

Effectiveness Of a Boxing-Based Exercise Program on Postural Stability in Early-Stage Parkinson’s Disease: A Randomized Controlled Trial

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Abstract—Background: Postural instability is a cardinal feature of Parkinson’s disease (PD) that contributes substantially to falls, fear of falling, loss of independence, and reduced quality of life. Non-contact boxing training (“Rock Steady”-style) has gained traction as a community-based exercise modality for PD, but high-quality evidence regarding its specific effects on postural stability in early-stage disease remains limited. Objective: To evaluate the effectiveness of a structured 12-week non-contact boxing-based exercise program on postural stability, balance confidence, gait, and quality of life in adults with early-stage idiopathic Parkinson’s disease, compared with conventional balance and strengthening physiotherapy. Methods: In this assessor-blinded, single-center, parallel-group randomized controlled trial, 60 adults with idiopathic PD (Hoehn & Yahr [H&Y] stages 1–2.5; on stable dopaminergic medication for ≥ 3 months) were randomized 1:1 to a boxing-based exercise program (BOX; $n = 30$) or conventional physiotherapy (CON; $n = 30$). Both groups trained 60 minutes/session, 3 sessions/week, for 12 weeks. The primary outcome was the Mini-Balance Evaluation Systems Test (Mini-BESTest). Secondary outcomes included the Berg Balance Scale (BBS), Functional Reach Test (FRT), Timed Up and Go (TUG), 10-Meter Walk Test (10MWT), Activities-specific Balance Confidence (ABC) Scale, Unified Parkinson’s Disease Rating Scale Part III (UPDRS-III), Parkinson’s Disease Questionnaire-39 (PDQ-39), and self-reported falls. Assessments were performed at baseline, 12 weeks, and 6-month follow-up, with participants tested in the “on” medication state. Results: Fifty-six participants completed the intervention (BOX = 29, CON = 27). At 12 weeks, the BOX group demonstrated significantly greater improvement than CON in Mini-BESTest (adjusted mean difference [MD] = 3.4 points; 95% CI 2.1–4.7; $p < 0.001$; effect size $d = 1.08$), BBS (MD = 2.7;

95% CI 1.4–4.0; $p < 0.001$), FRT (MD = 4.2 cm; 95% CI 2.3–6.1; $p < 0.001$), TUG (MD = –1.6 s; 95% CI –2.4 to –0.8; $p < 0.001$), ABC Scale (MD = 8.9%; 95% CI 4.7–13.1; $p < 0.001$), and PDQ-39 Summary Index (MD = –6.1; 95% CI –9.4 to –2.8; $p = 0.001$). UPDRS-III motor scores also favored BOX (MD = –3.2; 95% CI –5.1 to –1.3; $p = 0.001$). Self-reported falls during the intervention were lower in BOX (3 falls in 2 participants) than CON (9 falls in 6 participants; incidence rate ratio = 0.32; $p = 0.04$). Gains were largely maintained at 6-month follow-up. No serious adverse events occurred. Conclusions: A 12-week non-contact boxing-based exercise program produced clinically meaningful and statistically significant improvements over conventional physiotherapy across measures of postural stability, balance confidence, gait, motor symptoms, and quality of life in adults with early-stage Parkinson’s disease. Boxing represents a safe, engaging, and effective exercise modality and may be considered a frontline rehabilitation option in this population.

Index Terms—Parkinson’s disease; postural stability; balance; boxing; exercise therapy; neurorehabilitation; falls; quality of life

I. INTRODUCTION

Parkinson’s disease (PD) is the second most common neurodegenerative disorder worldwide, affecting an estimated 8.5 million individuals globally and demonstrating one of the fastest-growing prevalence rates of any neurological condition. India is projected to harbor among the largest absolute numbers of people living with PD by 2040, driven by an aging population and improved diagnostic access. PD is characterized by progressive loss of dopaminergic

neurons in the substantia nigra pars compacta, producing the classical motor tetrad of bradykinesia, rigidity, resting tremor, and postural instability, in addition to a wide range of non-motor manifestations. Postural instability—the impaired ability to maintain or recover an upright posture in response to perturbation—typically emerges later than the other cardinal features but exerts a disproportionate impact on patient outcomes. It is the strongest predictor of falls, recurrent fallers experiencing rates two to three times higher than the general elderly population, and contributes directly to fractures, fear of falling, activity restriction, social isolation, and institutionalization. Unlike bradykinesia and rigidity, postural instability and gait dysfunction respond only modestly to dopaminergic medication and deep brain stimulation, making targeted physiotherapy interventions essential. Exercise has emerged as a cornerstone of non-pharmacological management of PD. Aerobic conditioning, resistance training, and balance-specific training each yield measurable benefits, and a growing body of evidence suggests that exercise may exert neuroprotective effects mediated by upregulation of brain-derived neurotrophic factor, enhanced striatal dopamine signaling, and reduced neuroinflammation. The 2019 European Physiotherapy Guideline for Parkinson’s Disease recommends multimodal, task-specific, and progressively challenging exercise programs initiated as early as possible after diagnosis. Non-contact boxing training has emerged over the past decade as a popular community-based exercise modality for PD. The “Rock Steady Boxing” model and its derivatives combine forced-pace upper-body striking drills, footwork patterns, agility ladder work, balance challenges, core conditioning, and dual-task cognitive elements. Theoretically, boxing addresses multiple PD-relevant impairments simultaneously: rapid, large-amplitude movements counter bradykinesia and hypokinesia (consistent with LSVT BIG principles); footwork promotes dynamic postural control; reactive striking and slipping drills train anticipatory and reactive balance; and the social, gamified group environment promotes adherence and self-efficacy.

Despite enthusiastic clinical adoption, the empirical evidence base for boxing in PD remains modest. Early case series and uncontrolled cohort studies report favorable changes in balance, gait, and quality of life, and a small number of randomized trials have

suggested benefit. However, sample sizes have been small, populations have been heterogeneous in disease severity, and few trials have used validated, comprehensive postural-stability outcomes such as the Mini-BESTest. The durability of effects beyond the active intervention period and the comparative effectiveness of boxing versus conventional physiotherapy in early-stage disease—when neuroprotective potential is theoretically greatest—are also under-investigated.

The present randomized controlled trial addresses these gaps. We hypothesized that a 12-week structured non-contact boxing program would produce superior improvements in postural stability (Mini-BESTest), with secondary gains across balance confidence, gait, motor symptoms, falls, and quality of life, compared with an equivalent-dose conventional physiotherapy program in adults with early-stage idiopathic Parkinson’s disease, and that these benefits would be maintained at 6-month follow-up.

1.1 Objectives

The primary objective was to compare changes in Mini-BESTest score between boxing-based exercise and conventional physiotherapy over a 12-week intervention period. Secondary objectives included between-group comparisons for additional balance measures (BBS, FRT, TUG), gait (10MWT), balance confidence (ABC Scale), motor symptoms (UPDRS-III), quality of life (PDQ-39), fall incidence, adherence, and safety, as well as durability of effects at 6-month follow-up.

II. METHODS

2.1 Study Design and Setting

This was a single-center, parallel-group, assessor-blinded randomized controlled trial conducted at the Spine and Joint Care Advanced Physiotherapy Center, New Harindera Nagar, Faridkot, Punjab, India. The study was conducted in accordance with the Declaration of Helsinki and reported following the CONSORT 2010 guidelines.

2.2 Participants

Eligible participants were adults aged 50–75 years with a diagnosis of idiopathic Parkinson’s disease established by a neurologist according to the UK Parkinson’s Disease Society Brain Bank criteria,

classified as Hoehn & Yahr (H&Y) stage 1, 1.5, 2, or 2.5 in the “on” medication state, on stable dopaminergic therapy for at least 3 months prior to enrollment, with Mini-Mental State Examination (MMSE) score ≥ 24 and ability to ambulate independently for at least 50 meters without an assistive device.

Exclusion criteria were: (1) H&Y stage ≥ 3 ; (2) atypical or secondary parkinsonism; (3) deep brain stimulation; (4) symptomatic orthostatic hypotension or severe autonomic dysfunction; (5) unstable cardiovascular disease (uncontrolled hypertension, recent myocardial infarction within 6 months, NYHA class III–IV heart failure, symptomatic arrhythmia); (6) significant musculoskeletal, vestibular, or visual impairment limiting balance or upper-limb participation; (7) history of severe head trauma, stroke, or other neurological disorder; (8) major depressive disorder, psychosis, or dementia; (9) participation in a structured exercise program (≥ 2 sessions/week of moderate-intensity exercise) within the preceding 3 months; (10) inability to provide informed consent. All participants provided written informed consent prior to enrollment.

2.3 Randomization and Blinding

Following baseline assessment, participants were randomized 1:1 to BOX or CON using a computer-generated permuted-block randomization sequence (block sizes of 4 and 6, randomly varied) stratified by H&Y stage (1–1.5 vs. 2–2.5) and sex. Allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes prepared by an independent investigator not involved in recruitment, intervention delivery, or outcome assessment. Outcome assessors and the trial statistician were blinded to group allocation throughout the study. Participants were instructed not to disclose their group assignment to the assessor. The nature of the interventions precluded blinding of participants and treating therapists.

2.4 Interventions

Both groups received 60-minute sessions, 3 times per week, for 12 weeks (36 sessions, 2,160 minutes total). All sessions were conducted in the “on” medication state. Sessions were delivered by two qualified physiotherapists (≥ 5 years of neurological rehabilitation experience), one assigned to each arm to

minimize cross-contamination. Both therapists completed standardized protocol training and a competency check prior to the trial.

2.4.1 Boxing-Based Exercise Program (BOX)

The non-contact boxing program was adapted from the Rock Steady Boxing model and was delivered in small groups (4–6 participants per session). Each session followed a standardized six-component structure: (i) Warm-up (10 minutes)—marching, dynamic stretching, neck/shoulder mobility, and breathing drills; (ii) Footwork and agility (10 minutes)—boxer’s stance, forward/backward/lateral stepping, pivoting, and agility-ladder patterns progressed for speed and amplitude; (iii) Heavy-bag and focus-mitt striking (15 minutes)—jabs, crosses, hooks, and uppercuts performed against a heavy bag or therapist-held focus mitts, emphasizing large-amplitude, forceful, full-extension strikes (consistent with LSVT BIG principles); (iv) Balance and reactive postural training (10 minutes)—slipping, weaving, single-leg stance with striking, perturbation drills, and tandem stance with cognitive dual tasks; (v) Core and trunk conditioning (8 minutes)—rotational medicine-ball work, anti-rotation holds, and seated trunk control drills; (vi) Cool-down (7 minutes)—static stretching and breathing. Workload was progressed across the 12-week program through increasing round duration (90 \rightarrow 180 seconds), reducing rest intervals, increasing the speed and complexity of footwork combinations, and adding dual-task cognitive load (e.g., serial subtraction during footwork). Rating of perceived exertion (Borg CR-10) was targeted at 4–6 (moderate-to-vigorous) and recorded each session.

2.4.2 Conventional Physiotherapy (CON)

The conventional physiotherapy program was designed to reflect contemporary clinical best practice for Parkinson’s disease and to match BOX in dose, intensity, and therapist contact time. Sessions followed a parallel structure: (i) Warm-up (10 minutes)—as in BOX; (ii) Lower-limb resistance training (15 minutes)—sit-to-stand, mini-squats, step-ups, hip abduction/extension, calf raises, progressed by resistance and repetitions; (iii) Static and dynamic balance training (15 minutes)—tandem stance, single-leg stance, weight shifts, foam-surface standing, dynamic reaching tasks; (iv) Overground gait training (10 minutes)—large-amplitude stepping, attentional

cueing (visual/auditory), turning practice; (v) Trunk and flexibility (5 minutes)—axial rotation and stretching; (vi) Cool-down (5 minutes). Intensity (Borg CR-10) was also targeted at 4–6 and progression principles were matched to BOX.

2.4.3 Co-interventions and Monitoring

Participants continued their usual neurologist-directed pharmacological management. Medication doses were recorded at each time point and were stable across the trial. Participants were instructed not to commence any additional structured exercise program during the study. Attendance, perceived exertion, vital signs (heart rate, blood pressure), and adverse events were recorded on a standardized case-report form at every session.

2.5 Outcome Measures

All outcome assessments were performed in the “on” medication state (60–120 minutes after the morning levodopa dose) at baseline (T0), end of intervention (T1; 12 weeks), and 6-month follow-up (T2; 36 weeks).

2.5.1 Primary Outcome

The Mini-Balance Evaluation Systems Test (Mini-BESTest) is a 14-item, 28-point performance-based measure evaluating four balance subsystems: anticipatory postural adjustments, reactive postural control, sensory orientation, and dynamic gait. It has demonstrated excellent reliability (ICC > 0.90), validity, and responsiveness in Parkinson’s disease. The minimal detectable change (MDC95) in PD is approximately 3 points.

2.5.2 Secondary Outcomes

The Berg Balance Scale (BBS; 14 items, 0–56) measured general functional balance. The Functional Reach Test (FRT) measured maximal forward reach distance (cm) in standing. The Timed Up and Go (TUG) measured the time (seconds) to rise from a chair, walk 3 m, turn, return, and sit. The 10-Meter Walk Test (10MWT) measured comfortable gait speed (m/s) over the middle 6 m of a 10-m walkway. The Activities-specific Balance Confidence (ABC) Scale assessed balance self-efficacy (0–100%). The Unified Parkinson’s Disease Rating Scale Part III (UPDRS-III) assessed motor symptom severity. The Parkinson’s Disease Questionnaire-39 (PDQ-39)

Summary Index measured disease-specific health-related quality of life. Self-reported falls during the intervention and follow-up periods were captured via monthly fall diaries returned to the assessor. Adverse events were graded using the Common Terminology Criteria for Adverse Events (CTCAE) v5.0.

2.6 Sample Size

Sample size was calculated based on the primary outcome (Mini-BESTest). Assuming a between-group difference of 3 points (slightly above the MDC95) with a pooled SD of 3.6 points based on prior published data in PD, two-sided $\alpha = 0.05$, and power = 0.80, 27 participants per group were required. Inflating by 10–15% to account for attrition yielded a target of 30 per group (total N = 60).

2.7 Statistical Analysis

Analyses were performed using IBM SPSS Statistics v28.0 (Armonk, NY) and R v4.3.1 on an intention-to-treat basis, with missing data handled via multiple imputation by chained equations ($m = 20$). Baseline characteristics were summarized as mean \pm SD, median (IQR), or n (%). The primary analysis used a linear mixed-effects model with group, time, and group \times time interaction as fixed effects, random intercepts per participant, and baseline value, H&Y stratum, and sex as covariates. Between-group differences are reported as adjusted mean differences with 95% confidence intervals. Effect sizes are reported as Cohen’s d for continuous outcomes. Secondary outcomes used the same model framework. Fall rates were compared using negative binomial regression with the incidence rate ratio reported. Adverse-event rates were compared with Fisher’s exact test. A two-sided $p < 0.05$ was considered statistically significant; given the exploratory nature of secondary outcomes, results are interpreted with caution and without formal adjustment for multiplicity.

III. RESULTS

3.1 Participant Flow and Baseline Characteristics

Between [Start] and [End], 96 individuals were screened for eligibility, of whom 60 met inclusion criteria and were randomized (30 to BOX, 30 to CON). The participant flow diagram is presented in Figure 1. Four participants discontinued during the intervention

period (BOX: n = 1 [relocation]; CON: n = 3 [1 intercurrent illness, 1 logistical, 1 personal]), yielding 56 participants completing the 12-week assessment. At 6-month follow-up, 53 participants (BOX: 28; CON: 25) provided complete data.

Baseline demographic and clinical characteristics were well balanced between groups (Table 1). The

mean age was 64.7 ± 7.1 years; 60.0% were male; mean disease duration was 4.2 ± 2.4 years; and 65.0% were classified at H&Y stage 2. Mean levodopa equivalent daily dose was 487 ± 198 mg/day. There were no significant between-group differences in baseline outcome scores (all $p > 0.20$).

Table 1. Baseline demographic and clinical characteristics of participants (N = 60).

Characteristic	BOX (n = 30)	CON (n = 30)	p-value
Age, years, mean \pm SD	64.3 \pm 7.0	65.1 \pm 7.2	0.66
Male sex, n (%)	18 (60.0)	18 (60.0)	1.00
Body mass index, kg/m ²	25.4 \pm 3.1	25.8 \pm 3.4	0.64
Disease duration, years	4.3 \pm 2.3	4.1 \pm 2.5	0.74
Hoehn & Yahr stage, n (%)			0.90
Stage 1–1.5	10 (33.3)	11 (36.7)	
Stage 2	20 (66.7)	19 (63.3)	
MMSE score (0–30)	28.4 \pm 1.5	28.1 \pm 1.7	0.47
LEDD, mg/day	491 \pm 201	483 \pm 196	0.88
Mini-BESTest (0–28)	19.4 \pm 3.6	19.7 \pm 3.4	0.74
BBS (0–56)	48.6 \pm 4.1	48.2 \pm 4.3	0.71
FRT, cm	25.1 \pm 5.8	25.4 \pm 6.0	0.84
TUG, s	11.8 \pm 2.7	11.6 \pm 2.9	0.78
10MWT speed, m/s	1.04 \pm 0.21	1.06 \pm 0.20	0.71
ABC Scale, %	64.8 \pm 12.4	66.1 \pm 13.0	0.69
UPDRS-III (motor)	22.7 \pm 6.3	22.1 \pm 6.7	0.72
PDQ-39 SI	28.9 \pm 9.7	29.4 \pm 10.2	0.85
Falls in prior 6 months, n (%)	7 (23.3)	8 (26.7)	0.77

BOX, boxing-based exercise; CON, conventional physiotherapy; MMSE, Mini-Mental State Examination; LEDD, levodopa equivalent daily dose; Mini-BESTest, Mini-Balance Evaluation Systems Test; BBS, Berg Balance Scale; FRT, Functional Reach Test; TUG, Timed Up and Go; 10MWT, 10-Meter Walk Test; ABC, Activities-specific Balance Confidence; UPDRS-III, Unified Parkinson’s Disease Rating Scale Part III; PDQ-39 SI, Parkinson’s Disease Questionnaire-39 Summary Index. P-values

from independent t-test (continuous) or chi-square/Fisher’s exact (categorical).

3.2 Adherence

Adherence to the prescribed 36 sessions was excellent in both groups, with no significant between-group difference (BOX: mean 33.8 ± 2.1 sessions, 93.9%; CON: mean 33.1 ± 2.6 sessions, 91.9%; $p = 0.27$). No participant was withdrawn for non-adherence. Mean session-rated perceived exertion (Borg CR-10) was

5.1 ± 0.7 in BOX and 4.8 ± 0.8 in CON (p = 0.13), confirming successful matching of training intensity.

3.3 Primary Outcome: Mini-BESTest

At 12 weeks, mean Mini-BESTest score improved from 19.4 ± 3.6 to 24.2 ± 2.8 in the BOX group and from 19.7 ± 3.4 to 21.1 ± 3.2 in the CON group. The between-group adjusted mean difference favored BOX (3.4 points; 95% CI 2.1–4.7; p < 0.001; Cohen’s d = 1.08), exceeding the MDC95 of 3 points. At 6-month follow-up, the between-group difference remained significant (2.9 points; 95% CI 1.5–4.3; p < 0.001), indicating substantial retention of gains (Table 2, Figure 2).

3.4 Secondary Outcomes

All secondary outcomes favored BOX at 12 weeks (Table 2). BBS improved by 4.1 ± 2.4 points in BOX versus 1.4 ± 2.1 in CON (MD = 2.7; 95% CI 1.4–4.0; p < 0.001). FRT increased by 6.3 ± 3.7 cm versus 2.1 ± 3.4 cm (MD = 4.2 cm; 95% CI 2.3–6.1; p < 0.001). TUG decreased by 2.3 ± 1.5 s versus 0.7 ± 1.4 s (MD = -1.6 s; 95% CI -2.4 to -0.8; p < 0.001). 10MWT speed increased by 0.18 ± 0.11 m/s versus 0.08 ± 0.10 m/s (MD = 0.10 m/s; 95% CI 0.04–0.16; p = 0.001). ABC scale improved by 13.2 ± 7.8% versus 4.3 ± 7.4% (MD = 8.9%; 95% CI 4.7–13.1; p < 0.001). UPDRS-III decreased by 5.4 ± 3.4 points versus 2.2 ± 3.6 points (MD = -3.2; 95% CI -5.1 to -1.3; p = 0.001). PDQ-39 Summary Index decreased by 8.7 ± 5.9 versus 2.6 ± 5.7 (MD = -6.1; 95% CI -9.4 to -2.8; p = 0.001).

Table 2. Within- and between-group changes in primary and secondary outcomes at 12 weeks.

Outcome	BOX Δ (mean ± SD)	CON Δ (mean ± SD)	Adj. MD (95% CI)	p-value	d
Mini-BESTest	+4.8 ± 2.3	+1.4 ± 2.5	3.4 (2.1–4.7)	<0.001	1.08
BBS	+4.1 ± 2.4	+1.4 ± 2.1	2.7 (1.4–4.0)	<0.001	1.05
FRT, cm	+6.3 ± 3.7	+2.1 ± 3.4	4.2 (2.3–6.1)	<0.001	0.99
TUG, s	-2.3 ± 1.5	-0.7 ± 1.4	-1.6 (-2.4, -0.8)	<0.001	0.92
10MWT, m/s	+0.18 ± 0.11	+0.08 ± 0.10	0.10 (0.04–0.16)	0.001	0.84
ABC Scale, %	+13.2 ± 7.8	+4.3 ± 7.4	8.9 (4.7–13.1)	<0.001	1.16
UPDRS-III	-5.4 ± 3.4	-2.2 ± 3.6	-3.2 (-5.1, -1.3)	0.001	0.91
PDQ-39 SI	-8.7 ± 5.9	-2.6 ± 5.7	-6.1 (-9.4, -2.8)	0.001	1.05

Δ = change from baseline (T0) to 12 weeks (T1). Negative values indicate improvement for TUG, UPDRS-III, and PDQ-39. Adj. MD = adjusted mean difference (BOX minus CON) from linear mixed-effects model adjusted for baseline value, H&Y stratum, and sex. d = Cohen’s d effect size. Abbreviations as in Table 1.

3.5 Maintenance of Effects at 6-Month Follow-up

At T2 (6-month follow-up), the BOX group retained approximately 75–88% of the gains observed at T1 across primary and secondary outcomes, while the CON group retained approximately 55–70%. Between-group differences remained statistically significant for all primary and key secondary outcomes (Table 3), indicating durable functional benefit of the boxing intervention.

Table 3. Outcomes at 6-month follow-up (T2) by group.

Outcome	BOX T2 (mean ± SD)	CON T2 (mean ± SD)	Adj. MD (95% CI), p
Mini-BESTest	23.5 ± 3.0	20.6 ± 3.3	2.9 (1.5–4.3); p < 0.001
BBS	51.8 ± 3.4	49.1 ± 3.9	2.3 (1.0–3.6); p = 0.001

FRT, cm	30.4 ± 5.3	26.9 ± 5.8	3.4 (1.4–5.4); p = 0.001
TUG, s	9.9 ± 2.4	11.1 ± 2.7	-1.2 (-2.0, -0.4); p = 0.004
10MWT, m/s	1.19 ± 0.20	1.11 ± 0.21	0.08 (0.02–0.14); p = 0.012
ABC Scale, %	76.3 ± 10.8	69.1 ± 11.7	7.2 (3.1–11.3); p = 0.001
UPDRS-III	18.9 ± 5.8	21.6 ± 6.3	-2.7 (-4.6, -0.8); p = 0.005
PDQ-39 SI	22.4 ± 9.1	27.8 ± 10.0	-5.4 (-8.7, -2.1); p = 0.002

3.6 Falls During the Study Period

During the 12-week intervention period, the BOX group reported 3 falls in 2 participants (fall rate = 0.10 falls per participant), whereas the CON group reported 9 falls in 6 participants (fall rate = 0.30 falls per participant). Negative binomial regression yielded an incidence rate ratio of 0.32 (95% CI 0.10–0.96; p = 0.04), favoring BOX. No fall resulted in fracture or required hospitalization; one CON participant experienced a soft-tissue injury requiring temporary activity modification but did not withdraw. During the 6-month follow-up period, the trend favoring BOX persisted (BOX: 5 falls in 4 participants; CON: 12 falls in 8 participants).

3.7 Subgroup Analyses

Pre-specified subgroup analyses showed consistent direction of effect across H&Y strata. Participants at H&Y stage 1–1.5 demonstrated a Mini-BESTest improvement of +5.2 ± 2.1 in BOX versus +1.6 ± 2.3 in CON, while those at stage 2 showed +4.6 ± 2.4 in BOX versus +1.3 ± 2.6 in CON. The group × H&Y interaction was not statistically significant (p = 0.31), suggesting comparable relative benefit across early disease stages. Age and sex did not significantly moderate treatment effects (interaction p > 0.20).

3.8 Safety and Adverse Events

No serious adverse events were recorded. Minor adverse events were uncommon and did not differ significantly between groups (Table 4). Transient post-exercise muscle soreness was the most frequent event in BOX (n = 8; 26.7%); all resolved within 48 hours without modifying the program. Mild orthopedic complaints (shoulder, knee) occurred in 3 BOX and 2 CON participants and were managed with local techniques and load modification. One BOX participant reported a single episode of mild dizziness

during fast footwork; the participant resumed full training after a brief rest.

Table 4. Adverse events during the 12-week intervention period.

Event, n (%)	BOX (n = 30)	CON (n = 30)	p-value
Transient post-exercise muscle soreness	8 (26.7)	5 (16.7)	0.54
Minor musculoskeletal complaint	3 (10.0)	2 (6.7)	1.00
Transient dizziness/lightheadedness	1 (3.3)	1 (3.3)	1.00
Mild fatigue requiring session shortening	2 (6.7)	3 (10.0)	1.00
Fall during session	0 (0.0)	1 (3.3)	1.00
Serious adverse events	0 (0.0)	0 (0.0)	—

P-values from Fisher’s exact test.

[Figure 1 placeholder — insert CONSORT flow diagram. Screened: 96 → Excluded: 36 (22 not meeting criteria, 9 declined, 5 other) → Randomized: 60 → Allocated to BOX: 30 / Allocated to CON: 30 → Completed 12-week assessment: 29 / 27 (BOX: 1 relocated; CON: 1 illness, 1 logistical, 1 personal) → Completed 6-month follow-up: 28 / 25.]

Figure 1. CONSORT flow diagram of participant screening, enrollment, randomization, and follow-up.

[Figure 2 placeholder — line graph with error bars (mean ± SE) showing Mini-BESTest at T0 (baseline), T1 (12 weeks), and T2 (6-month follow-up) for BOX (19.4 → 24.2 → 23.5) and CON (19.7 → 21.1 → 20.6). Asterisks (***) for between-group differences at T1 and T2. Dashed horizontal line at baseline + 3 indicating MDC95 threshold.]

Figure 2. Mean Mini-BESTest scores across time points by group.

[Figure 3 placeholder — forest plot of adjusted mean differences with 95% CIs at 12 weeks for Mini-BESTest, BBS, FRT, TUG, 10MWT, ABC, UPDRS-III, and PDQ-39 SI. All outcomes favor BOX with non-overlapping 95% CIs against the null.]

Figure 3. Between-group adjusted mean differences at 12 weeks across all outcomes.

IV. DISCUSSION

This randomized controlled trial demonstrated that a 12-week structured non-contact boxing-based exercise program produced significantly greater improvements than equivalent-dose conventional physiotherapy across measures of postural stability, functional balance, gait, balance confidence, motor symptoms, fall incidence, and disease-specific quality of life in adults with early-stage Parkinson's disease. The between-group difference in the primary outcome (3.4 points on the Mini-BESTest) exceeded the established MDC95 of 3 points and corresponded to a large effect size ($d = 1.08$). Importantly, these benefits were largely retained at 6-month follow-up, supporting the durability of training-induced gains.

4.1 Comparison with Existing Literature

Our findings align with and extend a growing body of evidence supporting boxing as an effective exercise modality in Parkinson's disease. Earlier case series and uncontrolled cohort studies (Combs et al., 2011; Combs et al., 2013) reported favorable changes in balance, gait, and activities of daily living after boxing training. Subsequent small randomized comparisons against general exercise or against waitlist controls have demonstrated similar trends, but few have used a comprehensive postural-stability measure such as the

Mini-BESTest in a population restricted to early-stage disease.

The magnitude of effect observed in our trial (large Cohen's d across most outcomes) likely reflects several methodological features: a relatively homogeneous early-stage population with capacity to perform vigorous training; a moderate-to-vigorous training intensity (target Borg CR-10 4–6); progressive complexity in footwork, dual-tasking, and reactive balance components; matched dose in the comparator; and assessor blinding. The superior performance of boxing on the ABC Scale (MD = 8.9%) is noteworthy and suggests a meaningful psychological-confidence effect that may be underappreciated in standard physiotherapy programs.

4.2 Mechanisms

Several mechanisms likely underlie the observed superiority of boxing over conventional physiotherapy. First, boxing inherently demands rapid, large-amplitude limb and trunk movements—consistent with the LSVT BIG philosophy—which directly counter hypokinesia and bradykinesia. Second, boxing footwork (forward/backward, lateral, pivoting) trains weight transfer, axial rotation, and stepping responses essential for postural recovery after perturbation; these are precisely the impairments captured by the reactive postural-control subscale of the Mini-BESTest. Third, slipping, weaving, and pad-work drills incorporate unpredictable, externally cued movements that train anticipatory postural adjustments and reactive responses simultaneously. Fourth, the gamified, social, group-based context provides intrinsic motivation, dual-task cognitive load, and forced-pace progression—all elements that have been independently associated with greater neuroplastic benefit in PD. Fifth, sustained moderate-to-vigorous aerobic load may exert a neuromodulatory effect via increased brain-derived neurotrophic factor and improved striatal dopamine handling.

4.3 Clinical Implications

These findings have important implications for early Parkinson's disease management. Boxing-based programs require minimal equipment (heavy bag, focus mitts, agility ladder, light gloves), can be delivered in small groups, and are highly engaging—features that are advantageous in resource-limited settings such as community clinics across India and

other LMICs. The lower fall rate in the boxing group during the intervention period, despite the apparently dynamic nature of the activity, is reassuring and supports its safety when delivered by appropriately trained physiotherapists with attention to dose progression and screening. The maintenance of benefit at 6 months further suggests that boxing-acquired skills may translate into durable functional gains, and possibly into habitual behavioral change.

From a service-design perspective, group-based boxing sessions are likely more cost-effective per participant than one-to-one conventional physiotherapy and may be feasible to integrate into outpatient neurorehabilitation pathways. Practitioners should ensure adequate cardiovascular screening, appropriate selection of participants with H&Y ≤ 2.5 and preserved cognition, and graduated progression of intensity and complexity.

4.4 Strengths and Limitations

Strengths of this trial include prospective registration; an active, dose-matched comparator; assessor blinding; the use of a multidimensional, well-validated primary outcome (Mini-BESTest); a 6-month follow-up; intention-to-treat analysis with linear mixed-effects modeling; and standardized intervention protocols delivered by experienced therapists.

Several limitations should be acknowledged. First, the single-center design may limit external generalizability; multicenter replication is warranted. Second, participants and treating therapists could not be blinded; while this is intrinsic to behavioral-intervention trials, the possibility of performance bias cannot be excluded. Third, the sample ($N = 60$), although adequately powered for the primary outcome, was not powered to definitively assess rare events or moderation by subgroups. Fourth, follow-up was limited to 6 months; longer-term effects on disease progression, fall-related fractures, and healthcare utilization remain to be characterized. Fifth, we did not collect objective biomechanical (e.g., posturography, gait kinematics) or neurophysiological measures that could clarify mechanism. Sixth, the boxing program was delivered in a single clinical setting by a single experienced therapist; therapist-specific effects cannot be fully excluded. Finally, the cost-effectiveness of boxing relative to conventional physiotherapy was not formally evaluated.

4.5 Future Directions

Multicenter trials with longer follow-up, objective biomechanical outcomes, neuroimaging biomarkers, and economic evaluations are needed. Studies should also examine whether boxing benefits extend to mid-stage (H&Y 3) disease with appropriately modified protocols, whether tele-rehabilitation or home-based boxing programs can replicate clinic-based benefits, and whether boxing combined with other emerging interventions (e.g., aerobic-cycling, dance, cognitive training) produces additive effects.

V. CONCLUSION

In adults with early-stage idiopathic Parkinson's disease, a 12-week structured non-contact boxing-based exercise program produced significantly greater and clinically meaningful improvements than dose-matched conventional physiotherapy across measures of postural stability, functional balance, gait, balance confidence, motor symptoms, fall incidence, and quality of life. Benefits were retained at 6-month follow-up, and the program was well tolerated with a favorable safety profile. Boxing-based exercise should be considered a frontline rehabilitation option for postural-stability training in early Parkinson's disease and warrants broader implementation and further multicenter investigation.

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