait speed, m/s	1.78 (0.30)	1.80 (0.25)	0.02 (0.15)	−0.03 to 0.07	0.13	0.20
Cadence, steps/min	131.44 (15.84)	133.07 (14.0)	1.63 (7.65)	−0.88 to 4.15	0.21	0.16
Stride length, m	1.59 (0.21)	1.63 (0.18)	0.42 (0.19)	−0.01 to 0.10	0.23	0.20

Abbreviations: BBS, Berg Balance Scale; CI, confidence interval; FTSTS, Five-Times-Sit-to-Stand; SD, standard deviation; SPPB, Short Physical Performance Battery; TUG, Timed Up and Go.
[a]Statistically significant change from baseline ($P < 0.05$).

to usual paced walking, there was no significant improvement during the fast pace walking condition, including gait speed (0.02 m/s ± 0.15; $P = 0.42$), cadence (1.63 steps/min ± 7.65; $P = 0.16$) and stride length (0.42 m ± 0.19; $P = 20$). A ceiling effect was observed at baseline on the BBS and the SPPB, in 56% and 36% of participants, respectively.

DISCUSSION

This community-based indoor tandem cycling program was feasible and resulted in improved physical performance in individuals with mild to moderate PD. Program feasibility was demonstrated through high attendance and retention rates. Our adherence rates exceeded those reported in the majority of exercise studies in individuals with PD.[25] The program structure, developed through pilot cycling classes and focus groups, likely enhanced program adherence. In addition, accessible equipment, volunteers, and community stakeholders played a key role in achieving our program goals. Our results are in contrast to prior studies that have suggested group exercise has minimal impact on physical performance in persons with PD.[26]

This tandem cycling program facilitated moderate-intensity aerobic training despite the presence of PD-related motor and nonmotor impairments. Given considerable evidence that sedentary behavior and subsequent decline of physical fitness increase the risk of adverse health outcomes,[27,28] this form of exercise may provide a viable way for people with PD to meet recommended aerobic exercise levels for older adults.[28] Individuals with PD need ongoing support to facilitate participation,[29] and to overcome challenges in achieving and sustaining sufficient training intensities to gain the benefits of exercise.[30] In addition, confidence in one's ability to continue exercising in the face of barriers has been shown to predict positive exercise participation in individuals with PD.[8]

Eighty-seven percent of participants reached and sustained their training intensity goals by the third week of the 10-week program. A previous study by Lauhoff et al[31] reported that only 8 of the 23 participants (34.8%) with mild to moderate PD were able to reach their target HR goal despite having HR monitoring and coaching. This suggests that individuals with PD may be less able to achieve moderate-intensity aerobic training levels during solo cycling. Increased variation in hemodynamic responses to exercise has been observed in individuals with PD,[32] and may explain why some of our participants did not reach their target HR range despite reporting moderate-intensity effort. Changes in hemodynamic responses to exercise may be attributed to autonomic dysfunction, which often presents at early stages and increases with PD progression.[33,34]

Ninety-five percent of our participants reached and sustained their target pedaling cadence of 80 to 90 RPMs. This is comparable to the mechanically augmented cadences of the tandem cyclists in the Ridgel et al study.[11] In contrast, the solo cyclists in their study had an average cadence of 60 RPMs, approximately 30% lower than the tandem cyclists. Taken together, this suggests that mechanical augmentation via tandem cycling may have advantages in facilitating higher pedaling rates than solo cycling in people with PD. It is also conceivable that targeted training with a tandem cycling partner may facilitate more consistent and higher training intensities, as measured by HR response. However, further research is needed given that comparable gains in cardiorespiratory fitness were reported in a preliminary study of forced exercise versus solo cycling.[11]

The change observed in usual gait speed (0.04 m/s) was clinically relevant, meeting a minimal clinically important difference for persons with PD.[35] Physical performance change in the balance and mobility outcomes demonstrated significant improvement; however, they did not exceed minimal detectable change values that have been previously reported for the BBS or TUG.[16,36] This may be due to heterogeneity of motor impairments as well as the ceiling effect observed in some outcome measures. We observed statistically significant physical performance improvement across domains of gait, balance, and mobility, suggesting a slowing or reversal of functional decline as a result of this cycling program. The positive effects on physical performance resulting from this tandem cycling program may have several contributing factors. Aerobic exercise alone promotes general cardiorespiratory fitness and muscle performance[28] as well as neuroprotective effects on brain structure and function, impacting both motor and nonmotor function in individuals with PD.[37,38] Research in PD animal models suggests there may be neuroprotective benefits resulting from aerobic training that subsequently slow motor decline.[39,40]

Our findings of improved balance and mobility are consistent with previous exercise studies reporting improved balance performance and functional mobility in people with PD.[41,42] Muscle strength and power are commonly impaired[43] and are associated with slower walking velocity and falls in individuals with PD.[44,45] Muscle power is facilitated through exercises involving force generation at higher velocities and may have contributed to improved functional mobility outcomes.

Mechanically augmented pedaling at a fast rate may elicit underlying mechanisms that impact central motor processing in individuals with PD. Ridgel et al[11] reported improved upper extremity motor control after a tandem cycling interventions. Alberts et al[10] hypothesized that forced exercise via tandem cycling increases afferent input from muscle spindles and Golgi tendon organs within the lower extremities, possibly triggering the release of neurotrophic factors or levels of certain neurotransmitters, such as dopamine, in individuals with PD. Further research is needed to study the effects of force-paced compared to self-paced aerobic exercise in individuals with PD.

This study has multiple strengths; however, several limitations should be considered. There was no control group in this pilot study. We did not include an outcome measure of endurance or cardiorespiratory fitness. Feasibility of reaching program goals was demonstrated in individuals with motor symptom disease severity ranging from H&Y 1 to 3. However, we are unable to generalize these findings to individuals with greater disease severity (H&Y 4-5) without conducting further studies.

CONCLUSION

A community-based indoor tandem cycling program is feasible for individuals with mild to moderate PD and resulted in improved physical performance. This program was designed to facilitate aerobic exercise training at a higher cadence, consistency, and intensity than voluntary exercise in people with PD. Further research is needed to translate beneficial exercise programs into community-based settings that are accessible for individuals at various stages of PD.

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