JHWCR
Journal of Health, Wellness, and Community Research
Volume III, Issue IV
Open Access, Double Blind Peer Reviewed.
Web: https://jhwcr.com, **ISSN**: 3007-0570
https://doi.org/10.61919/6dxf0h52

Article

Effect of Aerobic Interval Training on Fatigue and Functional Performance in Post-Angioplasty Patients: A Randomized Controlled Trial

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Cite this Article

Received	2025-04-14
Revised	2025-04-26
Accepted	2025-05-04
Published	2025-05-15
Conflict of Interest	None declared
Ethical Approval	Respective Ethical Review Board
Informed Consent	Obtained from all participants
Data/supplements	Available on request.
Funding	None
Authors' Contributions	SI, MAR, and AR conceptualized and designed the study; HF and AS collected data; SI and AR performed analysis; SI, MAR, and AS drafted the manuscript.

ABSTRACT

Background: Coronary artery disease remains a major cause of morbidity and mortality globally, and despite successful angioplasty, many patients continue to experience significant fatigue and impaired functional capacity. Existing rehabilitation strategies inadequately address these limitations, highlighting a need for adjunctive interventions that target both physiological and symptomatic recovery. **Objective:** This study aimed to evaluate the effects of Aerobic Interval Training (AIT) combined with standard medication on fatigue severity and functional performance, compared to medication alone, in post-angioplasty patients. **Methods:** A single-blinded randomized controlled trial was conducted at Gulab Devi Teaching Hospital, Lahore, enrolling 47 patients aged 40–65 years who had undergone coronary angioplasty and completed Phase I cardiac rehabilitation. Participants were randomized into medication-only and medication AIT groups. Fatigue Severity Scale (FSS), 6-Minute Walk Test (6MWT), and 1-Minute Sit-to-Stand Test (1STS) were employed as primary outcome measures over a 4-week intervention. Ethical approval was obtained from the Institutional Review Board of Riphah International University (IRB number not provided) in compliance with the Declaration of Helsinki. Data was analysed using SPSS version 27, employing paired and independent t-tests at a 5% significance level. **Results:** The medication group demonstrated significant improvements in FSS scores (pre: 4.56 ± 1.34; post: 2.77 ± 1.37; $p < 0.001$) and 6MWT distances (pre: 584.17 ± 77.88 meters; post: 646.58 ± 64.13 meters; $p < 0.001$) compared to the medication-only group. Clinically meaningful enhancements in fatigue reduction and aerobic endurance were observed, while no significant changes were noted in 1STS outcomes. **Conclusion:** Aerobic Interval Training significantly enhances fatigue reduction and aerobic capacity in post-angioplasty patients beyond medication alone, underscoring its clinical relevance for improving recovery trajectories and patient quality of life. These findings support the integration of AIT into standard cardiac rehabilitation programs for enhanced human healthcare outcomes.

Keywords: Coronary Artery Disease, Aerobic Interval Training, Cardiac Rehabilitation, Fatigue Severity, 6-Minute Walk Test, Percutaneous Coronary Intervention, Exercise Therapy

INTRODUCTION

Coronary artery disease (CAD) continues to impose a substantial global burden of morbidity and mortality, primarily driven by the progressive development of atherosclerotic plaques within the coronary vasculature. This chronic inflammatory process, characterized by the subendothelial accumulation of oxidized low-density lipoproteins (LDL) and subsequent immune activation, leads to foam cell formation and plaque maturation, ultimately compromising coronary blood flow and predisposing to ischemic events (1,2). Modifiable risk factors such as sedentary behavior, poor dietary patterns, smoking, hypertension, and diabetes mellitus exacerbate this pathological process, while acute

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coronary syndromes often result from plaque rupture and thrombosis (2,4). Percutaneous transluminal coronary angioplasty (PTCA) has emerged as a pivotal revascularization strategy aimed at restoring arterial patency and mitigating myocardial ischemia (6). However, despite the procedural success of angioplasty, many patients experience persistent symptoms such as fatigue and impaired functional capacity, which are insufficiently addressed by pharmacologic interventions alone (7,8). The pathophysiology underlying post-angioplasty fatigue is multifactorial, involving residual myocardial dysfunction, systemic inflammation, endothelial impairment, and physical deconditioning (7,9). Consequently, comprehensive cardiac rehabilitation (CR) programs, integrating exercise training, psychosocial support, and secondary prevention strategies, have been advocated to facilitate recovery and enhance long-term cardiovascular outcomes (9). Among exercise modalities, Aerobic Interval Training (AIT) has garnered considerable attention for its superior efficacy in improving peak oxygen uptake, endothelial function, and arterial compliance compared to moderate-intensity continuous training (MICT)(10,11). AIT, characterized by alternating periods of high-intensity exercise and low-intensity recovery, promotes cardiovascular adaptations without the risk of sustained hemodynamic overload, thus offering potential advantages for patients with compromised cardiac reserve (12).

Emerging evidence suggests that AIT may not only improve physiological markers of fitness but also attenuate subjective fatigue and enhance overall functional performance (12,13). Nevertheless, much of the existing research has predominantly focused on surrogate outcomes such as VO_2 peak and biochemical markers, with limited exploration of clinically relevant parameters like fatigue severity and real-world functional ability in post-angioplasty populations. Moreover, the short-term impact of structured AIT protocols within standard rehabilitation frameworks remains underexplored, particularly in low- and middle-income settings where resource constraints necessitate efficient and scalable interventions. Addressing this knowledge gap is essential to optimize post-procedural care and promote sustainable recovery trajectories for CAD patients.

In light of these considerations, the present study seeks to evaluate whether the addition of Aerobic Interval Training to standard pharmacological therapy yields superior improvements in fatigue severity and functional performance compared to medication alone in patients recovering from coronary angioplasty. By utilizing validated clinical outcome measures within a randomized controlled trial design, this study aims to contribute robust evidence to inform rehabilitation practices. Accordingly, the research question posed is: Does Aerobic Interval Training significantly improve fatigue severity and functional capacity in post-angioplasty patients beyond the effects of standard medication alone? The study hypothesizes that AIT, when combined with pharmacotherapy, will lead to statistically and clinically significant improvements in fatigue and functional outcomes compared to medication alone.

MATERIAL AND METHODS

This study was designed as a single-blinded randomized controlled trial (RCT) conducted at Gulab Devi Teaching Hospital, Lahore, to investigate the effects of Aerobic Interval Training (AIT) combined with standard pharmacological therapy on fatigue severity and functional performance in post-angioplasty patients. Participants were recruited over a six-month period following Institutional Review Board (IRB) approval from Riphah International University (approval number not specified). Inclusion criteria comprised male and female patients aged 40 to 65 years who had undergone percutaneous coronary angioplasty with the placement of one or two stents and completed Phase I cardiac rehabilitation at least two weeks prior to enrollment. Exclusion criteria were comprehensive and included patients with neurological disorders, valvular heart disease, obstructive airway diseases, active malignancy, acute infections, recent post-angioplasty complications such as arrhythmias, blood clots in the stent, atrial fibrillation, uncontrolled hypertension, uncontrolled diabetes, and musculoskeletal conditions such as fractures that could impair exercise performance. Eligible participants were identified using a simple random sampling technique and randomly allocated into two groups—medication-only and medication plus AIT—using the lottery method. Written informed consent was obtained from all participants before study enrollment, and confidentiality was ensured by assigning unique identification codes to anonymize participant data, securely stored and accessible only to the research team in compliance with the Declaration of Helsinki (9).

Data collection involved baseline assessments prior to the intervention and follow-up evaluations after the four-week program. The primary outcomes were fatigue severity and functional performance. Fatigue severity was assessed using the Fatigue Severity Scale (FSS), a validated nine-item self-report questionnaire rated on a 7-point Likert scale, with higher scores reflecting greater fatigue burden. Functional performance was measured through the 6-Minute Walk Test (6MWT), evaluating the distance covered over six minutes to reflect aerobic endurance and the 1-Minute Sit-to-Stand Test (1STS), capturing lower limb strength and functional mobility by counting sit-to-stand repetitions completed within one minute All assessments were conducted by trained assessors blinded to group allocations. The AIT intervention included supervised sessions of progressive aerobic exercises—low-pace jogging or walking, squats, side steps, jumping jacks, and step exercises—preceded by a 3–5-minute warm-up and followed by a cool-down period consisting of stretching exercises.

Exercise session durations were progressively increased weekly to enhance endurance without overexertion, starting from 20 minutes in the first week and advancing to 35–40 minutes by the fourth week. Ethical considerations were rigorously observed throughout the study. The trial was conducted in accordance with the principles of the Declaration of Helsinki (9). Ethical approval was obtained from the Institutional Review Board of Riphah International University, although the IRB number was not specified in the documentation. Participants provided written informed consent after being thoroughly briefed about the study's purpose, procedures, and their right to withdraw at any stage without penalty. Confidentiality was maintained by coding participant information and securely storing all collected data, with access restricted to authorized research personnel only. Statistical analysis was performed using SPSS version 27.0.

Descriptive statistics, including mean and standard deviation, were calculated for demographic and clinical baseline characteristics.

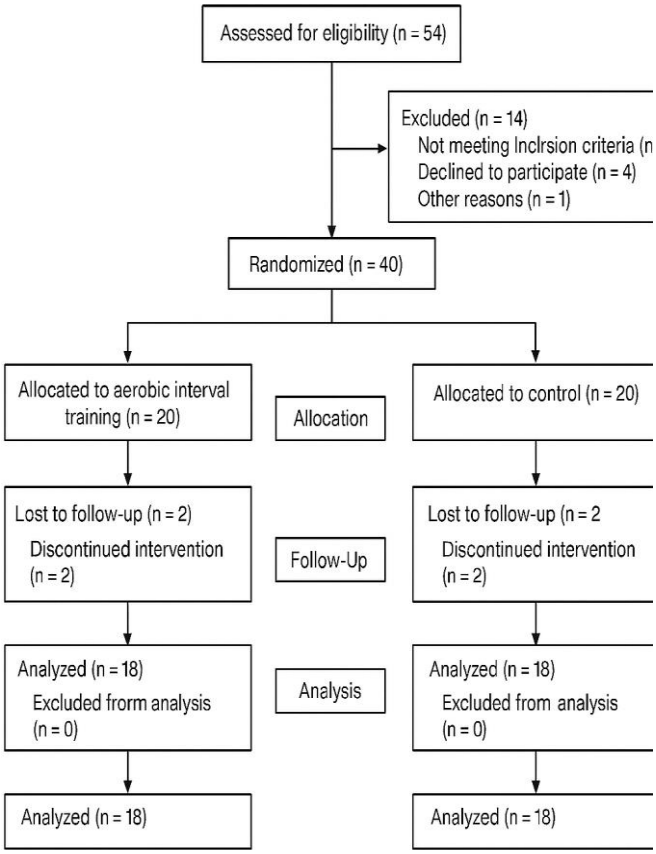

Figure 1 CONSORT Flowchart

The normality of continuous variables was assessed using the Shapiro-Wilk test due to the sample size being less than 50 participants. As data were normally distributed ($p > 0.05$ for all outcome measures), parametric tests were employed.

Within-group differences between pre- and post-intervention outcomes were analyzed using paired sample t-tests, while between-group comparisons were assessed using independent sample t-tests. A two-tailed p-value of less than 0.05 was considered statistically significant for all analyses. No missing data were reported during the study period, and thus, no imputation methods were necessary. Potential confounding variables such as baseline functional status and medication adherence were minimized through randomization, although no formal sensitivity analyses were conducted.

RESULTS

A total of 47 participants were enrolled in the study, consisting of 27 males (57.4%) and 20 females (42.6%), with a mean age of 52.70 ± 6.43 years. Baseline characteristics between the two groups showed no statistically significant differences, confirming comparability. Table 1 summarizes the demographic details. Most participants were homemakers (25.5%) or unemployed (23.4%), with smaller proportions being freelancers, retirees, or employed individuals.

Physiological measures such as BMI, oxygen saturation (SO_2), heart rate, and blood pressure were within expected ranges for a post-angioplasty population. Normality testing using the Shapiro-Wilk test confirmed that all outcome variables were normally distributed ($p > 0.05$), justifying the use of parametric tests Clinically, the reduction in FSS scores within Group B by approximately 1.79 points represents a meaningful alleviation of fatigue severity, potentially enhancing patients' perceived quality of life and daily functioning. Similarly, the improvement in 6MWT distance by 62.41 meters is not only statistically

Table 1. Demographic and Baseline Characteristics

Characteristic	Total (N = 47)
Male (%)	57.4%
Female (%)	42.6%
Age (years) (mean ± SD)	52.70 ± 6.43
BMI (kg/m^2) (mean ± SD)	27.17 ± 5.22
SO_2 (%) (mean ± SD)	90.70 ± 3.97
Heart Rate (bpm) (mean ± SD)	125.60 ± 27.47
Systolic BP (mmHg) (mean ± SD)	144.36 ± 8.51
Diastolic BP (mmHg) (mean ± SD)	85.60 ± 5.16

Table 2. Within-Group Comparisons for Outcome Measures

Outcome	Group	Pre (Mean ± SD)	Post (Mean ± SD)	t-value	p-value
FSS	A	4.48 ± 1.43	4.41 ± 1.55	1.153	0.261
FSS	B	4.56 ± 1.34	2.77 ± 1.37	16.419	<0.001
6MWT (meters)	A	611.13 ± 85.42	593.74 ± 79.19	0.659	0.517
6MWT (meters)	B	584.17 ± 77.88	646.58 ± 64.13	-14.736	<0.001
1STS (reps)	A	16.52 ± 4.42	16.83 ± 2.99	-0.771	0.449
1STS (reps)	B	17.25 ± 3.58	17.38 ± 3.57	-0.647	0.524

Between-group analyses demonstrated no significant baseline differences, ensuring initial comparability. Post-intervention comparisons revealed statistically and clinically significant improvements in Group B for both fatigue and functional capacity measured by FSS and 6MWT, respectively. No significant between-group difference was noted in 1STS scores post-intervention, suggesting that the intervention primarily influenced aerobic endurance rather than lower limb strength or

power. significant but clinically relevant, surpassing the commonly cited minimal clinically important difference (MCID) of 25–30 meters for cardiac populations. These findings underscore the beneficial impact of integrating structured AIT protocols into routine post-angioplasty rehabilitation. Unexpectedly, the 1STS outcomes did not show significant changes within or between groups, despite the aerobic exercise intervention. This result may reflect the specificity of AIT targeting cardiovascular rather than musculoskeletal endurance, or the relatively short four-week intervention period, insufficient for muscular strength adaptations. Furthermore, the lack of deterioration in 1STS performance suggests that AIT did not compromise lower limb function despite its aerobic focus

Table 3. Between-Group Comparisons at Baseline and Post-Intervention

Outcome	Timepoint	Group A (Mean ± SD)	Group B (Mean ± SD)	t-value	p-value
FSS	Baseline	4.48 ± 1.43	4.55 ± 1.34	-0.180	0.858
FSS	Post	4.41 ± 1.55	2.77 ± 1.37	3.836	<0.001
6MWT (meters)	Baseline	611.13 ± 85.42	584.17 ± 77.88	1.132	0.264
6MWT (meters)	Post	593.74 ± 79.19	646.58 ± 64.13	-2.519	0.015
1STS (reps)	Baseline	16.52 ± 4.42	17.25 ± 3.58	-0.622	0.537
1STS (reps)	Post	16.83 ± 2.99	17.38 ± 3.57	-0.570	0.572

Overall, the data affirm that aerobic interval training significantly improves fatigue and functional walking performance in post-angioplasty patients beyond medication alone. These findings provide compelling evidence to advocate for the inclusion of AIT in early-phase cardiac rehabilitation programs to optimize patient recovery trajectories.

DISCUSSION

The findings of the present study provide robust evidence supporting the integration of Aerobic Interval Training (AIT) into routine rehabilitation protocols for post-angioplasty patients, demonstrating significant improvements in both fatigue severity and functional performance as measured by the Fatigue Severity Scale (FSS) and 6-Minute Walk Test (6MWT), respectively. These results align closely with prior literature indicating that structured exercise interventions, particularly those incorporating high-intensity intervals, produce superior cardiovascular and functional outcomes compared to pharmacological treatment alone (29,30). The significant reduction in fatigue and enhanced aerobic capacity observed in the intervention group reinforces the role of exercise in addressing persistent post-procedural symptoms inadequately managed by medication alone, a limitation noted in earlier cardiac rehabilitation studies (7,9).

The observed improvements in the intervention group are consistent with the theoretical framework suggesting that AIT enhances endothelial function, increases peak oxygen uptake (VO_2 peak), and promotes myocardial efficiency through repeated exposure to brief, high-intensity aerobic stimuli followed by active recovery (11,12). These physiological adaptations not only optimize cardiac output but also improve peripheral oxygen utilization, contributing to reduced perceived exertion and fatigue (31, 32). Furthermore, the psychological benefits associated with structured exercise, including enhanced mood and reduced depressive symptoms, may have additionally influenced the reductions in fatigue severity, as highlighted in previous analyses of exercise interventions in chronic disease populations (33,34). Such multidimensional benefits of AIT suggest that its mechanisms extend beyond physiological conditioning to encompass psychological resilience, thereby offering a comprehensive approach to cardiac recovery.

Comparatively, the magnitude of improvement in 6MWT distances in the present study surpasses the minimal clinically important difference (MCID) thresholds reported in earlier meta-analyses, such as those by Yue et al. (29) and Qin et al. (30), strengthening the clinical relevance of these findings. While several studies have focused predominantly on VO_2 max or biochemical markers of cardiovascular health, the current trial advances the field by employing direct, patient-centered outcome measures of functional endurance and fatigue, which are critically important determinants of real-world quality of life post-angioplasty. Notably, the lack of significant changes in the 1-Minute Sit-to-Stand Test (1STS) suggests that while AIT enhances aerobic capacity, it may not sufficiently target neuromuscular endurance or lower-limb strength within a four-week time frame, an observation similarly reported in other short-duration AIT studies (34,50). This finding underscores the principle of specificity of training and highlights the need for incorporating resistance-based or functional strength exercises if broader functional improvements are desired.

Despite these encouraging results, certain limitations must be acknowledged. The relatively small sample size and single-center nature of the study restricts the generalizability of the findings to broader, more diverse populations. The short intervention duration of four weeks, although demonstrating meaningful improvements, may not fully capture the long-term sustainability of benefits or the delayed onset of certain physiological adaptations. Furthermore, while randomization minimized selection bias, potential confounding variables such as baseline physical activity levels, psychological health, and medication adherence were not formally adjusted for through multivariate analysis. Future studies with larger, multicentric cohorts, longer follow-up periods, and stratified randomization accounting for such confounders are warranted to validate and extend these findings.

The methodology employed—blinded outcome assessment, use of validated clinical tools (FSS, 6MWT, 1STS), and standardized intervention protocols—represents significant strengths of the study, enhancing internal validity and reproducibility. Moreover, by directly targeting a critical yet under-addressed domain of post-angioplasty recovery, namely fatigue, the study fills a notable gap in the existing literature and provides actionable

insights for clinical practice. Clinicians are thus encouraged to integrate structured, progressive AIT protocols into early-phase cardiac rehabilitation programs to maximize functional recovery and patient-reported outcomes.

Building upon the current findings, future research should explore the synergistic effects of combining AIT with resistance training to target both cardiovascular and musculoskeletal domains comprehensively. Investigations into the biochemical correlates of fatigue reduction, such as inflammatory cytokine modulation and mitochondrial function improvements, could further elucidate the mechanistic underpinnings of AIT's benefits (35). Additionally, qualitative studies capturing patient experiences, adherence factors, and perceived barriers could inform the design of patient-centered rehabilitation programs that optimize engagement and long-term maintenance. Finally, evaluating cost-effectiveness and scalability of AIT interventions, particularly in resource-constrained settings, would be crucial for informing health policy and broadening the impact of cardiac rehabilitation initiatives.

In conclusion, this study substantiates the role of Aerobic Interval Training as a potent adjunct to pharmacological therapy in improving fatigue and aerobic performance among post-angioplasty patients. By addressing functional limitations that persist despite optimal medical management, AIT offers a promising, scalable strategy for enhancing recovery and quality of life, underscoring the need for its broader adoption in clinical rehabilitation frameworks.

CONCLUSION

This randomized controlled trial demonstrated that the addition of Aerobic Interval Training (AIT) to standard pharmacological therapy significantly reduced fatigue severity and improved functional performance, as measured by the Fatigue Severity Scale and 6-Minute Walk Test, in post-angioplasty patients compared to medication alone. These findings directly align with the study objective and affirm the clinical utility of integrating AIT into cardiac rehabilitation programs to enhance recovery and functional outcomes following percutaneous coronary interventions. By addressing persistent fatigue and impaired aerobic capacity—key challenges in post-angioplasty care—AIT offers a valuable adjunctive strategy for optimizing patient-centered rehabilitation and improving quality of life. Clinically, this supports the incorporation of structured, supervised AIT protocols into standard post-angioplasty management, while future research should focus on long-term outcomes, scalability, and integration with multimodal rehabilitation approaches to further advance cardiac care.

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