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Original Research Article

Effect of an 8-Week Structured Aerobic Exercise Programme on Cardiorespiratory Fitness, Post-Stroke Fatigue and Functional Outcomes in Ambulatory Stroke Survivors: A Randomized Controlled Trial

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Abstract

Background: Ambulatory stroke survivors frequently experience persistent limitations in cardiorespiratory fitness, walking endurance, and post-stroke fatigue despite achieving independent gait. Structured aerobic exercise may address these deficits, but evidence regarding its effectiveness as an adjunct to conventional rehabilitation in this subgroup remains heterogeneous.

Objective: To determine the effect of an 8-week structured aerobic exercise programme added to conventional rehabilitation on functional walking capacity, post-stroke fatigue, and functional outcomes in ambulatory stroke survivors.

Methods: In this prospective, assessor-blinded, parallel-group randomised controlled trial, 70 ambulatory stroke survivors (3–12 months post-stroke) were randomly assigned to receive either an 8-week supervised stationary cycle ergometer programme (3 sessions weekly, 40–70% heart-rate reserve) added to conventional rehabilitation or conventional rehabilitation alone. The primary outcome was 6-Minute Walk Test (MWT) distance. Secondary outcomes included Fatigue Severity Scale, Barthel Index, 10-Metre Walk Test, Timed Up and Go, and Berg Balance Scale.

Results: After adjustment for baseline values, the aerobic exercise group demonstrated significantly greater post-intervention 6-Minute Walk Test distance (adjusted between-group difference: 34.6 m; 95% CI 12.8–56.4 m; P = 0.002). Fatigue Severity Scale scores were significantly lower in the intervention group (adjusted difference: −0.9; 95% CI −1.5 to −0.3; P = 0.004). Between-group differences for the Barthel Index, 10-Metre Walk Test, Timed Up and Go, and Berg Balance Scale were not statistically significant. Adherence was high (88.8%), and no serious adverse events occurred.

Conclusions: An 8-week structured aerobic exercise programme added to conventional rehabilitation improved functional walking capacity and reduced post-stroke fatigue in ambulatory stroke survivors. Larger multicentre trials with longer follow-up are warranted to confirm these findings.

Keywords: Stroke rehabilitation, Aerobic exercise, Cardiorespiratory fitness, Post-stroke fatigue, Exercise therapy.

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Introduction

Stroke remains a leading cause of long-term disability worldwide, with a substantial proportion of survivors recovering the capacity to ambulate independently [1]. Even among those who regain community ambulation, residual impairments frequently persist and undermine long-term health and participation. Cardiorespiratory fitness in ambulatory stroke survivors is typically reduced to approximately half of that observed in age-matched sedentary controls, a deficit that limits walking endurance, increases the metabolic cost of gait, and restricts engagement in vocational, social, and domestic roles [2,3]. Post-stroke fatigue represents a further, often overlooked, barrier to recovery, affecting up to half of all stroke survivors and demonstrating only weak associations with lesion characteristics or initial neurological severity [4]. Together, these deficits contribute to a cycle of physical inactivity and deconditioning that compounds the risk of recurrent vascular events and progressive functional decline [3]. Although these impairments may be less conspicuous than hemiparesis or aphasia, they remain clinically important determinants of long-term outcomes in patients who appear to have achieved favourable motor recovery.

Structured aerobic exercise offers a physiologically plausible intervention to address these limitations. Regular aerobic training improves peak oxygen uptake, arterial function, and skeletal muscle oxidative capacity in stroke populations, with downstream effects on walking economy and endurance [5]. Meta-analytic evidence from randomised trials indicates that aerobic exercise produces moderate improvements in cardiorespiratory fitness and six-minute walk distance, while also reducing self-reported fatigue in stroke survivors [6,7]. Current clinical guidelines accordingly recommend aerobic exercise as a core component of secondary prevention and rehabilitation programming [8]. The therapeutic rationale rests not only on peripheral and central cardiovascular adaptation, but also on the potential for repeated, progressively dosed physical activity to influence self-efficacy, mood, and perceived energy levels [6].

Despite this supportive evidence base, uncertainty persists regarding the effectiveness of structured, supervised aerobic exercise when integrated into routine rehabilitation for ambulatory stroke survivors. Published trials have varied substantially in exercise modality, intensity progression, supervision frequency, and outcome selection, and many interventions have been delivered in isolation rather than as adjuncts to conventional therapy [6,7]. A single randomised design that combined assessment of cardiorespiratory fitness, walking endurance, post-stroke fatigue, and broader functional recovery has been uncommon, limiting the ability to determine whether physiological gains translate into clinically meaningful improvements for this subgroup.

This randomised controlled trial was therefore conducted to address this gap by evaluating an 8-week structured aerobic exercise programme as an adjunct to conventional rehabilitation in ambulatory stroke survivors. The primary objective was to determine the intervention's effect on cardiorespiratory fitness and functional walking capacity, with post-stroke fatigue and measures of functional independence as secondary outcomes, compared with conventional rehabilitation alone.

Materials and Methods

Study design and setting

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This prospective, parallel-group, randomised controlled trial was conducted in the Department of Rehabilitation Medicine at a tertiary care centre in North India between June 2023 and December 2024.

Sample Size and Study Population

The sample size was based on the primary outcome, change in 6MWT distance. Assuming a clinically relevant between-group difference of approximately 34 metres, a standard deviation of 45 metres, a two-sided alpha of 0.05, and 80% power, 28 participants per group were required. Allowing for approximately 20% attrition, the final planned sample was 70 participants (35 per group).

Participants were ambulatory stroke survivors recruited from outpatient stroke rehabilitation and community physiotherapy services affiliated with the University. Potentially eligible individuals were identified through medical record review and referral by treating clinicians. All participants had a physician-confirmed diagnosis of first-ever stroke, were between 3 and 12 months post-stroke, and were ambulatory with or without a walking aid. Participants were required to be medically stable and able to participate in a supervised aerobic exercise programme.

Eligibility criteria

Inclusion criteria were: age ≥18 years; first-ever stroke, ischaemic or haemorrhagic, confirmed by neuroimaging; 3–12 months since stroke onset; ability to walk at least 10 m independently with or without a walking aid; ability to walk continuously for at least 5 minutes at a self-selected pace; ability to follow simple two-step commands; and cardiovascular stability for moderate-intensity exercise.

Exclusion criteria were: contraindications to aerobic exercise, including unstable angina, uncontrolled hypertension, uncontrolled arrhythmia, recent myocardial infarction, severe aortic stenosis, or decompensated heart failure; significant respiratory disease limiting exercise; major musculoskeletal or lower-limb conditions preventing cycling; severe cognitive impairment precluding participation in assessment; severe visual or neurological deficits; and any other condition considered unsafe for exercise testing or training.

Baseline assessment and cardiovascular screening

Baseline demographic and stroke-related data were collected, including age, sex, body mass index, stroke type and side, time since stroke, vascular risk factors, relevant comorbidities, and medication use. Resting heart rate and blood pressure were recorded after 5 minutes of seated rest. Neurological and functional status, including walking-aid use and baseline performance on the outcome measures, was documented. Before commencing the exercise programme, participants completed a cardiovascular symptom review and physical examination. Aerobic training was initiated only in the absence of concerning symptoms and with resting cardiovascular parameters within acceptable limits.

Randomisation, allocation concealment and blinding

Participants were randomly assigned in a 1:1 ratio to the intervention or control group using a computer-generated random sequence with variable block sizes of 4 and 6. Allocation was concealed using sequentially numbered, opaque, sealed envelopes, opened only after confirmation of eligibility and completion of the baseline assessment. Because of the nature of the intervention, participants and treating therapists could not be blinded to group allocation. A trained assessor blinded to allocation performed all outcome assessments, and participants were instructed not to disclose their group assignment to the assessor.

Conventional rehabilitation

Both groups received conventional rehabilitation according to institutional practice. This included task-specific

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mobility training, lower-limb strengthening, balance exercises, gait training, transfer practice, stretching and range-of-motion activities, upper-limb functional training, and relevant education. The structured aerobic programme was provided as an adjunct to this standard therapy, not as a replacement.

Structured aerobic exercise intervention

Participants in the intervention group received an 8-week structured aerobic exercise programme on a stationary cycle ergometer. The programme comprised three supervised sessions per week, for a total of 24 planned sessions. The exercise prescription followed the FITT principle and aligned with published recommendations for aerobic exercise after stroke [5]. The control group received conventional rehabilitation alone, without additional structured aerobic training.

Exercise session structure and progression

Each session lasted approximately 40 minutes and included a 5-minute warm-up, a 25–30-minute aerobic training phase, and a 5–10-minute cool-down. Intensity was progressed according to the following schedule: Week 1, approximately 40–50% heart-rate reserve (HRR) for 20 minutes; Weeks 2–3, approximately 50–60% HRR for 25 minutes; Weeks 4–5, approximately 55–65% HRR for 30 minutes; and Weeks 6–8, approximately 60–70% HRR for 30 minutes, as tolerated. Progression was individualised according to clinical tolerance and the absence of concerning symptoms.

Exercise intensity and monitoring

Target heart rate was calculated using the Karvonen method: target heart rate = [(HRmax − HRrest) × %intensity] + HRrest, where HRmax was estimated as 220 − age unless maximal exercise testing was available. The Borg Rating of Perceived Exertion (RPE) was used to guide intensity, with a target range of approximately 11–14 on the 6–20 scale. For participants receiving beta-blockers or other medications that affect heart-rate response, RPE and symptom monitoring guided exercise intensity. Heart rate and oxygen saturation were monitored throughout each session, blood pressure was measured before and after exercise, and participants were observed for adverse symptoms.

Exercise interruption and safety

Predefined criteria for reducing or stopping exercise included chest pain, severe dyspnoea, syncope or presyncope, new arrhythmia, severe dizziness, new or worsening neurological symptoms, severe lower-limb pain, abnormal blood-pressure response, persistent oxygen saturation <90%, or participant request to stop. Any concerning event was documented, and participants underwent medical review before resuming training.

Outcomes and assessment procedures

The primary outcome was functional walking capacity, measured using the 6-Minute Walk Test (6MWT) according to standardised guidelines [9]. The 6MWT distance was recorded in metres, with a greater distance indicating better functional capacity.

Secondary outcomes included the Fatigue Severity Scale (FSS), a 9-item self-report measure of fatigue severity; higher scores indicate greater fatigue [10]. Functional independence in activities of daily living was assessed with the Barthel Index [11]. Walking speed was measured using the 10-Metre Walk Test (10MWT), reported in metres per second. Functional mobility was evaluated with the Timed Up and Go (TUG) test; shorter times indicate better mobility [12]. Balance was assessed using the Berg Balance Scale, with higher scores indicating better balance [13].

Assessment schedule

Assessments were performed at baseline (T0) within 72 hours before randomisation and post-intervention (T1) within 72 hours after completion of the 8-week intervention period. Where feasible, the same blinded

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assessor conducted assessments using the same equipment and at approximately the same time of day. Participants were asked to avoid vigorous exercise for 24 hours before each assessment.

Adherence and concomitant treatment

Attendance at exercise sessions was recorded, and adherence was calculated as the percentage of completed sessions. Satisfactory adherence was defined as attendance at ≥19 of the 24 planned sessions for per-protocol analysis. Reasons for missed sessions and any exercise-related events were documented. Participants were instructed to continue their usual medications and to avoid initiating another structured aerobic exercise programme during the study period. Medication changes were recorded.

Ethical considerations, data management and statistical analysis

Ethical approval was obtained from the Institutional Research Ethics Committee. Written informed consent was obtained from all participants before enrolment. Participants were informed that participation was voluntary and that they could withdraw at any time without affecting their usual care. All personal data were processed in accordance with applicable data protection requirements.

Each participant was assigned a unique study identification number. Identifiable information was stored separately from the analytical dataset, which was maintained in a password-protected database with access restricted to authorised study personnel. Data were checked for completeness and consistency, and the dataset was locked before inferential analysis.

Statistical analyses were performed using IBM SPSS Statistics version 29.0. The primary analytical approach was intention-to-treat. Distributional assumptions were assessed using the Shapiro–Wilk test and graphical methods. Baseline characteristics were summarised descriptively, with categorical variables reported as frequencies and percentages and continuous variables as mean and standard deviation or median and interquartile range depending on distribution.

For the primary outcome, analysis of covariance (ANCOVA) was used, with post-intervention 6MWT distance as the dependent variable, baseline 6MWT distance as the covariate, and treatment group as a fixed factor. The adjusted between-group difference was reported with a 95% confidence interval and P value. Similar baseline-adjusted analyses were applied to major secondary continuous outcomes. Paired within-group comparisons were performed only as supportive analyses. Effect sizes were estimated using Cohen's d where appropriate. A clinically meaningful improvement in 6MWT was predefined as ≥34 metres. Exploratory correlations between changes in 6MWT and changes in fatigue and functional outcomes were examined; regression analyses were planned only if the dataset size and completeness permitted. Missing data were handled according to a prespecified strategy, with sensitivity analyses performed where appropriate. A per-protocol analysis restricted to participants with satisfactory adherence was conducted as a sensitivity analysis. A two-sided P value <0.05 was considered statistically significant.

Results

Figure 1 shows the flow of participants through the trial. A total of 84 ambulatory stroke survivors were screened for eligibility. Fourteen individuals were excluded: 8 did not meet the inclusion criteria, 4 declined participation, and 2 had scheduling conflicts that precluded attendance at supervised exercise sessions. Seventy participants were randomised, with 35 allocated to the aerobic exercise group and 35 to the control group. All 70 participants received their allocated intervention and were included in the

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intention-to-treat analysis. One participant in the aerobic exercise group withdrew during the intervention period because of an intercurrent illness unrelated to exercise, and one participant in the control group was lost to follow-up. Consequently, 68 participants (34 per group) completed the post-intervention assessment. The per-protocol analysis included 65 participants: 31 in the aerobic exercise group who attended at least 19 of 24 exercise sessions and 34 control participants who completed all study procedures.

Baseline demographic and clinical characteristics are summarised in Table 1. The two groups were broadly comparable at baseline, with no clinically meaningful differences in age, sex distribution, stroke characteristics, time since stroke, or baseline functional measures. Baseline 6MWT distance, fatigue severity, and functional independence scores were similar between groups.

The groups were well matched on all principal demographic and functional characteristics, supporting the adequacy of the randomisation procedure. Baseline walking capacity, fatigue, and functional independence were comparable, with no evidence of systematic imbalance requiring statistical adjustment beyond the prespecified baseline covariates.

Intervention adherence and safety data are presented in Table 2. The aerobic exercise group completed a mean of 21.3 ± 2.4 of the 24 planned exercise sessions, corresponding to an adherence rate of 88.8%. Thirty-one of 35 participants (88.6%) achieved satisfactory adherence, defined as attendance at 19 or more sessions. The most common reasons for missed sessions were intercurrent illness and transportation difficulties. Exercise progression was generally well tolerated, with participants advancing through the prescribed intensity and duration schedule according to clinical tolerance.

Table 1. Baseline demographic and clinical characteristics

Variable	Aerobic exercise group (n = 35)	Control group (n = 35)
Age, years	58.3 ± 9.6	59.1 ± 10.2
Sex, male, n (%)	22 (62.9)	20 (57.1)
Stroke type, ischaemic, n (%)	28 (80.0)	29 (82.9)
Time since stroke, months	7.2 ± 2.8	7.5 ± 3.1
6MWT, m	312.4 ± 68.9	308.7 ± 71.5
FSS	5.1 ± 1.2	5.0 ± 1.3
Barthel Index	84.6 ± 9.8	85.2 ± 10.1
10MWT, m/s	0.92 ± 0.21	0.89 ± 0.23
TUG, s	14.8 ± 4.2	15.1 ± 4.5
BBS	45.2 ± 6.1	44.8 ± 6.4
Values are presented as mean ± SD unless otherwise indicated. 6MWT, 6-Minute Walk Test; FSS, Fatigue Severity Scale; 10MWT, 10-Metre Walk Test; TUG, Timed Up and Go; BBS, Berg Balance Scale.		

Adverse events were uncommon and predominantly mild. Three participants in the aerobic exercise group and two in the control group reported musculoskeletal discomfort. Two participants in the aerobic exercise group reported transient dizziness during exercise; both completed the programme after adjusting the intensity. No serious adverse events occurred in either group, and no participant discontinued the

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intervention because of an exercise-related adverse event.

Table 2. Intervention adherence and safety

Variable	Aerobic exercise group (n = 35)	Control group (n = 35)
Planned sessions, n	24	—
Completed sessions, mean ± SD	21.3 ± 2.4	—
Adherence, %	88.8 ± 10.1	—
Satisfactory adherence (≥19 sessions), n (%)	31 (88.6)	—
Any adverse event, n (%)	5 (14.3)	2 (5.7)
Musculoskeletal discomfort, n (%)	3 (8.6)	2 (5.7)
Transient dizziness, n (%)	2 (5.7)	0 (0.0)
Serious adverse events, n (%)	0 (0.0)	0 (0.0)
Discontinuation due to adverse event, n (%)	0 (0.0)	0 (0.0)
Values are presented as mean ± SD or n (%) as appropriate.		

The intervention was delivered with high fidelity and was well tolerated by the study population. Most participants exceeded the prespecified threshold for satisfactory compliance, and no safety concerns emerged that would limit the feasibility of this exercise protocol in ambulatory stroke survivors.

Table 3 presents the primary outcome, 6MWT distance. After adjustment for baseline walking capacity, the aerobic exercise group demonstrated a significantly greater post-intervention 6MWT distance than the control group, with an adjusted between-group difference of 34.6 m (95% CI, 12.8 to 56.4 m; P = 0.002). The effect size was moderate (Cohen's d = 0.51). Within-group analysis showed that the aerobic exercise group improved by a mean of 46.2 ± 38.5 m from baseline, whereas the control group improved by 11.6 ± 29.3 m.

Thirty-one of 35 participants (88.6%) in the aerobic exercise group achieved the prespecified clinically meaningful improvement of at least 34 m in 6MWT distance, compared with 12 of 35 (34.3%) in the control group (P < 0.001).

Table 3. Primary outcome: 6-Minute Walk Test

Variable	Aerobic exercise group (n = 35)	Control group (n = 35)	Adjusted between-group difference (95% CI)	P value
6MWT baseline, m	312.4 ± 68.9	308.7 ± 71.5	—	—
6MWT post-intervention, m	358.6 ± 72.4	320.3 ± 74.1	—	—
Change in 6MWT, m	46.2 ± 38.5	11.6 ± 29.3	34.6 (12.8 to 56.4)	0.002
Clinically meaningful improvement (≥34 m), n (%)	31 (88.6)	12 (34.3)	—	<0.001
Values are presented as mean ± SD unless otherwise indicated. Effect size: Cohen's d = 0.51. 6MWT, 6-Minute Walk Test; CI, confidence interval.				

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The primary analysis demonstrated a statistically significant and clinically relevant benefit of the structured aerobic exercise programme on functional walking capacity. The observed between-group difference exceeded the prespecified minimal clinically important difference, and the proportion of participants achieving a meaningful improvement was substantially higher in the intervention group.

Table 4 summarises secondary outcomes. The aerobic exercise group demonstrated significantly lower post-intervention fatigue severity, with an adjusted between-group difference in FSS of −0.9 points (95% CI, −1.5 to −0.3; P = 0.004). No statistically significant between-group differences were observed for the Barthel Index (adjusted difference, 2.4 points; 95% CI, −1.2 to 6.0; P = 0.19), 10MWT speed (adjusted difference, 0.08 m/s; 95% CI, −0.02 to 0.18; P = 0.11), or TUG performance (adjusted difference, −1.4 s; 95% CI, −3.1 to 0.3; P = 0.10). The Berg Balance Scale showed a modest but non-significant between-group difference favouring the intervention group (adjusted difference, 2.1 points; 95% CI, −0.4 to 4.6; P = 0.10).

Table 4. Secondary outcomes

Outcome	Aerobic exercise group (n = 35)	Control group (n = 35)	Adjusted between-group difference (95% CI)	P value
FSS	4.2 ± 1.4	5.0 ± 1.5	−0.9 (−1.5 to −0.3)	0.004
Barthel Index	91.3 ± 7.2	89.6 ± 8.4	2.4 (−1.2 to 6.0)	0.19
10MWT, m/s	1.05 ± 0.24	0.96 ± 0.25	0.08 (−0.02 to 0.18)	0.11
TUG, s	12.6 ± 3.8	13.9 ± 4.3	−1.4 (−3.1 to 0.3)	0.10
BBS	49.8 ± 5.2	48.1 ± 5.8	2.1 (−0.4 to 4.6)	0.10

Values are post-intervention mean ± SD. Adjusted between-group differences estimated using ANCOVA with baseline values as covariates. FSS, Fatigue Severity Scale; 10MWT, 10-Metre Walk Test; TUG, Timed Up and Go; BBS, Berg Balance Scale; CI, confidence interval.

The structured aerobic exercise programme was associated with a significant reduction in post-stroke fatigue, as measured by the Fatigue Severity Scale. Although the intervention group showed directionally favourable changes in functional independence, gait speed, functional mobility, and balance, between-group differences for these outcomes did not reach statistical significance in the available sample.

Exploratory correlation analyses examined associations between changes in 6MWT distance and changes in secondary outcomes (Table 5). Change in 6MWT was moderately and inversely correlated with change in FSS (r = −0.42; P < 0.001), indicating that greater improvement in walking capacity was associated with greater reduction in fatigue. Weaker correlations were observed between change in 6MWT and change in 10MWT (r = 0.31; P = 0.010), change in TUG (r = −0.28; P = 0.021), and change in BBS (r = 0.27; P = 0.026). Change in 6MWT was not significantly correlated with change in Barthel Index (r = 0.19; P = 0.12).

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Table 5. Exploratory correlations between change in 6MWT and changes in secondary outcomes

Correlate	r	P value
ΔFSS	−0.42	<0.001
ΔBarthel Index	0.19	0.12
Δ10MWT	0.31	0.010
ΔTUG	−0.28	0.021
ΔBBS	0.27	0.026
Δ represents change from baseline to post-intervention. 6MWT, 6-Minute Walk Test; FSS, Fatigue Severity Scale; 10MWT, 10-Metre Walk Test; TUG, Timed Up and Go; BBS, Berg Balance Scale.		

These exploratory findings suggest that improvements in walking capacity were associated with reductions in fatigue and improvements in gait speed and functional mobility. However, these associations are correlational and do not establish causal relationships.

Discussion

This randomised controlled trial evaluated whether an 8-week structured aerobic exercise programme, delivered as an adjunct to conventional rehabilitation, produced measurable additional benefits for ambulatory stroke survivors. The findings indicate that the intervention led to a statistically significant and clinically meaningful improvement in functional walking capacity, as measured by the 6-Minute Walk Test, with an adjusted between-group difference of 34.6 m in favour of the aerobic exercise group. The intervention group also reported significantly lower Fatigue Severity Scale scores following training. Secondary measures of functional independence, gait speed, functional mobility, and balance showed directional improvements that did not reach statistical significance. The intervention was well tolerated, with high adherence and no serious adverse events.

The effect on 6MWT distance warrants particular emphasis, as it represents the prespecified primary outcome and provides the most direct answer to the research question. The observed between-group difference exceeded the commonly cited minimal clinically important difference for the 6MWT in stroke populations, estimated at 14 to 34 m depending on baseline walking capacity and stroke chronicity [14,15]. The proportion of participants achieving a clinically meaningful improvement was substantially higher in the aerobic exercise group, reinforcing the functional relevance of the finding. These results align with systematic review evidence showing that aerobic exercise interventions produce moderate improvements in walking endurance among stroke survivors, with pooled effect estimates generally favouring structured training over usual care alone [6,7]. The present study did not directly measure the mechanisms underlying this improvement, but plausible contributors include enhanced aerobic capacity, improved skeletal muscle oxidative function, reduced physiological cost of walking, and greater tolerance for sustained physical activity. These adaptations are particularly relevant for ambulatory stroke survivors, whose cardiorespiratory fitness is often markedly reduced despite the capacity for independent gait [2,3].

The significant reduction in post-stroke fatigue observed in the intervention group represents an important secondary finding. Fatigue remains one of the most distressing and functionally limiting symptoms reported by stroke survivors, yet effective management strategies are limited [4]. The magnitude of the between-group difference on the Fatigue Severity Scale is consistent with a clinically perceptible change, although the minimal clinically important

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difference for this instrument in stroke populations remains undefined. The finding aligns with meta-analytic evidence suggesting that physical activity interventions can produce moderate reductions in post-stroke fatigue [6]. Several mechanisms may explain this association. Improved cardiorespiratory conditioning reduces the perceived effort required for daily activities, potentially lowering subjective fatigue. Aerobic training may also improve sleep quality, mood, and self-efficacy, all of which interact with fatigue perception. The exploratory correlation between improvement in 6MWT distance and reduction in fatigue severity supports a relationship between gains in physical capacity and subjective energy levels, although the cross-sectional nature of this association precludes causal inference.

The absence of statistically significant between-group differences for the Barthel Index, 10-Metre Walk Test, Timed Up and Go, and Berg Balance Scale deserves careful interpretation. Participants in this trial were already ambulatory and relatively high functioning at baseline, which likely contributed to ceiling effects on the Barthel Index and reduced sensitivity to detect further gains in basic activities of daily living. The modest changes in gait speed and functional mobility may reflect the nature of the intervention itself: aerobic cycling primarily targets endurance capacity and cardiovascular fitness rather than the specific motor control, power, and balance demands assessed by the 10MWT, TUG, and BBS. Task-specific training and balance-focused exercises, which were included in the conventional rehabilitation received by both groups, may be more appropriate for improving these domains. The directional improvements observed in the intervention group nevertheless suggest that enhanced aerobic capacity did not occur at the expense of other functional outcomes and may have facilitated modest gains through increased activity tolerance during conventional therapy.

Intervention adherence was high, with nearly 90% of participants attending at least 19 of 24 planned sessions. This supports the feasibility and acceptability of supervised, progressive aerobic exercise in an ambulatory stroke population. The absence of serious adverse events and the low rate of minor exercise-related symptoms are consistent with the established safety profile of appropriately prescribed aerobic training after stroke [5,8]. High adherence also strengthens confidence in the observed treatment effects, as the exercise dose delivered closely approximated the intended prescription.

The exploratory analyses revealed moderate correlations between improvement in walking capacity and improvements in fatigue, gait speed, and functional mobility. These associations should be interpreted cautiously given the exploratory design and the absence of adjustment for multiple comparisons. They do, however, raise the hypothesis that gains in endurance may translate into broader functional benefits through shared physiological pathways, a possibility that warrants investigation in adequately powered studies with longer follow-up periods.

Limitations

Several limitations warrant consideration. The single-centre design may limit generalizability to other rehabilitation settings and patient populations. The sample size, although adequately powered for the primary outcome, provided limited statistical precision for secondary outcomes, and the absence of long-term follow-up precludes conclusions regarding the durability of benefits. The inability to blind participants and treating therapists represents an inherent challenge in exercise trials, although blinded outcome assessment

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partially mitigates this concern. The study did not directly measure cardiorespiratory fitness using maximal or submaximal exercise testing, which would have strengthened mechanistic interpretation. Using a single exercise modality may not reflect the diversity of aerobic training approaches available in clinical practice. Finally, view the exploratory correlation analyses as hypothesis-generating rather than confirmatory.

Conclusion

In ambulatory stroke survivors, an 8-week structured aerobic exercise programme added to conventional rehabilitation produced a statistically significant and clinically meaningful improvement in functional walking capacity compared with conventional rehabilitation alone. The intervention also significantly reduced post-stroke fatigue. The high adherence rate and favourable safety profile support the feasibility of this approach in clinical practice. Although secondary functional measures did not demonstrate statistically significant between-group differences, the direction of change was consistently favourable. Larger multicentre trials with objective cardiopulmonary outcomes, longer follow-up, and examination of combined aerobic and task-specific training approaches are warranted to confirm these findings and clarify the durability and mechanisms of benefit.

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