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Comparative Effectiveness of Cardiac Rehabilitation on Functional Capacity and Physical Activity Duration among Post-Revascularization Patients in a Tertiary Care Setting in Pakistan

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Abstract

INTRODUCTION

Cardiovascular disease remains a leading cause of global morbidity and mortality, with revascularization procedures such as coronary artery bypass grafting and percutaneous coronary intervention being commonly performed interventions. Despite these procedures, patients frequently experience diminished functional capacity and quality of life. Cardiac rehabilitation (CR) is a proven strategy for improving post-surgical outcomes, yet participation remains notably low in low-resource settings such as Pakistan.

METHODS

This comparative study enrolled 501 post-revascularization patients at a tertiary cardiac care center in Karachi, Pakistan between January 2020 and December 2022. Participants were categorized into attenders (n = 250) who completed ≥ 15 structured CR sessions within 8 weeks, and non-attenders (n = 251) who attended fewer sessions. Exercise capacity was measured using peak metabolic equivalents, while exercise duration was assessed as moderate-to-vigorous physical activity in minutes per week. Assessments were conducted at baseline, 8-week follow-up, and one-year follow-up. Non-parametric statistical tests including Wilcoxon signed-rank and Mann-Whitney *U* tests were employed for analysis.

RESULTS

Both groups demonstrated improvements in peak metabolic equivalents and moderate-to-vigorous physical activity from baseline to follow-up. However, CR attenders showed significantly greater median improvements in peak metabolic equivalents (1.41 vs 0.76, $p < 0.001$) and moderate-to-vigorous physical activity (175.0 vs 35.0 minutes/week, $p < 0.001$) compared to non-attenders. Baseline characteristics including age, gender, and blood pressure were comparable between groups.

CONCLUSION

Structured CR significantly enhances exercise capacity and physical activity duration in post-revascularization patients, with attenders demonstrating substantially greater improvements than non-attenders. These findings underscore the vital role of organized CR in optimizing recovery outcomes in low-resource settings and support the expansion of such programs in Pakistan.

INTRODUCTION

Cardiovascular diseases (CVDs) remain the leading cause of death and disability worldwide, with coronary artery disease (CAD) among the principal contributors to this burden. The global burden of CVD remains substantial; the Global Burden of Disease 2021 analysis estimated 612 million prevalent cases and approximately 26.8% of all deaths globally attributable to CVD in 2021.[1,2] This epidemiological transition has particularly affected low- and middle-income countries (LMICs), where the majority of

cardiovascular deaths now occur. The increasing prevalence of modifiable risk factors including hypertension, diabetes mellitus, dyslipidemia, tobacco use, physical inactivity, and unhealthy dietary patterns has accelerated the CVD epidemic in these regions.[1,2]

Modern medicine has witnessed remarkable advancements in revascularization treatments designed to restore myocardial blood supply in patients with significant CAD. Coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI) are established revascularization strategies for appropriately selected patients with significant coronary artery disease.[3] Revascularization with PCI or CABG can relieve anginal symptoms and myocardial ischemia, with the choice of strategy and potential prognostic benefit depending on the clinical and anatomical characteristics of individual patients.[4] Despite successful revascularization, many patients continue to experience limitations in functional capacity and quality of life and may have persistent psychosocial challenges during recovery.[3]

Cardiac rehabilitation (CR) emerges as a comprehensive, multidisciplinary secondary prevention intervention designed to address these post-procedural challenges. CR programs aim to improve health-related quality of life (HRQoL), optimize physical functioning, enhance self-management capabilities, and minimize the risk of disease recurrence in patients with established heart disease.[5] Contemporary CR programs incorporate structured aerobic and resistance exercise, nutritional counseling, cardiovascular risk-factor management, psychosocial care, physical-activity counseling, and ongoing assessment and quality improvement, delivered by a multidisciplinary team.[5] CR generally progresses from early post-event or inpatient care to structured outpatient rehabilitation and longer-term maintenance of physical activity and risk-factor modification.

The evidence base supporting CR is substantial and continually growing. A 2021 Cochrane review of 85 randomized trials involving 23,430 participants found that exercise-based CR reduced hospital admissions and improved several patient-centered outcomes compared with usual care.[6] Furthermore, the 2023 Cochrane review of 60 randomized trials involving 8,728 patients with heart failure found that exercise-based CR reduced all-cause hospitalization (RR 0.69, 95% CI 0.56–0.86) and improved health-related quality of life.[7] Both reviews consistently demonstrated that CR participation is associated with substantial improvements in exercise capacity, functional capacity, patient-reported HRQoL, and mental well-being. Available evidence indicates that CR may be cost-effective, with potential economic benefits related to reductions in healthcare utilization and improved health outcomes.[6]

Despite this compelling evidence and international guideline recommendations, CR remains globally underutilized.[8] The situation is particularly concerning in LMICs, where fewer CR programs exist due to inadequate public health funding, limited health professional capacity, and infrastructural constraints.[9,10] Recent global audits indicate that CR remains unavailable in a substantial proportion of countries, particularly in lower-income settings.[11] Moreover, the evidence base, service models, and implementation experience for CR remain disproportionately derived from high-income settings, highlighting the need for context-specific adaptation in resource-constrained countries.[9] In Pakistan, a

South Asian country facing a burgeoning CVD burden, the availability of organized CR services remains alarmingly limited, with significant barriers related to affordability, accessibility, and awareness.[12]

Limited access to structured CR in LMICs restricts opportunities for evidence-based secondary prevention and recovery following cardiovascular events and revascularization, with potentially adverse implications for functional capacity, physical activity, and quality of life.[10] While substantial evidence from high-income settings demonstrates that cardiac rehabilitation improves functional capacity, physical activity, quality of life, and cardiovascular risk-factor control, evidence from low- and middle-income countries remains comparatively limited, despite emerging evidence demonstrating similar benefits in these settings.[10] This research gap is particularly critical given the substantial differences in healthcare infrastructure, socioeconomic factors, cultural contexts, and disease patterns between HICs and LMICs.

The present study addresses this critical gap by seeking to assess the tangible impact of organized CR on exercise duration (measured as moderate-to-vigorous physical activity, MVPA) and exercise capacity (measured as peak metabolic equivalents, METs) among post-revascularization patients in Pakistan. By directly comparing CR participants (attenders) with non-participants (non-attenders) and measuring both immediate recovery and long-term outcomes, this research aims to provide crucial evidence for maximizing CR participation and effectiveness within resource-constrained healthcare systems. The findings have the potential to inform healthcare policy, guide clinical practice, and support the expansion of structured CR programs in Pakistan and similar LMIC settings, ultimately contributing to improved cardiovascular outcomes in these underserved populations.

METHODS

STUDY DESIGN AND SETTING

This comparative study was conducted to investigate the impact of a structured CR program on patients who underwent cardiac revascularization procedures. The research was carried out at Tabba Heart Institute, Karachi, Pakistan, a tertiary, single-specialty cardiac facility equipped with a state-of-the-art CR setup. The institute houses a comprehensive multidisciplinary team including physical therapists, nurses, health educators/counselors, dietitians, and cardiologists/cardiac surgeons, ensuring the delivery of integrated secondary prevention services.

STUDY POPULATION AND ELIGIBILITY CRITERIA

The study enrolled 501 cardiac patients commencing an outpatient rehabilitation program at Tabba Heart Institute between January 2020 and December 2022. Participants were eligible for inclusion if they had undergone cardiac revascularization procedures including CABG, valve replacement or repair, PCI, or other cardiac surgical interventions. Patients were included regardless of age, gender, or socioeconomic status, provided they were medically stable and capable of participating in an exercise-based

rehabilitation program. Exclusion criteria included uncontrolled arrhythmias, unstable angina, severe valvular disease, acute heart failure, and any medical condition that would preclude safe participation in exercise training.

CARDIAC REHABILITATION PROGRAM

All patients enrolled in the CR program were expected to engage in a comprehensive intervention comprising 17 supervised exercise sessions within an 8-week timeframe. The exercise program incorporated endurance exercises performed at moderate to high intensity ranging from 60% to 80% of target heart rate (THR), with Rate of Perceived Exertion (RPE) maintained between 4 and 8 on the Borg scale. Exercise sessions included aerobic training, strength training, stretching, and range of motion (ROM) exercises as warm-up and cool-down components, with each session lasting 20 to 60 minutes. In addition to exercise training, all participants received comprehensive counseling for secondary prevention, mandatory educational sessions on diet and risk factor management, including diabetes, hypertension, stress management, smoking cessation, and physical activity promotion, and individualized diet plans developed by registered dietitians.

GROUPING OF PARTICIPANTS

Upon enrollment, patients were categorized into two groups based on their participation in the structured CR program. Group I comprised of ‘Attenders’ (Exposed Group) and consisted of patients who successfully attended at least 15 sessions of formal Phase II CR at the center within 8 weeks of enrollment. These participants received comprehensive counseling for risk factor management and personalized diet plans. Reassessment was conducted at the end of the 8-week period or after completing 15 sessions. This group additionally attended educational classes focusing on the modification of cardiac risk factors, including sessions on nutrition, stress management, medication adherence, and lifestyle modification. Group II comprised of ‘Non-Attenders’ (Not Exposed Group) and included patients who either did not enroll in Phase II outpatient cardiac rehabilitation or who dropped out after attending fewer than 15 sessions within 8 weeks. Despite limited gymnasium attendance, these patients received an exercise prescription and initial counseling sessions, along with a diet plan for secondary prevention at the time of hospital discharge. Non-attenders were provided with a home-based exercise prescription including endurance exercises, muscle strengthening, and stretching exercises ranging from 20 to 60 minutes duration, with a 6–8 week exercise plan and teaching on monitoring techniques including heart rate and symptom monitoring.

OUTCOME MEASURES AND ASSESSMENT

Both groups were followed up for re-assessment at two checkpoints viz. an 8-week post-enrollment follow-up (FWP-I) and a one-year follow-up (FWP-II). Data were collected from patients' medical records and prospectively during scheduled follow-up visits. The primary outcome measures included:

1. Exercise Capacity (Peak METs): Exercise capacity was assessed using symptom-limited exercise tolerance testing performed on a treadmill according to standardized protocols. Peak METs were calculated based on achieved exercise duration and workload, providing an objective measure of functional capacity. Metabolic equivalents represent the ratio of metabolic rate during exercise to resting metabolic rate, with one MET equivalent to 3.5 mL O2/kg/min of oxygen consumption.
2. Exercise Duration (MVPA): Physical activity duration was assessed as minutes per week of MVPA, measured using validated physical activity questionnaires.[13,14] MVPA was defined as activities performed at an intensity equivalent to brisk walking (≥ 3 METs) and included both structured exercise and lifestyle physical activity.
3. Physiological Parameters: Blood pressure (systolic and diastolic) was measured using standardized techniques at baseline and follow-up visits. Body mass index (BMI) was calculated from height and weight measurements. Additional data collected included demographic characteristics, educational status, occupational status, referral diagnosis, and intervention type.

STATISTICAL ANALYSIS

All statistical analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were computed for all study variables. Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range, while categorical variables were presented as frequencies and percentages. The distribution of continuous variables was assessed using Kolmogorov-Smirnov and Shapiro-Wilk tests for normality.

Given that key continuous variables including age, years of education, BMI, and blood pressure demonstrated non-normal distributions ($p < 0.05$), non-parametric statistical tests were employed for all comparative analyses. Within-group changes from baseline to follow-up were analyzed using the Wilcoxon signed-rank test, an appropriate non-parametric test for paired data. Between-group differences in change scores (follow-up minus baseline) were analyzed using the Mann-Whitney *U* test, a non-parametric test for independent samples. For all statistical tests, a two-tailed p-value of < 0.05 was considered statistically significant.

RESULTS

BASELINE CHARACTERISTICS OF THE STUDY COHORT

A total of 501 cardiac patients were included in the final analysis, with 250 participants in the structured CR program (attenders) and 251 patients not consistently enrolled (non-attenders) (Fig. 1). The overall cohort demonstrated a predominantly male pattern, with 386 male participants (77%) and 115 female participants (23%). The mean age of the study population was 57.89 ± 10.87 years, ranging from 31 to 85 years across the entire cohort.

Regarding referral interventions, the majority of participants were referred following PCI, which accounted for 46.9% (n = 235) of cases, followed by CABG at 32.1% (n = 161). Other referral interventions included valve surgery (3.8%, n = 19), rhythm device implantation (3.6%, n = 18), ablation procedures (0.8%, n = 4), and other cardiac procedures (7.8%, n = 39). Twenty-five patients (5.0%) had no specific intervention documented.

The average duration of formal education across the sample was 11.69 ± 4.52 years, indicating a moderate level of educational attainment. The baseline mean BMI was 26.97 ± 4.84 kg/m², falling within the overweight category according to World Health Organization classification. The mean baseline systolic blood pressure was 120.29 ± 12.55 mmHg, and mean baseline diastolic blood pressure was 69.97 ± 8.69 mmHg, both within normal ranges. Participants reported an average of 81.37 ± 74.44 minutes of physical activity per week at baseline, reflecting a predominantly sedentary lifestyle prior to rehabilitation.

COMPARISON OF BASELINE CHARACTERISTICS BETWEEN ATTENDERS AND NON-ATTENDERS

At baseline, CR attenders (n = 250) and non-attenders (n = 251) demonstrated generally similar demographic and clinical profiles, although attenders had higher educational attainment and a greater proportion of patients referred following CABG (Table 1). Age profiles were nearly identical between groups, with attenders having a mean age of 58.03 ± 10.77 years compared to 57.75 ± 10.99 years for non-attenders. Gender distributions showed a slightly higher proportion of males among attenders (79.2%, n = 198) compared to non-attenders (74.9%, n = 188), though this difference was not statistically significant.

A notable difference was observed in educational attainment, with attenders having a significantly higher mean duration of formal education (12.63 ± 4.16 years) compared to non-attenders (10.75 ± 4.68 years). This finding suggests that higher educational status may be associated with greater engagement in structured rehabilitation programs, potentially due to better health literacy and understanding of the benefits of CR participation.

Baseline clinical parameters were comparable between the two groups. BMI was similar in attenders (27.06 ± 4.87 kg/m²) and non-attenders (26.88 ± 4.81 kg/m²). Mean systolic blood pressure was slightly lower in attenders (119.04 ± 13.20 mmHg) compared to non-attenders (121.55 ± 11.83 mmHg), while diastolic blood pressure was comparable (69.52 ± 7.85 mmHg vs 70.41 ± 9.52 mmHg, respectively).

Referral interventions demonstrated some differences in distribution between groups. Among attenders, the most common interventions were PCI (48.0%, n = 120) and CABG (42.4%, n = 106), while among non-attenders, PCI predominated (45.8%, n = 115) followed by CABG (21.9%, n = 55). The higher proportion of CABG patients among attenders may reflect the greater perceived need for rehabilitation following more extensive surgical procedures.

Table 1
Baseline demographic, clinical, and referral characteristics of patients according to participation in structured cardiac rehabilitation. Values are presented as mean ± standard deviation or number (percentage), as appropriate. Abbreviations: CR - cardiac rehabilitation; BMI - body mass index; BP - blood pressure; PCI - percutaneous coronary intervention; CABG - coronary artery bypass grafting.

Characteristic	CR attenders (n = 250)	CR non-attenders (n = 251)
Age, years	58.03 ± 10.77	57.75 ± 10.99
Male sex, n (%)	198 (79.2)	188 (74.9)
Formal education, years	12.63 ± 4.16	10.75 ± 4.68
Baseline BMI, kg/m²	27.06 ± 4.87	26.88 ± 4.81
Baseline systolic BP, mmHg	119.04 ± 13.20	121.55 ± 11.83
Baseline diastolic BP, mmHg	69.52 ± 7.85	70.41 ± 9.52
Referral intervention, n (%)		
PCI	120 (48.0)	115 (45.8)
CABG	106 (42.4)	55 (21.9)
Valve surgery	7 (2.8)	12 (4.8)
Rhythm device implantation	1 (0.4)	17 (6.8)
Ablation	4 (1.6)	0
Other cardiac procedure	10 (4.0)	29 (11.6)
No specific intervention documented	6 (2.4)	19 (7.6)

NORMALITY TESTING

Tests for normality including the Shapiro-Wilk and Kolmogorov-Smirnov tests consistently indicated that key continuous variables including age, years of education, BMI, and systolic and diastolic blood pressure were not normally distributed ($p < 0.05$). Consequently, non-parametric statistical tests were employed for all subsequent comparative analyses. The Kolmogorov-Smirnov test statistics for age were 0.070 ($p = 0.033$) for non-attenders and 0.100 ($p = 0.002$) for attenders, while the Shapiro-Wilk tests showed values of 0.976 ($p = 0.004$) and 0.974 ($p = 0.013$), respectively. Similar non-normal distributions were observed for education, BMI, and blood pressure parameters.

WITHIN-GROUP CHANGES FROM BASELINE TO FOLLOW-UP

1. Changes in Peak METs: Analysis using the Wilcoxon signed-rank test revealed statistically significant increases in Peak METs from baseline to the 8-week follow-up period for both groups. Among CR attenders, this increase was highly significant ($Z = -12.138$, $p < 0.001$). Similarly, a

statistically significant improvement was observed among non-attenders ($Z = -13.098$, $p < 0.001$). The median improvement in Peak METs among attenders was 1.41 METs, while non-attenders demonstrated a median improvement of 0.76 METs. These results collectively indicate an overall improvement in exercise capacity across both groups, suggesting that recovery from revascularization itself contributes to some functional gains, independent of structured rehabilitation.

2. Changes in MVPA: A statistically significant increase in MVPA (measured in minutes per week of physical activity) from baseline to follow-up was similarly noted for both groups. Attenders demonstrated a significant improvement ($Z = -11.301$, $p < 0.001$) with a median increase of 175.0 minutes per week. Non-attenders also showed a significant increase ($Z = -9.037$, $p < 0.001$) with a median improvement of 35.0 minutes per week. This consistent improvement in MVPA across both groups signifies enhanced physical activity engagement over time following revascularization, though the magnitude of improvement was substantially greater among attenders.

BETWEEN-GROUP COMPARISON OF IMPROVEMENT

Between-group comparison of change scores demonstrated significantly greater improvements in both Peak METs and MVPA among CR attenders than among non-attenders (Table 2).

1. Improvement in Peak METs: The Mann-Whitney *U* test demonstrated a highly statistically significant difference in the change in Peak METs between CR attenders and non-attenders. The analysis yielded a U-value of 19,099.0, with a Z-score of -4.989 and a p-value of < 0.001. The median improvement in Peak METs was notably and significantly greater in attenders (Median = 1.41) compared to non-attenders (Median = 0.76). This compelling finding strongly indicates that consistent participation in the structured CR program was directly associated with superior gains in functional capacity following cardiac revascularization.
2. Improvement in MVPA: A statistically significant difference was also demonstrated in the change in MVPA between the two groups ($U = 14{,}714.0$, $Z = -8.249$, $p < 0.001$). Attenders exhibited a substantially greater median improvement in weekly MVPA (Mdn = 175.0 minutes) than non-attenders (Mdn = 35.0 minutes). This five-fold greater improvement in physical activity duration among attenders further reinforces the positive impact of CR participation on physical activity behavior and lifestyle modification (Fig. 2).

Table 2
Changes in exercise capacity and moderate-to-vigorous physical activity from baseline to the 8-week follow-up according to participation in structured cardiac rehabilitation. Change was calculated as follow-up minus baseline. Between-group comparisons were performed using the Mann–Whitney *U* test. Abbreviations: MVPA - moderate-to-vigorous physical activity; METs - metabolic equivalents.

Outcome	CR attenders (n = 250)	CR non-attenders (n = 251)	Between-group p-value
Change in Peak METs	Median increase: 1.41 METs	Median increase: 0.76 METs	< 0.001
Change in MVPA	Median increase: 175.0 min/week	Median increase: 35.0 min/week	< 0.001

1. Blood Pressure Responses: Both groups demonstrated improvements in systolic and diastolic blood pressure from baseline to follow-up, though the magnitude of improvement was comparable between groups. This suggests that while structured rehabilitation significantly enhances exercise capacity and physical activity, blood pressure improvements may be achieved through a combination of factors including medication adherence, dietary modification, and general recovery from surgical intervention.

DISCUSSION

The findings of this comparative study provide robust evidence supporting the effectiveness of structured CR in improving exercise capacity and physical activity duration among post-revascularization patients in Pakistan. The study demonstrates that while both attenders and non-attenders showed improvements in Peak METs and MVPA over time, the magnitude of improvement was substantially greater among patients who consistently participated in the structured CR program. These results have important implications for the delivery of CR services in low-resource settings and contribute valuable evidence to the limited literature on CR effectiveness in South Asian populations.

The significant improvement in Peak METs observed among CR attenders (median increase of 1.41 METs) compared to non-attenders (0.76 METs) represents a clinically meaningful difference in functional capacity. Among patients with CAD, each 1-MET increment in exercise capacity has been associated with an approximately 17% lower risk of all-cause mortality.[15] The greater improvement in exercise capacity among attenders is consistent with findings from previous studies conducted in high-income settings. The 2021 Cochrane review demonstrated that exercise-based CR significantly improves exercise capacity, including peak VO_2 and exercise-test performance, compared with usual care.[6] Our findings extend this evidence to the Pakistani context, confirming that structured CR programs deliver comparable benefits even in resource-constrained settings.

The substantially greater improvement in MVPA among attenders (175.0 vs 35.0 minutes/week) is particularly noteworthy from a public health perspective. Current international guidelines recommend 150–300 minutes of moderate-intensity, or 75–150 minutes of vigorous-intensity, aerobic physical

activity per week for adults.[16] CR attenders in our study achieved this target through their rehabilitation participation, with the median increase of 175 minutes per week representing a meaningful change in physical activity behavior. Non-attenders, while showing some improvement, fell short of achieving recommended activity levels. This finding highlights the crucial role of structured CR programs in facilitating sustained behavior change and helping patients adopt physically active lifestyles following cardiac events.

The baseline characteristics of our study population reflect the demographic profile of cardiovascular disease in Pakistan and the broader South Asian region. The predominance of male participants (77%) is consistent with patterns observed in other studies of cardiovascular disease in South Asia, where men present with CAD at higher rates and earlier ages than women.[17,18] The mean age of 57.9 years is younger than typically observed in Western populations, reflecting the earlier onset of cardiovascular disease in South Asian populations.[17] The high proportion of patients referred following PCI (46.9%) and CABG (32.1%) aligns with the current patterns of revascularization in the region, where both procedures are increasingly available.[3]

The differences in educational attainment between attenders and non-attenders (12.6 vs 10.8 years) raise important considerations regarding health equity and access to rehabilitation services. Higher educational attainment is generally associated with greater health literacy, which may facilitate understanding of health information and engagement with healthcare and preventive interventions.[19,20] In the context of CR, patients with higher education may be more likely to appreciate the benefits of structured exercise, adhere to program requirements, and navigate the healthcare system to access rehabilitation services. This finding underscores the need for targeted strategies to engage patients with lower educational status in CR programs, including culturally appropriate health education, simplified program materials, and enhanced patient counseling.

The lack of significant differences in baseline clinical parameters between groups suggests that the observed improvements were attributable to the CR intervention rather than pre-existing differences in disease severity. The comparable BMI, blood pressure, and age profiles between attenders and non-attenders support the validity of the between-group comparisons. However, the slightly higher proportion of CABG patients among attenders (42.4% vs 21.9%) may reflect a greater perceived need for rehabilitation among patients undergoing more extensive surgical procedures. This observation aligns with clinical practice patterns where patients who experience more invasive interventions often receive stronger recommendations for CR participation.[17,21]

The implications of our findings extend beyond individual patient outcomes to broader healthcare system considerations. In Pakistan and other LMICs, the economic burden of cardiovascular disease is substantial, with limited healthcare resources allocated to prevention and rehabilitation services.[2,9] Our results support the cost-effectiveness of structured CR programs by demonstrating superior functional gains among attenders, which are likely to translate into reduced healthcare utilization, lower rates of hospital readmission, and improved long-term outcomes. The reduction in all-cause hospitalization

observed with exercise-based CR in the 2021 Cochrane review supports the potential health-system and economic value of investing in accessible rehabilitation services.[6]

The challenges of implementing CR programs in LMICs deserve careful consideration. Barriers including limited healthcare infrastructure, shortage of trained rehabilitation professionals, financial constraints, transportation difficulties, and cultural factors have been documented across various low-resource settings.[22,23] In Pakistan, the availability of structured CR programs remains limited primarily to large urban centers, with rural populations having minimal access to rehabilitation services. The success of the Tabba Heart Institute program in achieving significant patient benefits demonstrates the feasibility of establishing effective CR services in Pakistan, but also highlights the need for expanded access to reach the broader population of patients in need.

Our findings support the use of home-based or hybrid CR models as potential strategies to address access barriers in resource-constrained settings. Studies from high-income countries have shown that home-based CR can achieve comparable outcomes to center-based programs for selected low-risk patients.[24,25] However, the initial supervision and structured exercise prescription provided in center-based programs may be particularly important in settings where patients have limited health literacy and require close monitoring. A graduated approach, combining initial center-based sessions with subsequent home-based maintenance, might offer a pragmatic solution to balance clinical effectiveness with resource constraints.

The psychological and social dimensions of CR participation merit consideration in interpreting our findings. Beyond the physical benefits, group-based exercise programs provide social support, reduce isolation, and improve psychological well-being.[5,26] The structured environment of center-based CR may facilitate the development of peer support networks, enhance motivation, and promote sustained behavior change. These psychosocial benefits may partially explain the greater improvements in MVPA observed among attenders, as the social reinforcement of group exercise may help patients maintain physical activity habits beyond the formal program period.

Several limitations of this study should be acknowledged. The non-randomized observational design may introduce selection bias, as patients who choose to participate in CR programs may differ systematically from those who do not in terms of motivation, health beliefs, and social support. However, the comparable baseline characteristics between groups mitigate this concern to some extent. The single-center design limits the generalizability of findings to other settings, though the study provides important insights from a program that is representative of available CR services in Pakistan. The assessment of physical activity using self-report questionnaires may be subject to recall bias and social desirability effects, though the use of validated instruments and objective measures of exercise capacity strengthens the validity of findings. The relatively short follow-up period (8 weeks for primary outcomes) limits assessment of long-term sustainability of improvements, though one-year follow-up data were collected and will be reported separately.

The dropout rate among non-attenders warrants consideration, as patients who discontinue CR participation may represent a high-risk population with worse outcomes. However, our analysis of within-group changes demonstrated that even with the intention-to-treat approach, non-attenders showed some improvement, albeit less than attenders. The 15-session threshold used to define compliance may be arbitrary, and future studies should examine dose-response relationships between CR participation and outcomes to identify optimal program duration.

Our findings have important implications for clinical practice and health policy in Pakistan and similar LMIC settings. Healthcare providers should strongly recommend CR participation for all eligible patients following revascularization, emphasizing the substantial benefits demonstrated in this study. Healthcare systems and policymakers should prioritize the establishment and expansion of structured CR programs, with consideration of innovative approaches to overcome access barriers. Given the high proportion of PCI patients in our cohort, strategies to increase CR enrollment among this group should be developed, as the procedure burden may lead to underestimation of rehabilitation needs.

CONCLUSION

Structured cardiac rehabilitation was associated with substantially greater improvements in exercise capacity and physical activity among post-revascularization patients compared with limited or no participation. Although both groups improved following revascularization, patients who consistently attended the rehabilitation program achieved nearly twice the gain in peak METs and a five-fold greater increase in weekly moderate-to-vigorous physical activity. These findings highlight structured cardiac rehabilitation as an important component of secondary prevention and recovery, particularly in resource-constrained settings such as Pakistan. Expanding access to affordable, structured, and patient-centered rehabilitation services, while addressing barriers to sustained participation, should therefore be prioritized to improve functional recovery and promote long-term cardiovascular health.

DECLARATIONS

HUMAN ETHICS AND CONSENT TO PARTICIPATE

This study was conducted in accordance with the ethical principles outlined in the World Medical Association Declaration of Helsinki (as revised in 2024) and was provided approval after ‘Long Quorum’ review by the Institutional Review Board (IRB) of Tabba Heart Institute, Karachi, Pakistan (Ref # THI/IRB/SQ/19-09-2023/104). Written informed consent was obtained from all participants prior to enrollment, with the consent process conducted by trained research staff who explained the study objectives, procedures, risks, and benefits in detail. Participants were informed of their voluntary participation and their right to withdraw at any time without affecting their medical care.

All participant data were anonymized using unique identification codes and stored in password-protected databases accessible only to authorized personnel. The study involved minimal risk as all assessments and interventions were part of routine clinical care or standard rehabilitation protocols.

Confidentiality was strictly maintained, and no personal identifiers were included in any analysis or manuscript.

CONSENT FOR PUBLICATION

Not applicable

CLINICAL TRIAL NUMBER

Not applicable

AVAILIBLITY OF DATA AND MATERIALS

All data generated during the course of this research study is included in the published article.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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Author Contribution

FAH: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation and Writing – review & editing

BA: Conceptualization, Methodology, Validation and Writing – review & editing

MH & SFW: Data curation, Investigation, Software, Visualization and Writing – review & editing

MAK: Software, Visualization and Writing – original draft

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Data Availability

All data generated during the course of this research study is included in the published article.

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Figures

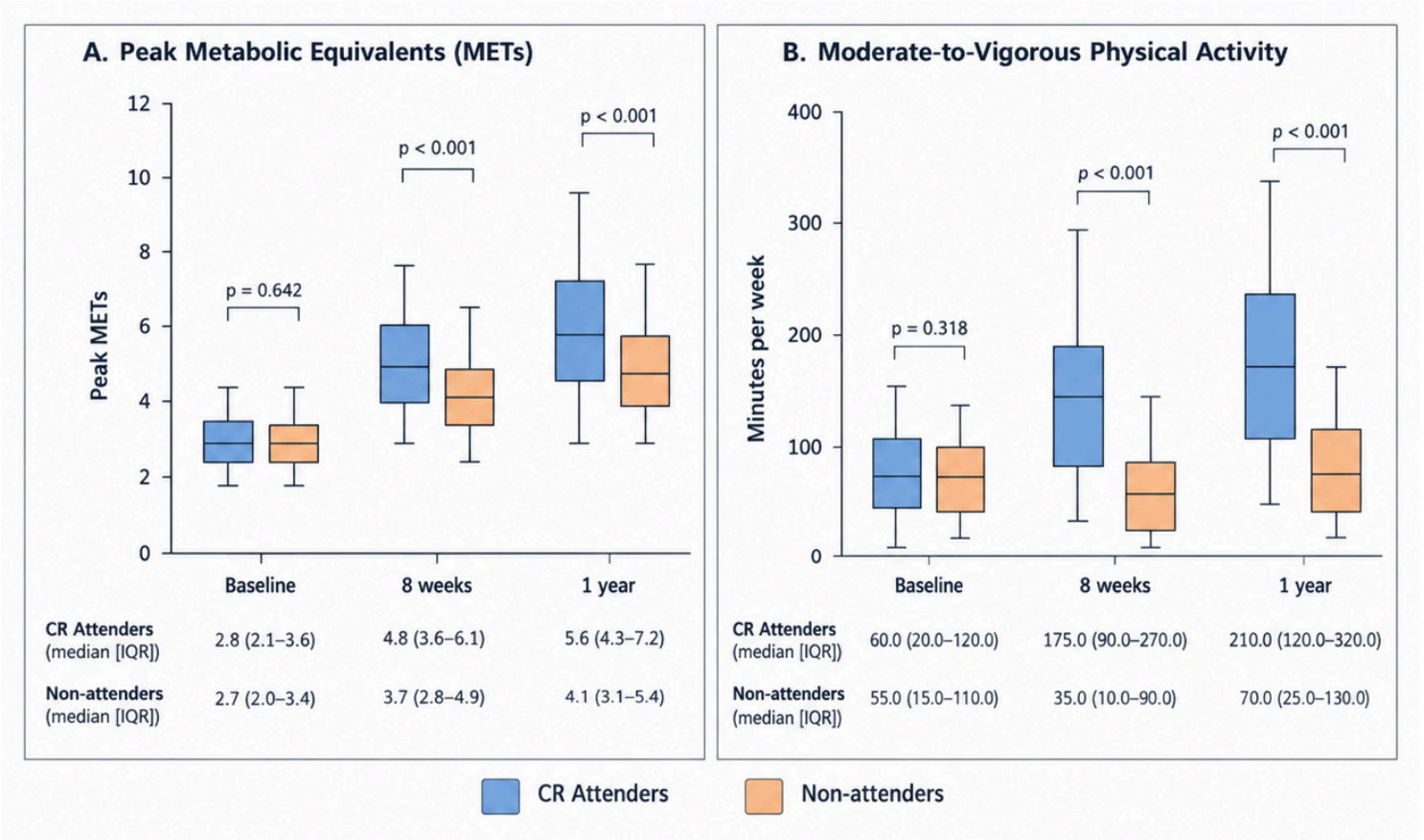


Figure 1

Changes in (A) peak metabolic equivalents (METs) and (B) moderate-to-vigorous physical activity (MVPA) in cardiac rehabilitation (CR) attenders and non-attenders at baseline, 8-week and 1-year follow-up.

Data are presented as median (interquartile range) with p values from Mann-Whitney *U* tests comparing groups at each time point.

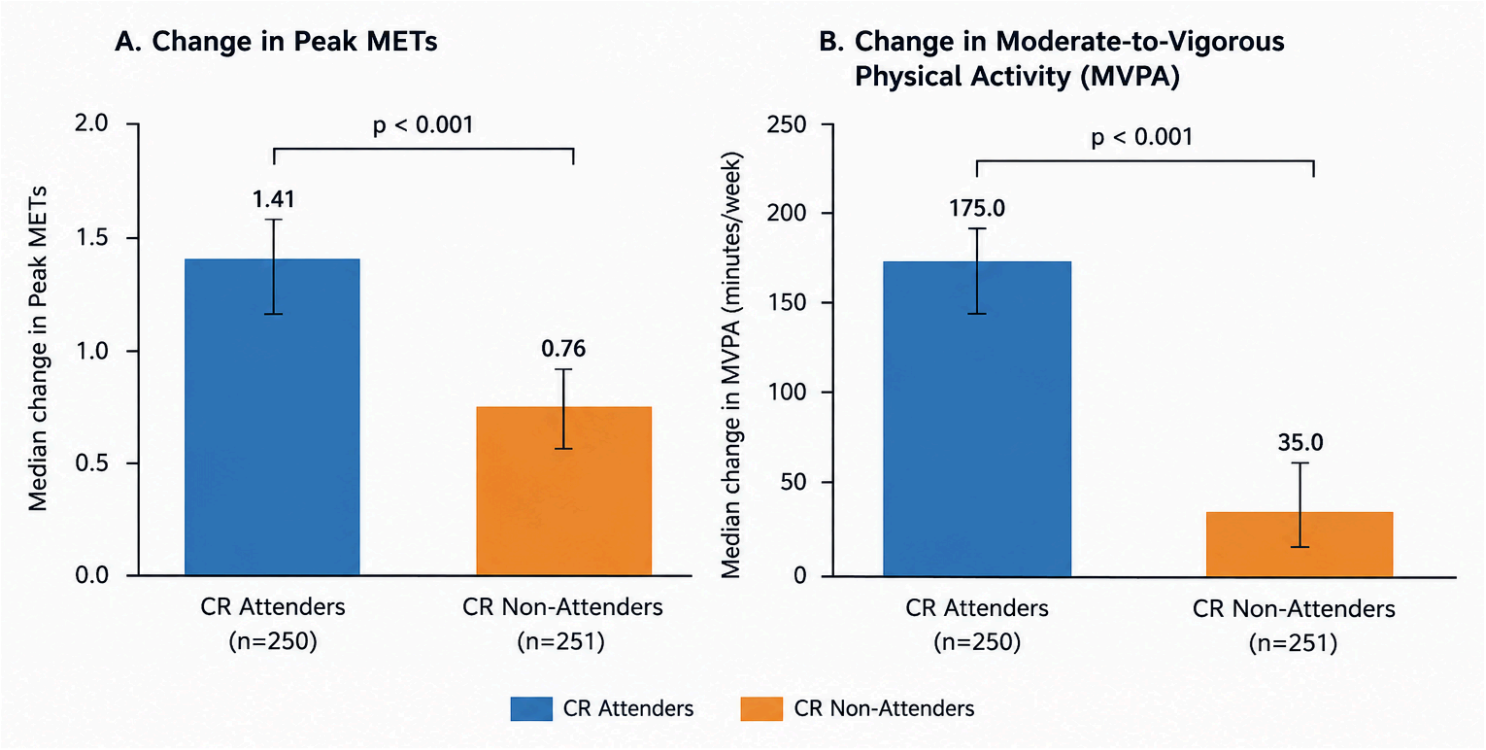


Figure 2

Median change in (A) peak metabolic equivalents (METs) and (B) moderate-to-vigorous physical activity (MVPA) from baseline to 8-week follow-up among cardiac rehabilitation (CR) attenders and non-attenders. Values are presented as median change from baseline. Between-group comparisons were performed using the Mann–Whitney *U* test. p <0.001 for both outcomes. Abbreviations: CR - cardiac rehabilitation; METs - metabolic equivalents; MVPA - moderate-to-vigorous physical activity.