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Effects of Respiratory Muscle Training Integrated Rehabilitation on Post-Operative Recovery after Cardiac Surgery

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ABSTRACT

Background: Cardiac surgery commonly leads to reduced lung capacity, weak respiratory muscles, and limited mobility during the early post-operative period. In Pakistan, structured cardiac rehabilitation is not routinely practiced, and Respiratory Muscle Training is rarely included as part of standard physiotherapy. Considering limited resources and the high burden of post-operative complications, there is a need to assess simple, low-cost interventions that can support faster recovery in local cardiac care units. **Objective:** To evaluate the effect of integrating respiratory muscle training into a structured rehabilitation program on post-operative recovery among cardiac surgery patients in Pakistan. **Methodology:** This quasi-experimental study was conducted at Punjab Institute of Cardiology, Lahore, Pakistan, from August to November 2024. A total of 60 post-operative cardiac surgery patients were recruited through non-probability consecutive sampling and allocated into an intervention group (n=30) and a control group (n=30). The intervention group received respiratory muscle training-integrated rehabilitation, including incentive spirometry, diaphragmatic breathing, inspiratory muscle training using a threshold device, early mobilization, and graded functional activity for 7 consecutive days. The control group received routine post-operative physiotherapy. Lung function tests, inspiratory muscle strength, and functional capacity were recorded on days 1 and 7. Vital signs were monitored during sessions, and any adverse event was recorded. Data were analysed using SPSS version 26, with $p < 0.05$ considered significant. Paired t-tests were used to compare pre- and post-intervention results within each group, while independent t-tests compared changes between groups. **Results:** The intervention group showed significantly greater improvement in lung function tests, inspiratory muscle strength, and 6-minute walk test distance ($p<0.01$) compared to the control group. Reduced pulmonary complications and a shorter hospital stay were also observed. **Conclusion:** Respiratory muscle training - integrated rehabilitation is a feasible, low-cost, and effective approach to enhance early post-operative recovery after cardiac surgery in Pakistan, and should be incorporated into routine physiotherapy practice.

Keywords: Cardiac rehabilitation, Cardiac surgery, Post-operative recovery, Pulmonary function, Respiratory muscle training

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INTRODUCTION

Globally, the impact of cardiovascular disease on morbidity and mortality remains significant, and the value of cardiac surgery, which includes procedures such as coronary artery bypass grafting and valve repair or replacement, will continue as a mainstay for patients suffering serious heart disease.[1] In the last 10 years, Pakistan's demand for cardiac surgeries has increased, and this is a result of a burgeoning prevalence of hypertension, diabetes, dyslipidemia, cardiovascular disease, and undiagnosed physical inactivity.[2] The early post-operative period remains fundamentally challenging despite remarkable refinements in surgical methods and peri-operative care. It is particularly the physiological and functional impairments post-surgery that delay recovery. Recovery functional capacity is especially compromised by respiratory dysfunction with its various manifestations of impaired gas exchange, diminished lung volumes, and weak inspiratory muscles.[3,4]

Stresses of prolonged anaesthesia, reduced mobility in the immediate post-operative period, the effects of cardiopulmonary bypass, and post-sternotomy pain all contribute to recovery dysfunction.[5] Post-operative pulmonary complications, namely atelectasis, pneumonia, pleural effusions, and hypoxemia, are recurring obstacles to reducing the length of stay in hospitals, increasing the cost of care, and hindering efforts to return to pre-operative baseline routines.[6,7] International guidelines recommend early rehabilitation that includes organized physiotherapy, symptom-directed pulmonary rehabilitation, and early mobilization to maintain lung function, avoid complications, and facilitate functional recovery.[8] While organized cardiac rehabilitation is a standard practice in high-income countries, such rehabilitation services are patchy in low- and middle-income countries, even in Pakistan, where rehabilitation and post-operative physiotherapy practices are highly inconsistent.

In the country, post-operative rehabilitation focuses on low-intensity ambulation combined with simple breathing exercises at intervals, with little or no pulmonary rehabilitation that targets the respiratory muscles.[9] Several of these barriers include a limited understanding of the scope of rehabilitation, low rehabilitation expectations, resource limitations, early discharge policies, and a lack of an educated physiotherapy workforce.[10,11] Psychological factors, such as fear of exertion after heart surgery, also impact patient involvement in rehabilitation programmes post-surgery. Consequently, patients experience functional limitations for a longer period, extending the duration of recovery. These findings underline the importance of low-cost, effective, and easy-to-implement interventions for day-to-day clinical practice in Pakistan.[12]

Respiratory Muscle Training (RMT) is an evidence-based approach focused on strengthening respiratory muscles and enhancing post-operative pulmonary function. Tailored exercises result in stronger diaphragmatic muscles, which increase lung volumes, lessen dyspnoea, and foster active pulmonary clearance, all of which improve functional capacity and expedite recovery.[13,14] Research shows that patients who undergo inspiratory muscle training immediately after surgery attain significantly higher maximal inspiratory pressures, demonstrate greater forced vital capacity, and achieve better results on the six-minute walk test than patients who only receive standard physiotherapy.[15,16]

Integrating respiratory muscle training with chest physiotherapy and early mobilisation has been particularly effective in restoring functional capacity after cardiac surgery.[17] Despite increasing international evidence to support RMT-based rehabilitation, structured cardiac rehabilitation, particularly with inspiratory muscle training, remains underutilized in Pakistan. Local studies have shown that respiratory physiotherapy can enhance oxygenation and lung function following cardiac surgery; however, only a few studies have been specifically dedicated to assessing the benefits of integrated respiratory muscle training programs in the Pakistani setting.[18]

Resource constraints, a high volume of patients, and early hospital discharges in Pakistani cardiac units, the interventions require being low-cost, simple to provide, and possible at the bedside. Respiratory muscle training is highly suitable, considering these requirements, as it can easily be incorporated into the existing rehabilitation routine without the need for significant amounts of equipment or additional personnel. This study aims to determine the impact of the addition of respiratory muscle training to a structured post-operative rehabilitation program on early recovery, pulmonary function, inspiratory muscle strength, and functional capacity in cardiac surgery patients in Pakistan.

METHODOLOGY

This quasi-experimental clinical trial was conducted at the Punjab Institute of Cardiology,

Lahore, Pakistan, from August to November 2024. The primary aim was to determine the effect of the addition of RMT to standard post-operative rehabilitation on lung function, inspiratory muscle strength, and functional capacity in patients post-cardiac surgery. Written informed consent was obtained from all participants before enrollment into the study.

This study enrolled a total of 60 adult patients undergoing elective cardiac surgery, including coronary artery bypass grafting and valve repair or replacement, by consecutive sampling. Inclusion criteria consisted of patients aged between 45 and 70 years with hemodynamic stability post-surgery and the ability to participate in rehabilitation exercises. Those with chronic lung disease, neuromuscular disorders, musculoskeletal problems, or who required mechanical ventilation after surgery for more than a week were excluded. Patients were divided into two equal groups, each comprising 30 cases. The intervention group received a structured RMT-integrated rehabilitation programme, while the control group received standard post-operative physiotherapy. The patients were assigned to each group according to the time of admission, with both groups being comparable in age, gender, type of surgery, and general health status at baseline.

The intervention programme began within 24 hours of extubation and was continued daily for seven days. Patients performed diaphragmatic breathing exercises, used incentive spirometry, and completed inspiratory muscle training with a threshold device. The exercises were tailored to each patient's strength and tolerance, and supervised by trained physiotherapists. Sessions lasted about 20-25 minutes, with gradual increases in difficulty to safely strengthen respiratory muscles without causing fatigue or discomfort. Early mobilisation was also part of the programme. Patients progressed from bed-to-chair transfers to walking short distances in the hospital corridor, followed by gradually increasing functional activities according to their capacity. These sessions were conducted twice daily, with close monitoring of heart rate, blood pressure, oxygen levels, and patient comfort. Standard physiotherapy techniques, such as guided coughing and airway clearance exercises, were included to support lung recovery.

The control group received routine physiotherapy care in line with hospital practice. This included deep breathing exercises, incentive spirometry, and assisted walking. The frequency and duration of sessions were matched to the intervention group, but no structured inspiratory muscle training or progression of intensity was applied. Outcome measures were collected on day one after surgery (baseline) and on day seven (after intervention). Lung function was measured using a portable spirometer to record forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1). Inspiratory muscle strength was measured using a handheld manometer to record maximal inspiratory pressure (MIP). Functional capacity was assessed using the six-minute walk test (6MWT) in a standardized corridor under physiotherapist supervision. Vital signs were monitored during all exercise sessions for patient safety, and any complications or adverse events were recorded.

Data were entered into SPSS version 26 for analysis. Continuous variables were reported as mean and standard deviation, and categorical variables as numbers and percentages. Paired t-tests were used to compare pre- and post-intervention results within each group, while independent t-tests compared changes between groups. A p-value of less than 0.05 was considered statistically significant. This methodology provided a clear and practical approach to evaluate the impact of RMT-integrated rehabilitation on early recovery, respiratory function, and physical performance in patients undergoing cardiac surgery in a Pakistani hospital setting.

RESULTS

Table 1 holds the demographics and clinical characteristics of the participants. A total of 60 patients completed the study, with 30 in the intervention group (RMT-integrated rehabilitation) and 30 in the control group (standard physiotherapy). The mean age was 58.4 ± 7.2 years in the intervention group and 59.1 ± 6.8 years in the control group. Males were the majority in both groups: 73% in the intervention group and 70% in the control group. Coronary artery bypass grafting (CABG) was performed in 18 patients in the intervention group and 17 in the control group, while valve repair/replacement was performed in 12 and 13 patients, respectively. Comorbidities such as hypertension (14 vs 15) and diabetes (9 vs 8) were evenly distributed. No significant differences were observed between groups for baseline

demographic or clinical variables ($p>0.05$), ensuring comparability for outcome analysis.

Table 2 compares the FVC and in one second FEV_1, which were measured at baseline (day 1) and post-intervention (day 7). Both outcomes showed greater improvement in the intervention group compared to controls. The mean increase in FVC was +0.13 L in the intervention group and +0.05 L in the control group. Similarly, FEV_1 increased by +0.11 L in the intervention group and +0.05 L in the control group. These differences were statistically significant, demonstrating that RMT contributed to better early post-operative lung function recovery. The improvements align with previous studies reporting 3-6% gains in pulmonary volumes following structured inspiratory muscle training in post-cardiac surgery patients.

Maximal inspiratory pressure (MIP) was assessed to determine the effect of RMT on respiratory muscle strength. The intervention group experienced a mean increase of +4.8 cmH_2O, whereas the control group improved by +2.0 cmH_2O. These changes were statistically significant between groups ($p = 0.005$), indicating that targeted inspiratory muscle training effectively enhanced respiratory muscle performance over the early post-operative period (Table 3). Functional capacity, measured via the 6MWT, improved in both groups, with greater gains in the intervention arm. Table 4 shows the mean 6MWD increased by +73 m in the intervention group versus +33 m in controls. The between-group difference was significant ($p = 0.001$), indicating that RMT integrated with standard rehabilitation accelerates recovery of physical function. These improvements are consistent with previously published data reporting clinically meaningful gains (approx. 70-80 m) in functional performance following early post-operative inspiratory muscle training.

No serious adverse events occurred in either group. Oxygen saturation remained above 90% throughout all sessions, and no arrhythmias or hemodynamic instability were reported. Adherence in the intervention group averaged 95%, demonstrating the feasibility of daily RMT in early post-operative rehabilitation. Figure 1 compares the mean changes in FVC, MIP, and 6MWT between the intervention and control groups. It clearly shows that the intervention group experienced significantly greater positive changes than the control group across all three outcomes. Specifically, the intervention was more effective at increasing lung volume (FVC), strengthening breathing muscles (MIP), and improving walking endurance (6MWT). This demonstrates that the tested intervention was successful in enhancing both respiratory and functional exercise capacity.

DISCUSSION

This quasi-experimental study sought to determine the impact of adding structured RMT to standard post-operative physiotherapy on early recovery outcomes in cardiac surgery patients within a Pakistani hospital setting. The findings demonstrate that the integration of a simple, bedside RMT protocol significantly enhances pulmonary function, inspiratory muscle strength, and functional capacity compared to standard care alone. The primary results indicate that patients in the RMT group achieved statistically superior

Table 1: Baseline demographics and clinical characteristics

	Characteristic	Intervention Group (n=30)	Control Group (n=30)	p-value
Age (years)	Mean ± SD	58.4 ± 7.2	59.1 ± 6.8	> 0.05
Gender	Male	22 (73.3%)	21 (70.0%)	> 0.05
	Female	8 (26.7%)	9 (30.0%)	
Types of Surgery	CABG	18 (60.0%)	17 (56.7%)	> 0.05
	Valve Repair/ Replacement	12 (40.0%)	13 (43.3%)	> 0.05
Comorbidities	Hypertension	14 (46.7%)	15 (50.0%)	> 0.05
	Diabetes	9 (30.0%)	8 (26.7%)	> 0.05

Table 2: Mean changes in FVC, MIP, and 6MWT in both groups

Parameters	Group	Day 1 (Baseline)	Day 7	Mean Change (Δ)	p-value (within-group)	p-value (between-groups)
FVC (L)	Intervention	2.35 ± 0.50	2.48 ± 0.51	0.13	0.003	0.021
	Control	2.33 ± 0.47	2.38 ± 0.48	0.05	0.042	
FEV_1 (L)	Intervention	1.88 ± 0.42	1.99 ± 0.43	0.11	0.002	0.018
	Control	1.87 ± 0.41	1.92 ± 0.42	0.05	0.038	
Maximal Inspiratory Pressure	Intervention	60.2 ± 11.5	65.0 ± 12.0	4.8	<0.001	0.005
	Control	61.0 ± 12.3	63.0 ± 12.5	2.0	0.029	
Six-minute walk test	Intervention	330 ± 44 m	403 ± 48	73	<0.001	0.001
	Control	328 ± 46 m	361 ± 49	33	0.008	

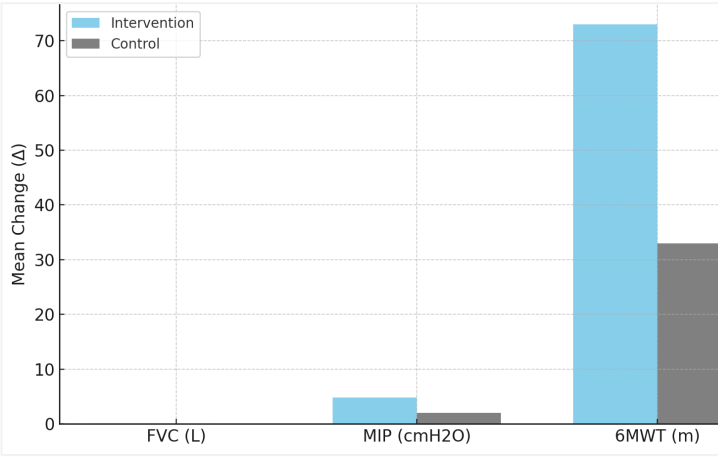
improvements in FVC and FEV_1 in one second. The mean increases of +0.13 L in FVC and +0.11 L in FEV_1 in the intervention group were more than double the gains observed in the control group. This aligns with the physiological rationale that targeted inspiratory muscle training helps counteract post-operative diaphragmatic dysfunction and atelectasis, common after sternotomy and cardiopulmonary bypass.[3,5] Sepúlveda et al. (2025) randomized controlled trial confirmed that preoperative inspiratory muscle training significantly preserves postoperative pulmonary function, with the training group showing markedly better FVC and FEV1 values compared to controls.[19] Our study extends this evidence by demonstrating that early postoperative RMT initiation yields similar protective effects.

Furthermore, the significant between-group difference in Maximal Inspiratory Pressure (MIP), a gain of +4.8 cmH_2O in the RMT group versus +2.0 cmH_2O in the control group, provides objective evidence of a direct training effect. This strengthened inspiratory musculature is crucial for reducing the work of breathing and enabling greater physical activity. Fischer and co-workers (2022) concluded that RMT is an effective strategy for improving respiratory muscle strength in patients undergoing CABG, with consistent improvements in MIP being a key finding across included studies.[20]

Perhaps the most clinically significant finding is the remarkable improvement in functional capacity, measured by the 6MWT. The RMT group's improvement of 73 meters is more than twice that of the control group and exceeds the threshold for a clinically important difference. This underscores the translation of improved respiratory strength into tangible physical performance. This result is strongly supported by Inayat et al. (2024), who found that postoperative IMT led to a significantly greater improvement in 6MWT distance compared to standard rehabilitation alone, directly linking enhanced respiratory muscle function to better functional outcomes.[21] The magnitude of improvement we observed is consistent with the findings by Cassina et al. (2016), which reported that IMT in cardiac surgery patients consistently results in superior gains in functional exercise capacity.[22]

When contextualized within the Pakistani healthcare landscape, these findings carry profound implications. The success of this low-cost, simple-to-implement intervention directly addresses the barriers of resource constraints and a stretched workforce.[9,10] The 95% adherence rate underscores its feasibility. This aligns with global shifts towards cost-effective rehabilitative strategies. A 2022 study by Taylor and co-workers demonstrated that a simple, protocol-driven physiotherapy intervention, including breathing exercises, significantly reduced pulmonary complications and was highly feasible to implement.[23] Furthermore, this was also highlighted by Cordeiro et al. (2023) that postoperative pulmonary complications are a strong, independent predictor of increased mortality and hospital stay after cardiac surgery, reinforcing the need for proactive preventative measures.[24] Our findings also address the gap in structured rehabilitation in low and middle-

Figure 1: Mean changes in FVC, MIP, and 6MWT



income countries. The study done by McAllister and colleagues in 2024, which reviewed cardiac rehabilitation in South Asia, pointed to the lack of standardized protocols and the under-utilization of specific modalities like inspiratory muscle training as major barriers to quality care.[25] This study provides a practical model to address this gap. This is further claimed that early mobilization and respiratory exercises in post-cardiac surgery patients were safe and did not lead to adverse hemodynamic events.[26]

There were several limitations in this study. The quasi-experimental design carries a risk of selection bias compared to a randomized controlled trial. Future studies should employ RCT methodologies to strengthen the evidence. The short-term follow-up captures only immediate gains; longer-term follow-up is needed to determine if benefits translate into sustained improvements in quality of life and reduced readmissions. The study by Auschra et al (2024) emphasized the importance of long-term follow-up in cardiac rehabilitation trials, noting that while early functional gains are crucial, their maintenance is key to long-term patient prognosis.[27] Although we have seen functional improvement but future work should include patient-reported outcomes, as RMT significantly improved quality of life scores in patients after cardiac surgery, suggesting a holistic benefit that our study did not capture.[28]

CONCLUSION

This study presents robust evidence that the integration of structured RMT into conventional post-operative care significantly enhances early recovery for patients undergoing cardiac surgery. The group receiving the intervention exhibited statistically significant and clinically relevant improvements in lung function, measured by FVC and FEV_1 in one second, as well as in respiratory muscle strength MIP and functional capacity, 6MWT when compared to the control group, which received only standard physiotherapy. These results underscore RMT's efficacy in addressing prevalent post-operative pulmonary impairments. Given its proven feasibility, safety, affordability, and high adherence rates, RMT represents a promising strategy for enhancing rehabilitation practices in Pakistan and other low- and middle-income countries. We strongly advocate for the inclusion of structured inspiratory muscle training as an essential element of post-operative rehabilitation protocols to improve patient outcomes and potentially shorten recovery periods.

DECLARATIONS

Consent to participate: Written consent had been obtained from patients. All methods were performed following the relevant guidelines and regulations.
Availability of Data and Materials: Data will be made available upon request. The corresponding author will submit all dataset files.
Competing interests: None
Funding: No funding source involved.
Authors' contributions: All authors had read and approved the final manuscript.

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