

Effects of Aerobic Exercise on Physical, Mental, and Cognitive Impairments in Patients with Parkinson's Disease: A Systematic Review

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Abstract

Purpose/Hypothesis: Parkinson's disease (PD) is a progressive, neurodegenerative disorder characterized by both motor and non-motor symptoms. The motor symptoms comprise bradykinesia, rigidity, tremor, and postural instability. The non-motor symptoms may include anxiety, depression, and cognitive impairment. As the disease advances, PD symptoms also progress, leading to deterioration in physical, mental, and cognitive function. Mounting evidence shows that aerobic exercise may boost neuroplasticity in aging adults and patients with PD. Thus, the purpose of this systematic review was to examine the effects of aerobic exercise on motor, mental, and cognitive impairments in people with PD. **Materials and Methods:** Five databases (PubMed, CINAHL, Medline Complete, Cochrane Library, and Google Scholar) were systematically searched. To be eligible for inclusion, the study must have: 1) enrolled participants with idiopathic PD, 2) administered aerobic exercise as an intervention, (3) compared aerobic exercise with no exercise/other exercise, (4) measured motor, mental, and cognitive functions, and (5) used a randomized controlled design. The Physiotherapy Evidence Database (PEDro) scale was applied to assess the methodological quality of each trial. **Results:** Eight studies were included in this review, with a sample size of 507 patient participants. PEDro scores ranged from 5/10 to 9/10, indicating a fair to strong quality of the trials. Motor severity was assessed using the Unified PD Rating Scale-III. Significant between-group differences were reported in four of seven studies in favor of aerobic exercise ($p < 0.05$). Five trials found significant between-group differences in mental function favoring aerobic training ($p < 0.01$). Among the seven trials that assessed cognitive function, significant between-group differences ($P < 0.05$) were observed in three studies. The results were in support of the aerobic exercise program. **Conclusions:** Findings of this review study suggest that aerobic exercise improves physical, mental, and cog-

nitive function in patients with PD. Aerobic exercise may stimulate neuroplasticity and facilitate cognitive control networks in PD. More research is needed to expand the evidence on this topic to guide treatment for this patient population. **Clinical Relevance:** Patients with PD may benefit from aerobic exercise for improved function in several domains. Integrating aerobic exercise with the clinical management of PD can be pivotal for enhancing the quality of life in people living with PD.

Keywords

Parkinson's Disease (PD), Aerobic Exercise, Motor Symptoms, Mental Symptoms, Cognitive Symptoms, Systematic Review

1. Introduction

Parkinson's disease (PD) is a chronic, progressive neurodegenerative disease resulting from a loss of dopaminergic neurons and the involvement of other neurotransmitter pathways and brain regions [1]. This pathology leads to motor symptoms such as bradykinesia and postural instability. In addition, patients with PD may also experience non-motor symptoms which include, but are not limited to, psychological challenges (e.g., depression) and cognitive impairments (e.g., executive dysfunction) [2]. Cognitive and psychological issues result from disruptions in neurotransmitter systems, particularly the dopaminergic and serotonergic pathways, and are further exacerbated by structural atrophy in cortical and sub-cortical regions [1] [3]. Motor and cognitive impairments in PD are major contributors to disease progression and diminished quality of life [4] [5]. They cause restrictions in activities of daily living and community participation in individuals with PD, as outlined in the International Classification of Functioning, Disability, and Health framework [6] [7].

These limitations create a recurring pattern of negative effects, where a lack of physical and social engagement further affects physical and psychological health. Clinical management, including levodopa and dopamine agonists, remains the cornerstone of PD treatment, primarily addressing motor symptoms in the early stages of the disease. However, these treatments provide limited relief for non-motor symptoms such as cognitive decline, and often lead to medication-related motor complications, psychosis, and other adverse effects as the disease progresses [1] [8]. Recently, non-pharmacological interventions, particularly exercise and physical therapy, have been increasingly incorporated to modify PD progression and improve patients' overall functioning and quality of life.

Aerobic exercise, characterized by continuous, rhythmic, and repetitive physical activity that relies on oxygen to produce energy, has emerged as a promising intervention for PD due to its broad-ranging benefits [4]. It has been shown to enhance neuroplasticity by stimulating the release of Brain-Derived Neurotrophic Factor (BDNF), improving dopaminergic transmission, and increasing functional

connectivity in motor and cognitive pathways [4] [9]. Additionally, aerobic exercise decreases depression, anxiety, and fatigue, while improving mobility, balance, and quality of life [10]. Physical therapy interventions have also demonstrated significant improvements, with high-quality evidence and strong recommendations for approaches such as aerobic training, strength exercises, balance activities, external cueing, and other therapeutic services as stated in clinical practice guidelines [11]. These interventions address both motor and non-motor symptoms, including cognitive and psychological aspects.

The objective of this systematic review was to evaluate the effects of aerobic exercise on motor, mental, and cognitive impairments in individuals with Parkinson's disease. This review aimed to synthesize existing evidence on the efficacy of aerobic exercise in enhancing motor function, alleviating mental and psychological symptoms, and improving cognition in patients with PD.

2. Methods

This systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [12]. The protocol for this review was registered with PROSPERO, an international database of prospectively registered systematic reviews (Registration No. CRD42024588088).

2.1. Data Sources and Search

Five E-databases (CINAHL Complete, Cochrane Library, Medline Complete, PubMed and Google Scholar) were searched from their inception until July 2025. Studies were limited to English. Search terms included: ((idiopathic Parkinson's disease OR Parkinson OR PD) AND (Physio OR Physical Therapy OR Therapy)) OR (Aerobic Exercise OR Exercise rehab OR Intervention) AND (Motor AND Mental AND (Cognitive function OR Cognition)).

2.2. Eligibility Criteria and Study Selection

To be included, the studies must have: 1) enrolled participants with idiopathic PD; 2) administered an aerobic exercise intervention at moderate intensity, at least three times per week, for a minimum duration of four weeks; 3) had a comparative group receiving no exercise or any other types of exercise (e.g., education, and usual daily activity, etc.); 4) measured motor symptoms as well as mental and/or cognitive function; 5) utilized a Randomized Controlled Trial (RCT) design.

Two reviewers (F. S. and C. B.) independently screened the titles and abstracts of the studies for possible inclusion according to the eligibility criteria. The full texts of potentially relevant studies were obtained and independently evaluated by the two reviewers to determine eligibility based on content. If disagreements arose, a third and/or fourth reviewer (Z. V. and R. P.) was consulted to make the final decisions.

2.3. Data Extraction and Quality Assessment

Data were independently extracted from the included studies by two reviewers (C.

B. and F. S.) and cross-checked by a third and/or fourth independent reviewer (Z. V. and R. P.). Disagreements were settled by discussion until a consensus was reached. The following items were extracted from the included studies: author, year of publication, design, number of participants, type of intervention group, type of control or comparison group, outcome measures, and the duration of the study.

Quality and risk of bias were assessed by two reviewers (C. B. and Z. V.) who independently applied the Physiotherapy Evidence Database (PEDro) scale to each RCT for a cumulative score (**Table 1**). The PEDro scale is a valid and reliable assessment tool of methodologic quality of clinical trials [13]. Cut-off scores between 0-3 are considered “poor”, 4 - 5 “fair”, 6 - 8 “good”, and 9 - 10 “excellent” study designs.

2.4. Data Synthesis

No meta-analysis was performed due to a high degree of heterogeneity among the included trials. The intervention mode included several types of aerobic exercises. The duration of treatment ranged from 4 to 13 weeks among the trials. Outcome measures varied from trial to trial (refer to **Table 1** for details). Results of the included studies were qualitatively aggregated by summarizing measures of motor, mental, and cognitive function, respectively.

3. Results

3.1. Study Selection

Figure 1 illustrates the PRISMA flow diagram of the search and selection process for the current study, in which 368 articles were screened. The initial search of electronic databases and the removal of duplicate articles resulted in a total of 225 records. Eligibility criteria were utilized to screen study titles and abstracts, resulting in the elimination of 143 articles. A full-text review determined that eight records of RCTs were eligible for final analysis.

3.2. Characteristics of Included Studies

Eight RCTs were included and were published between 2010 and 2021 (**Table 1**). All included trials consisted of patients diagnosed with PD, including a total of 507 participants who were treated and/or followed for a minimum of 4 weeks to a maximum of 6 months in each trial [14]-[21]. Experimental interventions reported in those trials were various modalities targeting aerobic exercise training, such as stationary cycling, treadmill training, boot camp, and walking at home. Comparison programs included usual activities, flexibility training, educational intervention, standard physical therapy services, social interactions, and routine care.

Outcome measures assessed both motor and non-motor symptoms in all included trials. The Unified Parkinson’s Disease Rating Scale—Part III on motor examination (UPDRS III) was consistently used to measure the severity of the

Table 1. Characteristics of all included studies.

<i>Study (Author, Study Year)</i>	<i>Study Design (N)</i>	<i>Intervention</i>	<i>Comparison</i>	<i>Motor symptom (Motor function)</i>	<i>Non-motor symptom (Mental and/or cognitive function)</i>	<i>PEDro scale</i>
Altmann <i>et al.</i> , 2016 [14]	RCT (30)	Treadmill aerobic exercise	Seated stretch balance training No activity control	UPDRS III	Mental: BDI Cognitive: Stroop Test	6
Cruise <i>et al.</i> , 2010 [15]	RCT (34)	Multimodal program	Usual activities	PDQ-39	Mental: GDS Cognitive: Executive function	5
Ferrazzoli <i>et al.</i> , 2018 [16]	RCT (234)	MIRT	Non-MIRT	UPDRS III PDQ-39 Between group difference	Mental: PDQ-39 Emotional Well-Being Cognitive: PDQ-39 Cognition	7
King <i>et al.</i> (2020) [17]	RCT (46)	Cognitively challenging agility boot camp exercises	Education on living better with PD	UPDRS III	Mental: n/a Cognitive: Trail Making Test Stroop Test	8
Marusiak <i>et al.</i> , 2019 [18]	RCT (20)	Stationary bike	Usual daily activity with standard physical therapy	UPDRS III	Mental: UPDRS I depression Cognitive: Stroop Test	8
Picelli <i>et al.</i> , 2016 [19]	RCT (10)	Treadmill training	No physical contact is encouraged in social interactions.	UPDRS III	Mental: BDI Cognitive: Frontal Assessment Battery	8
Sacheli <i>et al.</i> , 2019 [20]	RCT (35)	Stationary cycling	Seated and standing stretches with low-impact exercises	UPDRS III	Mental: BDI Cognitive: Trail Making Test	7
Wu <i>et al.</i> , 2021 [21]	RCT (98)	Home-based exercise	Daily lifestyle and routine care	UPDRS III PDQ-8	Mental: GDS Cognitive: n/a	9

BDI: Beck Depression Inventory; GDS: Geriatric Depression Scale; MIRT: Multidisciplinary, aerobic, motor-cognitive, and Intensive Rehabilitation Treatment; N: sample size; PDQ: Parkinson's Disease Questionnaire; PEDro scale: Physiotherapy Evidence Database scale; RCT: Randomized Controlled Trial; UPDRS: Unified Parkinson's Disease Rating Scale.

disease and motor function in seven of the eight trials [14] [16]-[21]. UPDRS III is a clinical tool to assess the motor severity in people with PD and is widely used in clinical research as well [22]. In addition, the Parkinson's Disease Questionnaire (PDQ) was employed to evaluate physical function in three trials [15] [16] [21]. PDQ is a self-report questionnaire that assesses PD-specific health status including mobility and activities of daily living [23].

Assessment of non-motor symptoms covered mental function, cognitive function, or both mental and cognitive functional measures. Mental function was evaluated by various self-reported questionnaires such as the Beck Depression Inventory (BDI) [24], Geriatric Depression Scale (GDS) [25], and PDQ-39 Emotional Wellbeing. Cognitive function was measured by different tools such as the

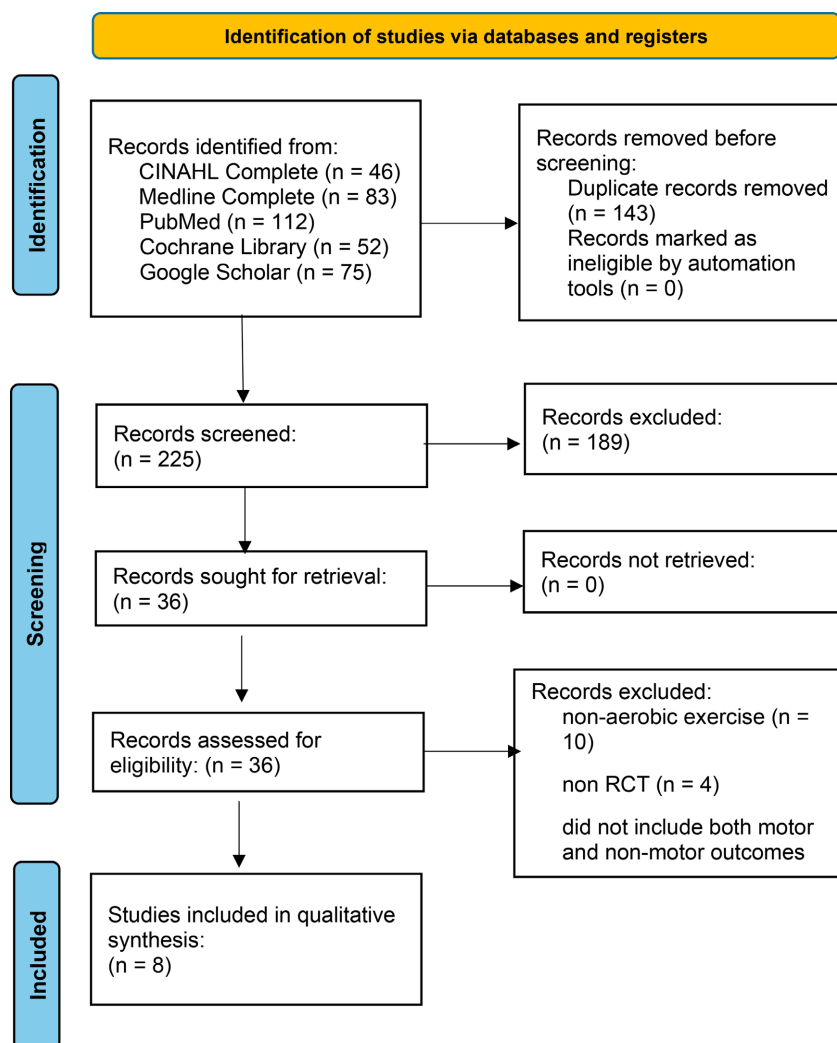


Figure 1. Flow diagram of the study selection.

Stroop Test [26] and Trail Making Test [27] among the included articles.

3.3. Quality Assessment and Risk of Bias

Methodological quality of the included studies is generally high, according to the PEDro scales ranging from 5 to 9 with a mean (SD) of 7.25/10 (1.28). PEDro scores for all individual studies are presented in **Table 1**. Specifically, six of the eight trials implemented concealed allocation [16]-[21]. Outcome assessors were blinded in seven studies [14] [16]-[21], whereas blinding of participants was achieved in only one trial [21]. Given the nature of rehabilitation research, blinding of therapists and subjects is often impractical. Moreover, an Intention-to-Treat analysis was performed in three trials to address attrition while one study reported no attrition [17] [19] [21] [18].

3.4. Outcome Measures of Motor Function

Seven of the eight trials consistently utilized the UPDRS Part III to assess motor

function in participants with PD [14] [16]-[21]. Significant between-group differences ($P < 0.05$) in UPDRS-III were revealed in four of the seven trials [16] [18] [19] [21]. The results supported aerobic exercise. Two of the three trials reported significant improvements in physical function using the PDQ-39 and PDQ-8 outcomes for the aerobic exercise group [16] [21]. The remaining studies showed no significant difference when comparing the posttests with the pretests within the groups.

3.5. Outcome Measures of Non-Motor Function

Measures of non-motor function had a high degree of heterogeneity regarding the assessment tools applied. For mental function, five trials reported that individuals receiving aerobic exercise intervention exhibited significant benefits ($P < 0.05$) compared to those in the control group as measured by the BDI in two studies [14] [19], the GDS in two trials [15] [21], and PDQ-39 Emotional Wellbeing in one trial [16], respectively. It is noted that within-group improvement measured by the UPDRS Depression was reported in one study [18].

Among the seven trials that assessed cognitive function, significant between-group differences ($P < 0.05$) were observed in three studies as evaluated by the Stroop Test [14], PDQ-39 Cognition [16], and Frontal Assessment Battery [19], individually. The results were in support of the aerobic exercise program. Two studies found significant within-group differences in scores of the Stroop Test [18] and clinically meaningful benefits in executive function [15] following the intervention.

Since meta-analysis is not feasible, a summary of effect direction was provided to visualize trends across the studies for motor and non-motor outcomes (Table 2). Most studies showed positive effects of aerobic exercise on motor, mental, and cognitive function.

Table 2. Summary of effect directions on motor, mental, and cognitive function

Study (Author, Year)	Motor function		Mental function	Cognitive function
	UPDRS III	PDQ		
Altmann <i>et al.</i> , 2016 [14]	→		▲	▲
Cruise <i>et al.</i> , 2010 [15]		→	▲	□
Ferrazzoli <i>et al.</i> , 2018 [16]	▲	▲	▲	▲
King <i>et al.</i> (2020) [17]	→		n/a	→
Marusiak <i>et al.</i> , 2019 [18]	▲		→	▲*
Picelli <i>et al.</i> , 2016 [19]	▲		▲	▲
Sacheli <i>et al.</i> , 2019 [20]	→		→	→
Wu <i>et al.</i> , 2021 [21]	▲	▲	▲	n/a

▲ significant between-group improvement; ▲* significant within-group improvement; → no significant between-group change; □ Clinically beneficial.

4. Discussion

In this systematic review, we have screened 368 studies and identified eight eligible trials. To the best of our knowledge, this is the first systematic review that has examined the effectiveness of aerobic exercise on motor, mental, and cognitive function in patients with PD. Most of the studies included in this review utilized treadmill training or stationary cycling, either administered as part of a multimodal exercise program or implemented alone. This review shows that a moderate-to-high intensity aerobic exercise routine over a minimum of one month leads to improvement in motor severity, depression-related symptoms, executive function, and attention/memory.

There is no similar review study with which this systematic review could be directly compared. Although many studies have assessed the effect of aerobic exercise on relieving PD symptoms, a great majority of those studies examined either motor symptoms/function or non-motor symptoms/function alone. Aerobic exercise was shown to attenuate motor severity as indicated by the UPDRS III [20] [28]-[30]. It is noted that participants were primarily tested in the medication off-state. Therefore, it is plausible that the improvement was merely a result of aerobic exercise. Furthermore, a recent systematic review and meta-analysis demonstrated beneficial effects of aerobic exercise on motor function, balance, and gait in individuals with PD [31]. The current systematic review extends this evidence by examining both motor and non-motor symptoms as well as overall functional outcomes.

With respect to non-motor symptoms, a recent meta-analysis showed and supported the beneficial effects of aerobic exercise and resistance exercise on improving symptoms of depression and anxiety in adults diagnosed with depression and/or anxiety [32]. Despite these benefits, aerobic exercise has not been regularly incorporated into the routine management of mental illness. In research on patients with PD, mental functions such as depressive symptoms were reported to have improved in participants of aerobic exercise programs compared to those in control groups [33] [34].

There has been an increasing amount of research on exercise intervention for cognitive impairments in neurodegenerative diseases including PD. Findings associated with the effect of aerobic exercise have been largely positive in enhancing cognitive function [35] [36]. Several trials, including a few reviewed in the present study, have demonstrated statistically significant cognitive improvements in patients with PD [14]-[16] [19] [37] [38]. Although there were inconsistencies across cognitive measures and variability in the intensity and dosing of the exercises, evidence has suggested favorable trends regarding the implication of aerobic exercise in clinical practice [4].

Underlying mechanisms of aerobic exercise in neuroplasticity have been widely explored over the past decades. Research from animal models suggests that long-term exercise facilitates neuroplasticity, increases Brain-Derived Neurotrophic Factor (BDNF) levels, and elevates striatal expression of dopamine D2 receptor,

which plays a role in motor function [39]. Aerobic-type exercise has been observed to increase dopamine D2 receptor expression, brain activation, functional connectivity, and enhance neuroplasticity in patients with PD [40].

PD progression is characterized by multifaceted aspects such as physical, mental, and cognitive dysfunction. Our systematic review reiterates the importance of therapeutic exercise addressing both motor and non-motor symptoms in patients with PD. It is implied that aerobic exercise should be an integral component of clinical management of symptoms in PD. It is recommended that clinicians design therapeutic programs by feasibly and effectively customizing the type, intensity, and frequency of aerobic exercise to the mobility, cardiovascular fitness, and disease stage of individual patients. Understanding the benefits of aerobic exercise to health and well-being in patients with PD is pivotal for delivering evidence-based patient-centered plans of care.

There are a few limitations in this review study. To be included in this review, the study must have measured both motor and non-motor symptoms, and the non-motor symptoms specifically refer to mental/psychological and cognitive function. Few studies to date have met the criteria specific to this review. Thus, only eight articles were included and reviewed. In addition, six trials had small sample sizes ranging from 10 to 46, with a median of 32 participants. Heterogeneity in disease stages among participants and the lack of blinding for researchers and participants may compromise the validity of this study. Another limitation is associated with the aerobic component implemented within a multimodal program consisting of other exercises such as resistance training and task-specific training in about a quarter of the included trials. The combined training programs made it difficult to determine the precise influence of aerobic exercise on the outcomes. The potential placebo effect of supervised exercise is acknowledged. Another notable limitation was the inconsistent use of measurement tools for non-motor function across the trials, compromising the objectivity of data synthesis.

5. Conclusion

Aerobic exercise appears to be a beneficial and promising intervention for improving motor, mental, and cognitive symptoms in individuals with Parkinson's disease. Healthcare providers should consider incorporating structured aerobic exercise programs into PD treatment plans to optimize motor and cognitive function while addressing mental health concerns. Future research is needed to determine the most effective exercise intensity, duration, and frequency, as well as to explore long-term benefits and potential disease-modifying effects.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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