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Research Notes

Real-time intensity feedback can improve the benefits of aerobic stimuli in Parkinson's disease: randomized, crossover-controlled feasibility trial

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HIGHLIGHTS

- Real-time feedback induced higher exercise intensities in Parkinson's disease
- Critical heart rate is a feasible method for prescribing aerobic exercise in Parkinson's disease
- Low retention rates were observed in the randomized crossover-controlled trial
- The effects of WB+F on cognition and walking capacity require further investigation

ABBREVIATIONS

6MWT	6-minute walk test
CHR	Critical heart rate
CS	Critical Speed
H&Y	Hoen & Yahr
HBs	Heartbeats
HR	Heart rate
HRmax	Heart rate maximum
MMSE	Mini-Mental State Examination
PD	Parkinson's disease
PwPD	People with Parkinson's disease
RPE	Rating of perceived exertion
SSS	Self-selected speed
STS	Sit-to-stand
TUG	Timed up and go
UPDRS	Unified Parkinson's Disease Rating Scale
WB+F	Walking-based efforts with real-time intensity feedback

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BACKGROUND: Prescribing and maintaining adherence to high-intensity exercise is challenging in people with Parkinson's disease (PwPD). Adding cognitive engagement may enhance exercise benefits. Critical heart rate (CHR) offers a promising method to prescribe aerobic intensity and provide feedback during training. However, it is unclear whether this approach achieves higher training loads than self-selected intensity while preserving adherence.
AIM: To investigate the feasibility of a walking-based intervention with intensity feedback prescribed using CHR (WB+F) in PwPD. Secondarily, the effects on motor and non-motor outcomes were explored.
METHODS: Twenty-four PwPD were invited to participate in a randomized crossover-controlled trial consisting of two 8-week training cycles (WB+F: walking at CHR with intensity feedback; SSS: self-selected speed), separated by a 3-week washout period. Feasibility outcomes included retention, adherence, and compliance. Motor and non-motor outcomes were assessed before and after each training cycle.
RESULTS: Retention comprised 10 participants (42% of those enrolled), with adherence rates above 75% in both training conditions (p=0.572). Compliance analyses showed higher values for WB+F compared with SSS for distance covered (p=0.004), rating of perceived exertion (p=0.006), and training load (p=0.002). Cognitive performance improved (p=0.032), and time to complete the 400-m walk test decreased (p=0.043) following WB+F.
INTERPRETATION: Despite the promising cognitive and motor outcomes, this feasibility study demonstrated low retention rates, which limit the clinical relevance of the findings. Nevertheless, the compliance results suggest that CHR-based prescription is feasible in PwPD. Future studies should adopt parallel-group designs to ensure larger sample sizes and adequately test the efficacy of the WB+F approach

KEYWORDS: Functional capacity | Aerobic exercises | Controlled intensity| Motor symptoms

INTRODUCTION

Exercise intensity plays a crucial role in influencing motor symptoms in people with Parkinson's disease (PwPD), with higher intensities producing more significant improvements in motor symptoms than moderate intensities [1]. High-intensity aerobic training not only provides general health benefits and enhances physical fitness (VO_2max) but also offers symptomatic relief for PwPD [1]. It may boost dopaminergic signaling and increase neural activity in the basal ganglia and motor cortex [2]. A secondary effect of intense aerobic exercise is to slow the progression of symptoms such as gait impairments or cognitive decline [1]. However, prescribing and ensuring adherence to high-intensity exercise remains a major challenge for PwPD, particularly when sessions are delivered in group settings without access to ergometers, making it difficult to maintain the desired intensity throughout the effort.

Incorporating cognitive engagement into exercise may offer additional benefits for PwPD. Real-time intensity feedback during aerobic exercise (e.g., walking at a target velocity) can enhance cognitive engagement by encouraging participants to exceed their self-

selected intensity levels, thereby boosting motivation and awareness throughout the session [3]. Walking-based efforts also offer a goal-oriented approach for gait improvement, incorporating constraints such as obstacle negotiation and changes in speed or direction. Studies suggest that combining high-intensity and challenging goal-based stimuli can promote neuroplasticity in PwPD, potentially yielding greater benefits than moderate-intensity walking-based alone efforts [3]. However, most studies have investigated the effects of intensive and challenging goal-based stimuli solely prescribed in longer-duration sessions (i.e., over 30 minutes) [4–6], which is not applicable during other types of exercise.

Among the various types of exercise, multicomponent training is frequently applied to PwPD. During multicomponent sessions, various physical capacities (e.g., flexibility, strength, balance, coordination, and aerobic capacity) are stimulated [7], enabling the application of complex stimuli that may offer advantages over exercise modalities performed in isolation [7]. Multimodal sessions incorporating aerobic stimuli have been shown to induce significant benefits in both motor [7–10] and non-motor symptoms [7,11] in individuals with PD. Therefore, it is plausible that multimodal sessions incorporating intensive and challenging aerobic components may yield greater effects than those using moderate-intensity efforts. However, the effects of shorter-duration aerobic efforts (i.e., under 30 minutes) remain unclear, which limits their integration into multicomponent programs –especially given the need to address multiple physical domains within a single session.

Considering the aspects mentioned above, the effects of a multimodal program that includes intensive and challenging aerobic stimuli — induced through walking-based efforts with real-time intensity feedback (WB+F) — should be investigated. However, for the implementation of WB+F in daily practice, several issues need to be addressed. First, exercise intensity should be prescribed using a robust and safe method capable of inducing a higher training load than the traditional self-selected speed (SSS) approach. In this context, Barbieri and colleagues [12] proposed the critical heart rate (CHR) as a physiological target for prescribing aerobic exercise intensity. Theoretically, CHR represents the boundary between the heavy and severe exercise domains and is therefore expected to elicit higher intensities than SSS, which is typically performed within the moderate domain. However, to date, no studies have demonstrated whether CHR-based prescription induces higher training loads than SSS in PwPD. Moreover, although exercise tolerance was previously reported, adherence to CHR-based training programs was relatively low, with only 53% of participants completing at least 90% of sessions [12]. Importantly, this adherence rate was not compared with a control group, limiting conclusions regarding the practical applicability of CHR-based prescriptions. Therefore, to support future large-scale investigations, the primary objective of the present study was to test the feasibility (retention, adherence and compliance) of a randomized controlled trial designed to evaluate a WB+F intervention prescribed using CHR in PwPD. The primary outcome was the feasibility of physical exercise protocols, comparing the WB+F and SSS groups. Additionally, clinical, cognitive, and motor outcomes were assessed.

METHODS

Participants

Twenty-four PwPD participated in this feasibility study. Inclusion criteria were: i) age >55 years, ii) diagnosis of idiopathic Parkinson's disease (PD) according to the UK Parkinson's Disease Society Brain Bank Diagnostic Criteria, iii) stable dopaminergic medication for at least 3 months, and iv) disease stage 1 to 3 according to Modified Hoehn & Yahr Scale (H&Y). Exclusion criteria were: i) orthopedic conditions preventing exercise participation, and ii) attendance below 75% of training sessions. All procedures were approved by the institutional research ethics committee from the School of Sciences at São Paulo State University (UNESP), Campus Bauru (CAAE 17892819.9.0000.5398). Written informed consent was obtained from all participants.

Experimental design and distribution of groups

This feasibility study employed a randomized crossover-controlled trial design. Participants completed two 8-week training cycles, separated by a 3-week washout period. Initially, they were randomly assigned to either the WB+F or SSS training group, with stratification by disease stage and gender. After the first cycle, participants crossed over to the alternate training condition. Assessments were conducted at three time points: baseline (before the first cycle), after 8 weeks (end of the first cycle), and after 16 weeks (end of the second cycle). The assessment at the end of the first cycle also served as the baseline for the second cycle. A CONSORT diagram illustrating the study design is shown in Figure 1.

All training sessions were group-based and supervised by physiotherapists and physical education professionals, maintaining a participant-to-professional ratio of less than 3:1. Sessions were held during the morning from 8:30 a.m. to 9:30 a.m. All training sessions and assessments were performed while participants were in the 'ON' stage of dopaminergic medication, approximately one hour after intake [13].

Physical exercise protocol

Both WB+F and SSS interventions followed identical activities. The intervention spanned 8 weeks, with two sessions per week, each lasting 50–55 minutes (a total of 845 minutes per training cycle). All sessions were conducted in a flat indoor court, and participants wore appropriate footwear for physical activity. Each session was structured into three segments: i) initial activity (stretching/warm-up;

5min), ii) main activity focused on aerobic capacity, starting with 20min in the first eight sessions and progressing to 25min by the end of the cycle. This was followed by 15 minutes of coordination, balance, and/or strength exercises (totaling 35–40 minutes), and iii) cool down with stretching exercises (10 minutes). Details of the session structure and progression over the 8-week period are provided in Supplementary Table S1.

The primary difference between interventions was the use of real-time intensity feedback during the aerobic exercise component. Participants in the WB+F intervention wore a heart rate monitor (Polar Team Pro®, Polar Electro, Finland) and received verbal intensity feedback every 1–2 minutes, with instructions to maintain their heart rate at or above the CHR. Heart rate values were not visible to participants; instead, feedback was provided by the researchers to encourage maintenance of the target intensity (e.g., "You're doing well; try to slightly increase your pace"). The participants of the SSS group were encouraged to do the activity according to their physical condition. In contrast, the SSS group was instructed to exercise at a self-selected pace based on their perceived best capacity.

For both groups, distance covered and ratings of perceived exertion (RPE; 10-point scale) were recorded after each session. Training load was calculated by multiplying RPE by session duration[14]. Both protocols included multiple constraints during walking (e.g., obstacle avoidance, direction changes), and identical coordination, balance, and strength exercises. Similar feedback was provided during these components in both interventions.

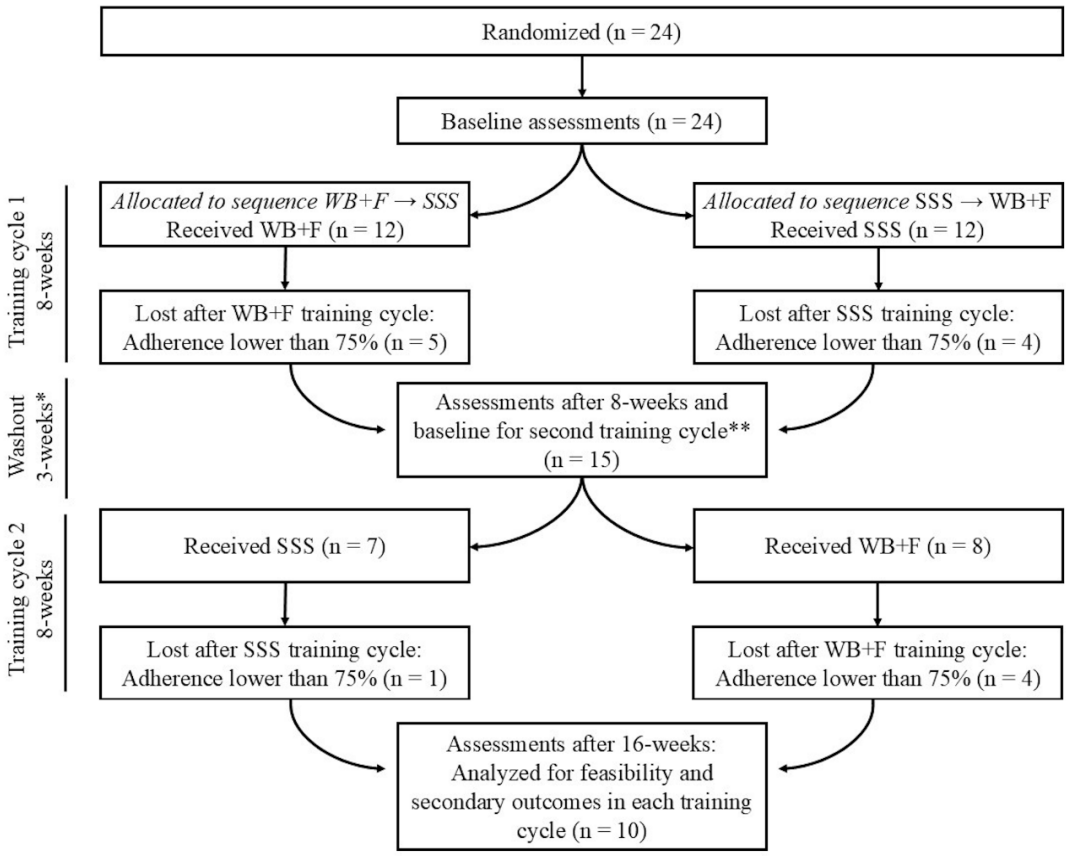

Figure 1. CONSORT flow diagram of the crossover design used to compare different aerobic training stimuli. WB+F: walking-based training with real-time intensity feedback; SSS: self-selected speed. *The washout period lasted 3 weeks, was arbitrarily defined, and may have led to residual effects during the subsequent training phase. **Assessments conducted after 8 weeks were used to evaluate the effects of the first intervention and to establish baseline values for the second training cycle.

Feasibility of physical exercise protocols

Retention was defined as the number of participants who completed the experimental protocol. Adherence was calculated as the percentage of training sessions completed relative to those prescribed in each training cycle. Compliance rate was defined as the proportion of participants who exhibited higher exercise demands during WB+F compared with SSS, based on distance covered, RPE, and training load recorded during each training cycle.

Secondary Assessments

Clinical assessments were conducted by an experienced evaluator trained in clinical and cognitive assessment. Parkinson's disease severity was assessed using the H&Y[15] and Unified Parkinson's Disease Rating Scale - UPDRS parts II and III[16]. Cognitive

function was evaluated using the Mini-Mental State Examination (MMSE) [17]. In addition, participants completed the following motor assessments: i) 6-minute walk test (6MWT) – to assess walking ability with high levels of reliability for PwPD [18]. To standardize and control the distance covered, two cones were positioned in an indoor court, 30 meters apart, with distance markers placed every five meters. Participants were instructed to walk back and forth between the cones, performing a 180° turn at each end. They were asked to walk as fast as possible for six minutes and were strongly encouraged throughout the test; ii) Timed up and go (TUG) - performed twice, with the average time recorded. The TUG is a validated tool for assessing functional mobility and demonstrates strong clinimetric properties in PwPD [19]; iii) sit-to-stand (STS) - Participants were instructed to repeatedly stand up from and sit down on a chair (seat height ≈ 43 cm) as quickly as possible for 30 seconds. The test was performed twice, and the highest number of completed repetitions was used for analysis. iv) CHR and Critical Speed (CS) – assessed following the protocol described by Barbieri and colleagues [12]. CS was calculated as the slope of the linear distance-time relationship. The total number of heartbeats (HBs) was determined by multiplying the average heart rate (HR) by the time taken to complete the distance. CHR was derived as the slope of the HB-time linear relationship. All regressions were performed using OriginPro (Version 8.5; OriginLab Corporation, Northampton, MA, USA). CHR values were also expressed relative to the estimated maximum heart rate (HRmax = 208 − 0.7 × age).

Statistical analysis

Absolute gains (final assessment minus the initial value for each period) were calculated for both training phases. Analyses were conducted using R software version 4.4.2 with a significance level of $p < 0.05$.

Given the small sample size, the potential for positive and negative gains, and the discrete nature of some variables (e.g., RPE, MMSE, UPDRS-II, UPDRS-III), non-parametric tests were used. Outcomes were presented as median [minimum-to-maximum]. Wilcoxon signed-rank tests compared WB+F and SSS interventions regarding training adherence, compliance (distance covered, RPE, and training load), and gains (i.e., pre-post differences within each training cycle). These comparisons were accompanied by effect size (*r*), interpreted as negligible (<0.10), small (0.10–0.29), moderate (0.30–0.49), and large (≥0.50) [20]. In addition, statistical power (SP) was estimated using a Monte Carlo simulation approach (10,000 simulations) to characterize the sensitivity of the study design, based on the observed effect size, retention (i.e., final sample size), and the adopted significance level ($\alpha = 0.05$).

RESULTS

Feasibility of physical exercise protocols

Figure 2 illustrates participant adherence throughout the experimental protocol. Fourteen participants did not meet the minimum adherence criterion (i.e., >75% of the prescribed sessions). All dropouts were due to personal reasons. Consequently, retention comprised 10 participants, corresponding to 42% of the initially enrolled sample. When the first training cycle consisted of WB+F, retention was six participants (50% of the starters), whereas four participants (33% of the starters) completed the protocol when SSS was applied first. Training adherence did not differ between WB+F (88 ± 5) [75–94] %) and SSS (91 ± 11 [75–100] %; $p = 0.572$; $r = 0.333$ [Moderate]; SP = 0.121). Participant characteristics were as follows: age 72 ± 11 [64–83] years, body mass 64.0 ± 24.5 [48.8–86.0] kg, and height 1.63 ± 0.10 [1.46–1.69] m. Most participants were classified as Hoehn and Yahr stage II (n = 9), with one participant classified as stage III.

The WB+F sessions were performed at or above 68 ± 7 [48–98]% of HRmax. Figure 3 presents the compliance outcomes. Participants covered a significantly greater distance during WB+F sessions compared with SSS sessions (Compliance rate = 90%; $p = 0.004$; $r = 0.964$ [Large]; SP = 0.709). RPE was also higher during WB+F than during SSS (Compliance rate = 100%; $p = 0.006$; $r = 1.000$ [Large]; SP = 0.742), as was the mean training load (Compliance rate = 100%; $p = 0.002$; $r = 1.000$ [Large]; SP = 0.740).

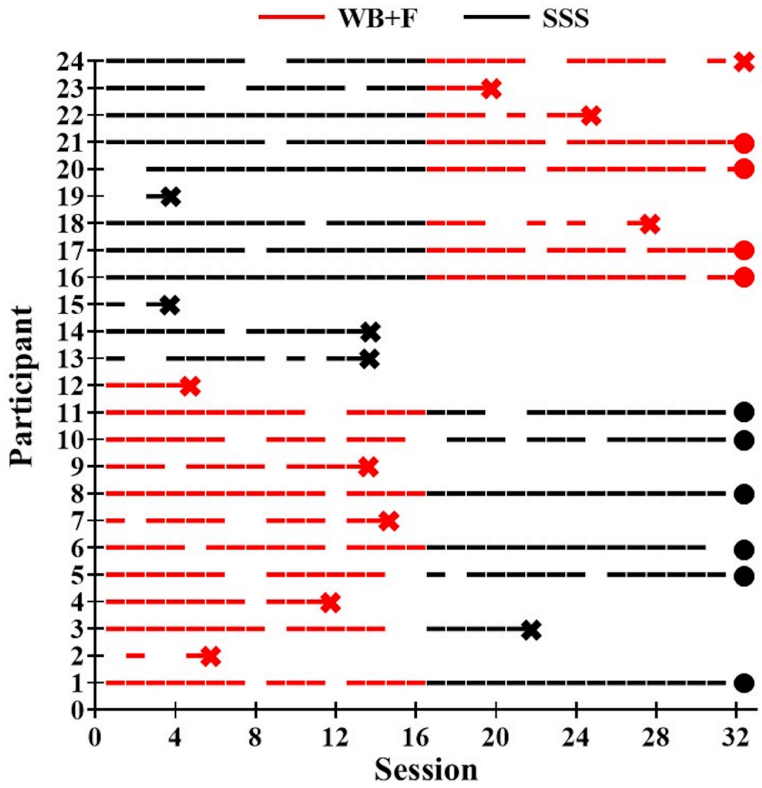

Figure 2. Participant adherence throughout the experimental protocol. Each symbol represents a completed training session for each participant. WB+F: walking-based training with real-time intensity feedback; SSS: self-selected speed; ×: low-adherence dropout; ●: participant included in the final analysis

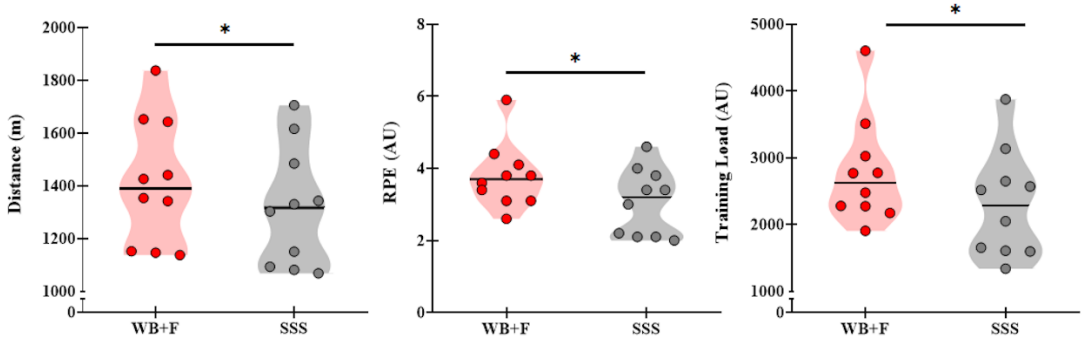

Figure 3. Violin plots of compliance outcomes following walking-based training with real-time intensity feedback (WB+F) and self-selected speed (SSS). Symbols represent individual data points, and horizontal lines indicate the median. RPE: rating of perceived exertion. *Significant differences between training conditions ($p < 0.05$).

Secondary outcomes

Baseline values and post-training outcomes for WB+F and SSS are presented in Table 1. Table 2 shows the absolute gains observed after the training period for both conditions. MMSE scores improved following WB+F training but declined after SSS ($p = 0.043$; $r = 0.778$ [Large]; SP = 0.527). Similarly, 400m completion time decreased after WB+F and increased after SSS ($p= 0.032$; $r = –0.782$ [Large]; SP = 0.522).

No significant differences between training modalities were observed for UPDRS-II ($p = 0.906$; $r = 0.067$; [Negligible]; SP = 0.043) and UPDRS-III ($p = 1.000$; $r = –0.018$; [Negligible]; SP = 0.035). Similarly, the 800m ($p = 0.284$; $r = 0.400$ [Moderate]; SP = 0.158), 1200m ($p = 0.395$; $r = –0.345$ [Moderate]; SP = 0.125), STS ($p = 0.918$; $r = 0.055$ [Negligible]; SP = 0.038), TUG ($p = 0.232$; $r = –0.218$ [Small]; SP = 0.209) and 6MWT ($p = 0.922$; $r = 0.055$ [Negligible]; SP = 0.038) showed no significant differences between training modalities. Additionally, CS ($p = 0.959$; $r = –0.036$ [Negligible]; SP = 0.036) and CHR ($p = 0.770$; $r = –0.127$ [Small]; SP = 0.051) showed no significant changes.

Table 1. Descriptive statistics of the initial values and after 8-weeks of training cycle after walking-based training with intensity feedback (WB+F) or self-selected speed (SSS) during aerobic stimuli. Data are presented as median (IQR) [min to max].

	WB+F		SSS	
	Baseline	8-weeks	Baseline	8-weeks
Clinical assessments				
MMSE (scores)	27 (4) [21 to 30]	28 (1) [24 to 30]	28 (3) [24 to 30]	27 (3) [24 to 30]
UPDRS-II (scores)	11 (5) [6 to 15]	10 (3) [7 to 22]	10 (5) [8 to 22]	11 (4) [6 to 15]
UPDRS-III (scores)	27 (8) [20 to 48]	24 (5) [22 to 46]	25 (7) [22 to 39]	26 (8) [17 to 58]
Functional parameters				
STS (reps)	14 (4) [9 to 22]	16 (3) [11 to 20]	16 (4) [8 to 20]	16 (6) [9 to 22]
TUG (s)	7 (2) [5 to 9]	7 (2) [5 to 10]	7 (2) [5 to 10]	7 (1) [6 to 9]
6MWT (m)	489 (88) [426 to 602]	525 (93) [447 to 654]	501 (98) [367 to 632]	527 (109) [426 to 612]
Critical models				
400 m (s)	320 (52) [253 to 391]	298 (23) [234 to 433]	298 (42) [234 to 343]	318 (64) [255 to 376]
800 m (s)	640 (94) [512 to 744]	639 (46) [482 to 785]	642 (92) [489 to 728]	622 (85) [495 to 744]
1200 m (s)	994 (143) [731 to 1136]	912 (113) [713 to 1046]	913 (153) [756 to 1131]	954 (200) [695 to 1133]
400 m (bpm)	104 (24) [69 to 129]	97 (23) [85 to 132]	103 (16) [88 to 132]	100 (20) [70 to 129]
800 m (bpm)	110 (29) [74 to 138]	104 (22) [72 to 147]	103 (22) [72 to 147]	104 (13) [73 to 135]
1200 m (bpm)	108 (16) [73 to 149]	111 (25) [74 to 147]	106 (22) [74 to 147]	105 (15) [79 to 151]
CS ($km.h^{-1}$)	5 (1) [3 to 6]	5 (1) [4 to 6]	5 (1) [4 to 6]	5 (1) [4 to 7]
CHR (bpm)	106 (16) [75 to 159]	114 (36) [68 to 154]	104 (27) [68 to 154]	107 (12) [83 to 162]

MMSE: Mini-Mental Status Exam; **UPDRS**: Unified Parkinson's Disease Rating Scale - second (II) and third parts (III); **TUG**: Timed Up and Go test; **6MWT**: six-minute walking test; **CS**: critical speed; **CHR**: critical heart rate; **STS**: sit-to-stand.

Table 2. Absolute gains induced by walking-based training with intensity feedback (WB+F) or self-selected speed (SSS). Data are presented as median (IQR) [min to max].

	WB+F	**SSS**
Clinical assessments		
MMSE (scores)	1 (3) [-1 to 4]	-1 (2) [-3 to 1]*
UPDRS-II (scores)	1 (5) [-6 to 8]	1 (4) [-8 to 3]
UPDRS-III (scores)	0 (8) [-9 to 11]	1 (9) [8 to 19]
Functional parameters		
STS (reps)	2 (3) [-5 to 4]	0 (6) [-2 to 6]
TUG (s)	0 (0) [-1 to 3]	0 (1) [-1 to 2]
6MWT (m)	14 (74) [-74 to 114]	11 (41) [-51 to 171]
Critical models		
400 m (s)	-21 (35) [-95 to 64]	15 (21) [4 to 48]*
800 m (s)	4 (54) [-65 to 41]	-21 (38) [-57 to 37]
1200 m (s)	-41 (82) [-199 to 79]	-6 (79) [-195 to 85]
400 m (bpm)	-2 (6) [-28 to 19]	-5 (9) [-18 to 6]
800 m (bpm)	-1 (22) [-42 to 16]	-1 (9) [-22 to 41]
1200 m (bpm)	0 (8) [-35 to 12]	1 (6) [-7 to 11]
CS ($km.h^{-1}$)	0 (1) [0 to 1]	0 (1) [-1 to 2]
CHR (bpm)	1 (24) [-54 to 24]	5 (11) [8 to 18]

MMSE: Mini-Mental Status Exam; **UPDRS**: Unified Parkinson's Disease Rating Scale - second (II) and third parts (III); **TUG**: Timed Up and Go test; **6MWT**: six-minute walking test; **CS**: critical speed; **CHR**: critical heart rate; **STS**: sit-to-stand; *Significant differences from WB+F.

DISCUSSION

This study investigated the feasibility of a randomized, counterbalanced controlled trial designed to evaluate WB+F prescribed using CHR in PwPD. Secondarily, the effects on clinical, cognitive, and motor outcomes were explored. The main findings indicate that WB+F is feasible in PwPD, as evidenced by higher compliance outcomes, while adherence was similar to values observed with SSS. However, retention was low (42% of the enrolled sample), which limits conclusions regarding the secondary outcomes and, consequently, the applicability of the present experimental design to large-scale trials.

The greater distances covered, higher ratings of perceived exertion, and higher internal training load observed during WB+F suggest that real-time intensity feedback effectively encouraged participants to exceed their self-selected intensity levels. Given the potential for increased cognitive engagement during the sessions, WB+F may offer additional benefits for PwPD. In addition, our results showed similar retention and adherence between the two intervention arms, indicating that the training modality itself was unlikely to explain the observed dropouts. In the present study, specific reasons for attrition were not systematically recorded. However, previous studies have demonstrated that barriers to exercise in PwPD encompass a wide range of factors, which should be considered by health

professionals when implementing different exercise programs [21]. Therefore, to improve retention in future large-scale trials, researchers should identify and consider potential exercise-related barriers in individuals eligible for inclusion before study implementation.

Despite the apparent superiority of WB+F compared with SSS in improving MMSE scores and time to complete the 400-m walk test, the clinical relevance of these findings remains questionable. Although statistically significant differences and large effect sizes were observed between training modalities, the statistical power of these comparisons was negatively affected by the low retention rate. The improvement in MMSE following WB+F was below the minimal detectable change of 3 points for PwPD [17], with only three participants exhibiting changes exceeding this threshold. In addition, previous studies have shown that the MMSE is subject to ceiling effects and is sensitive to practice effects, suggesting that future studies should confirm potential cognitive benefits using more sensitive and robust instruments, such as the Montreal Cognitive Assessment [22,23]. In addition, our findings for 400-m walk test are consistent with those reported by Barbieri et al. [12], who observed improvements in 400-m walk performance following multimodal training prescribed using CHR, without concomitant changes in CS or CHR. Taken together, despite the promising effects observed with WB+F, the present results do not support definitive clinical inferences and should be interpreted with caution.

Other motor outcomes, such as 6MWT, TUG and STS, showed limited responsiveness to the WB+F and SSS. It may be attributed to the relatively mild motor impairments of our participants and the heterogeneity in training protocols across studies. Evidence suggests that the effectiveness of exercise interventions in PwPD is often inversely related to baseline motor impairment levels [24,25]. In this context, our results differ from those reported by Mafra and colleagues [8], who found significant improvements in UPDRS-III scores following a similar training protocol (2 sessions/week, 60min, for 16 weeks). Notably, their participants had higher baseline motor impairment (~33 vs. ~26 in the present study), which may explain the contrasting outcomes. Similarly, the lack of improvement in UPDRS-II scores contrasts with earlier findings showing significant reductions after only 5 weeks of training in individuals with higher initial scores (~14 vs. ~10) [26]. Further supporting this interpretation, previous studies have reported significant gains in TUG performance only when baseline times exceeded 10s, compared to ~7s in our sample [8]. Taken together, these findings suggest that the present aerobic exercise may be insufficient to induce meaningful improvements in UPDRS-II, UPDRS-III, STS, 6MWT and TUG in individuals with relatively mild baseline impairments.

This study has several limitations. First, although all dropouts were attributed to personal reasons, specific causes of attrition were not systematically recorded, which limits the contribution of the present findings to the planning of future large-scale randomized controlled trials. Second, neither the participants nor the professionals were blinded during the intervention sessions. Third, participant attrition resulted in an unbalanced design, with a greater number of individuals allocated to WB+F in the first training cycle. Considering the possibility of cumulative training effects, the largest improvements may have occurred during the initial cycle, potentially introducing bias in the comparison between WB+F and SSS. Finally, despite the advantages of using a randomized crossover-controlled design to investigate within-subject comparisons, the washout period may have limited the interpretation of the results. The 3-week washout period may have been insufficient to eliminate residual effects from the first training cycle, potentially compromising responses observed during the second cycle. In addition, considering the feasibility nature of the present study, assessments performed after the first 8-week cycle were used both to evaluate the effects of the initial intervention and to establish baseline values for the second training cycle. This methodological decision may have introduced additional residual effects, particularly for secondary outcomes. To explore this limitation, we conducted a sequence/order analysis in which absolute changes were independently compared between participants who initiated the protocol with WB+F and those who started with SSS (Supplementary Material, Table S2). This analysis demonstrated trivial sequence/order effects on both feasibility and secondary outcomes. However, despite these findings, the low retention rate within each sequence substantially reduced the statistical power of this analysis, precluding definitive conclusions regarding the adequacy of the 3-week washout period. Therefore, to minimize potential residual effects between training periods and to ensure adequate retention, future investigations should adopt alternative study designs—such as randomized controlled trials with parallel groups—to more robustly evaluate the effectiveness of the WB+F intervention.

CONCLUSION

Our results indicate that the proposed experimental design presents important limitations that should be addressed in future studies. Although higher training demands were observed in the WB+F condition, resulting in satisfactory compliance, the retention and adherence rates indicate that the experimental design would require a substantially larger initial sample. Specifically, considering the observed retention rate (~40%), future studies should recruit more than twice the number of participants required for the final analysis. In addition, despite the advantages of a crossover design, the 3-week washout period represents an important limitation of the present study. Therefore, to minimize potential residual effects between training periods, future investigations should adopt a randomized controlled trial with parallel groups. Finally, the low retention observed in the present study limits the clinical relevance of the apparent superiority of WB+F over SSS and precludes definitive conclusions regarding the secondary outcomes.

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REFERENCES

1. Schootemeijer S, van der Kolk NM, Bloem BR, de Vries NM. Current perspectives on aerobic exercise in people with Parkinson's disease. *Neurotherapeutics*. 2020;17(4):1418-1433. doi:10.1007/s13311-020-00904-8
2. Duchesne C, Gheysen F, Boré A, et al. Influence of aerobic exercise training on the neural correlates of motor learning in Parkinson's disease individuals. *NeuroImage Clin*. 2016;12:559-569. doi:10.1016/j.nicl.2016.09.011
3. Petzinger GM, Fisher BE, McEwen S, Beeler JA, Walsh JP, Jakowec MW. Exercise-enhanced neuroplasticity targeting motor and cognitive circuitry in Parkinson's disease. *Lancet Neurol*. 2013;12(7):716-726. doi:10.1016/S1474-4422(13)70123-6
4. Fisher BE, Wu AD, Salem GJ, et al. The effect of exercise training in improving motor performance and corticomotor excitability in people with early Parkinson's disease. *Arch Phys Med Rehabil*. 2008;89(7):1221-1229. doi:10.1016/j.apmr.2008.01.013
5. Nadeau A, Pourcher E, Corbeil P. Effects of 24 weaks of treadmill training on gait performance in Parkinson's disease. *Med Sci Sport Exerc*. 2014;46(4):645-655. doi:10.1249/MSS.0000000000000144
6. Ridgel AL, Vitek JL, Alberts JL. Forced, not voluntary, exercise improves motor function in Parkinson's disease patients. *Neurorehabil Neural Repair*. 2009;23(6):600-608. doi:10.1177/1545968308328726
7. Ferrusola-Pastrana A, Davison G, Meadows SN. The therapeutic effects of multimodal exercise for people with Parkinson's: A longitudinal community-based study. *Parkinsonism Relat Disord*. 2023;110:105366. doi:10.1016/j.parkreldis.2023.105366
8. Mafra M, Lenzi OMW, Silveira FS, Schmitt M V., Oliveira JFD, Sousa CAD. Multimodal exercise program contributes to balance and motor functions in men and women with Parkinson's disease differently: an intervention study. *Mot Rev Educ Física*. 2022;28:e10220015221. doi:10.1590/s1980-657420220015221
9. Li F, Wang D, Ba X, Liu Z, Zhang M. The comparative effects of exercise type on motor function of patients with Parkinson's disease: a three-arm randomized trial. *Front Hum Neurosci*. 2022;16:1033289. doi:10.3389/fnhum.2022.1033289
10. Song H, Ge S, Li J, Jiao C, Ran L. Effects of aerobic and resistance training on walking and balance abilities in older adults with Parkinson's disease: A systematic review and meta-analysis. *PLoS One*. 2025;20(1):e0314539. doi:10.1371/journal.pone.0314539
11. Frisaldi E, Bottino P, Fabbri M, et al. Effectiveness of a dance-physiotherapy combined intervention in Parkinson's disease: a randomized controlled pilot trial. *Neurol Sci*. 2021;42(12):5045-5053. doi:10.1007/s10072-021-05171-9
12. Barbieri RA, Kalva-Filho CA, Faria MH, et al. Parkinson's critical heart rate test: applying the critical power model for people with Parkinson's disease. *J Hum Kinet*. 2024;93:81-92. doi:10.5114/jhk/186562
13. Araújo-Silva F, Santinelli FB, Imaizumi LFI, et al. Temporal dynamics of cortical activity and postural control in response to the first levodopa dose of the day in people with Parkinson's disease. *Brain Res*. 2022;1775:147727. doi:10.1016/j.brainres.2021.147727
14. Haddad M, Stylianides G, Djaoui L, Dellal A, Chamari K. Session-RPE method for training load monitoring: validity, ecological usefulness, and influencing factors. *Front Neurosci*. 2017;11:612. doi:10.3389/fnins.2017.00612
15. Goetz CG, Poewe W, Rascol O, et al. Movement Disorder Society Task Force report on the Hoehn and Yahr staging scale: status and recommendations the Movement Disorder Society Task Force on rating scales for Parkinson's disease. *Mov Disord*. 2004;19(9):1020-1028. doi:10.1002/mds.20213
16. Fahn S, Elton R. Unified Parkinson's disease rating scale. In: *Recent Development in Parkinson's Disease*. Macmillan Health Care Information; 1987:153-163.
17. Feeney J, Savva GM, O'Regan C, King-Kallimanis B, Cronin H, Kenny RA. Measurement error, reliability, and minimum detectable change in the Mini-Mental State Examination, Montreal Cognitive Assessment, and Color Trails Test among community living middle-aged and older adults. *J Alzheimer's Dis*. 2016;53(3):1107-1114. doi:10.3233/JAD-160248
18. Steffen T, Seney M. Test-retest reliability and minimal detectable change on balance and ambulation tests, the 36-item short-form health survey, and the unified Parkinson disease rating scale in people with parkinsonism. *Phys Ther*. 2008;88(6):733-746. doi:10.2522/ptj.20070214
19. Bouça-Machado R, Duarte GS, Patriarca M, et al. Measurement instruments to assess functional mobility in Parkinson's disease: a systematic review. *Mov Disord Clin Pract*. 2020;7(2):129-139. doi:10.1002/mdc3.12874
20. Fritz CO, Morris PE, Richler JJ. Effect size estimates: current use, calculations, and interpretation. *J Exp Psychol Gen*. 2012;141(1):2. doi:10.1037/a0024338
21. Schootemeijer S, Van Der Kolk NM, Ellis T, et al. Barriers and motivators to engage in exercise for persons with Parkinson's disease. *J Park Dis*. 2020;10(4):1293-1299. doi:10.3233/JPD-202247
22. Smith T, Gildeh N, Holmes C. The Montreal Cognitive Assessment: validity and utility in a memory clinic setting. *Can J Psychiatry*. 2007;52(5):329-332. doi:10.1177/07067437070520050
23. Hoops S, Nazem S, Siderowf AD, et al. Validity of the MoCA and MMSE in the detection of MCI and dementia in Parkinson disease.

Neurology. 2009;73(21):1738-1745. doi:10.1212/WNL.0b013e3181c34b47
24. Hartelt E, Scherbaum R, Kinkel M, Gold R, Muhlack S, Tönges L. Parkinson's disease multimodal complex treatment (PD-MCT): analysis of therapeutic effects and predictors for improvement. *J Clin Med*. 2020;9(6):1874. doi:10.3390/jcm9061874
25. Scherbaum R, Hartelt E, Kinkel M, Gold R, Muhlack S, Toenges L. Parkinson's Disease multimodal complex treatment improves motor symptoms, depression and quality of life. *J Neurol*. 2020;267(4):954-965. doi:10.1007/s00415-019-09657-7
26. Capato TT, de Vries NM, IntHout J, Barbosa ER, Nonnekes J, Bloem BR. Multimodal balance training supported by rhythmical auditory stimuli in Parkinson's disease: a randomized clinical trial. *J Park Dis*. 2020;10(1):333-346. doi:10.3233/JPD-191752

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