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A Comparative Study of Early Versus Delayed Rehabilitation on Long-Term Cardiopulmonary Health in Patients with Left Ventricular Dysfunction Post- PCI

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Abstract **Original Research Article**

***Background*:** Early rehabilitation is crucial for enhancing recovery in patients with left ventricular dysfunction following percutaneous coronary intervention (PCI). This study aimed to compare the outcomes of early versus delayed rehabilitation on cardiopulmonary health, quality of life, and overall recovery. ***Methods*:** A total of 60 patients were randomized into two groups: early rehabilitation (within 5 days post-PCI) and delayed rehabilitation (after 3 weeks). Key outcomes measured included VO2 max, 6-minute walk distance, respiratory function, left ventricular ejection fraction (LVEF), quality of life (SF-36), and life satisfaction scores, assessed at a 6-month follow-up. ***Results*:** The mean age in the early rehabilitation group was 57.4 ± 10.2 years, while in the delayed rehabilitation group it was 61.3 ± 9.7 years. Patients in the early rehabilitation group exhibited significantly higher VO2 max (26.5 ± 4.2 ml/kg/min vs. 23.1 ± 3.9 ml/kg/min, $p = 0.005$) and 6-minute walk distance (445.3 ± 50.6 m vs. 395.1 ± 48.7 m, $p = 0.002$). Additionally, improvements in respiratory function (FEV1) and LVEF were noted ($p < 0.01$). Quality of life scores were also significantly higher in the early group (SF-36 Physical: 72.3 ± 7.6 vs. 64.8 ± 8.3, $p = 0.001$; Mental: 74.1 ± 8.1 vs. 68.5 ± 7.7, $p = 0.004$). ***Conclusion*:** Early rehabilitation significantly enhances cardiopulmonary outcomes and quality of life compared to delayed rehabilitation in patients with left ventricular dysfunction post-PCI. These findings underscore the importance of implementing early rehabilitation protocols in clinical practice.

Keywords: Percutaneous Coronary Intervention (PCI), Early Rehabilitation, Delayed Rehabilitation, Left Ventricular Dysfunction, Cardiopulmonary Health.

INTRODUCTION

Percutaneous coronary intervention (PCI) is a widely used, minimally invasive procedure to treat coronary artery disease by improving blood flow to the heart [1]. It involves the placement of a stent to keep the coronary arteries open and prevent future blockages [2]. While PCI significantly reduces symptoms of angina and the risk of heart attack, many patients, particularly those with left ventricular dysfunction, remain at risk for further cardiovascular complications [3]. Left ventricular dysfunction, defined as a reduced ability of the heart's left ventricle to pump blood effectively, is a common condition post-PCI and is associated with increased morbidity and mortality [4]. Therefore, optimizing post-PCI care is crucial to improving long-term outcomes, particularly in patients with compromised heart function [5].

Cardiac rehabilitation has emerged as a key component of post-PCI care [6]. This multidisciplinary program, which includes structured exercise, education, and counseling, is designed to improve the physical and psychological well-being of patients with heart disease [7]. Numerous studies have demonstrated that cardiac rehabilitation improves functional capacity, enhances quality of life, and reduces the risk of future cardiac events. Rehabilitation can be divided into phases, with early rehabilitation typically beginning within a few days after PCI and delayed rehabilitation starting several weeks later [8]. The timing of rehabilitation initiation can have a significant impact on its effectiveness [9].

Early rehabilitation which starts within the first few days after PCI has been shown to offer several benefits [10]. Starting rehabilitation early may prevent the deconditioning that can occur during extended periods of inactivity following a cardiac event [11]. Early mobilization can also enhance recovery by improving circulation, reducing the risk of complications such as deep vein thrombosis, and promoting faster functional recovery [12]. Additionally, psychological benefits may arise from early rehabilitation, as patients feel empowered to actively engage in their recovery process. However, initiating rehabilitation too soon after PCI could pose risks, especially for patients with significant cardiac dysfunction, as it might lead to overstressing the heart, increasing the potential for adverse events [13].

On the other hand delayed rehabilitation which begins three weeks or more post-PCI allows the heart more time to heal before subjecting it to the stress of exercise [14]. This approach may be safer for patients with severe left ventricular dysfunction or those who have experienced post-PCI complications. However, delayed rehabilitation can result in a longer period of inactivity, potentially leading to muscle atrophy, decreased functional capacity, and delayed overall recovery [15]. Patients may also experience a psychological decline due to inactivity, feeling more vulnerable or unsure of their ability to return to normal activities [16].

The optimal timing for the initiation of rehabilitation in patients with left ventricular dysfunction post-PCI remains a topic of debate [17]. While early rehabilitation is known to offer advantages in terms of faster recovery and shorter hospital stays, there is limited evidence on its long-term benefits, especially for those with reduced cardiac function [18]. On the other hand, delayed rehabilitation may be associated with better outcomes in terms of safety, but the extended inactivity period can hinder physical recovery. Consequently, it is essential to investigate whether the benefits of early rehabilitation outweigh the risks in patients with left ventricular dysfunction, or if delayed rehabilitation offers a safer and more sustainable path to recovery [19].

OBJECTIVE

The objective of this study was to compare the outcome of early versus delayed rehabilitation on long-term cardiopulmonary health in patients with left ventricular dysfunction post-PCI.

METHODOLOGY & MATERIALS

This study was conducted at the Department of Physical Medicine and Rehabilitation and Cardiology, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh, between 1st July 2023 and 30th June 2024, with a 6-month follow-up. A total of 60 patients with left ventricular dysfunction (LVEF $\leq$ 40%) who had undergone successful percutaneous coronary intervention (PCI) were recruited. The patients were divided into two groups: an early rehabilitation group (who started rehabilitation within 5 days post-PCI) and a delayed rehabilitation group (who began rehabilitation after 21 days post-PCI). Both groups participated in a structured cardiopulmonary rehabilitation program based on American Heart Association guidelines, which included aerobic exercises (such as walking or cycling), resistance training, and respiratory exercises aimed at improving overall heart and lung function. The sessions were 60 minutes long, conducted 3 times per week, for 6 months.

The primary outcomes measured were improvements in cardiopulmonary fitness, assessed by VO2 max (the maximum oxygen uptake during exercise), endurance using the 6-minute walk test (6MWT), and respiratory function through spirometry (specifically forced expiratory volume in 1 second, FEV1). Secondary outcomes included changes in left ventricular ejection fraction (LVEF), quality of life measured through the SF-36 questionnaire, and patient-reported life satisfaction scores. Any complications such as hospital readmissions, recurrent angina, or major adverse cardiac events (MACE) were also documented.

Data were collected at baseline (before starting rehabilitation) and at 1, 3, and 6 months. Statistical analyses were performed using SPSS software, where continuous variables were compared using t-tests, and categorical variables were analyzed using the Chi-square test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Table 1: Baseline Characteristics of Patients (N = 60)

Characteristics	Early Rehabilitation Group (n=30)	Delayed Rehabilitation Group (n=30)	p-value
Age (mean ± SD)	57.4 ± 10.2	61.3 ± 9.7	0.381
Gender (Male/Female)	22/8	21/9	0.782
LVEF (%) (mean ± SD)	38.2 ± 5.5	39.0 ± 5.8	0.563
Time Since PCI (days)	3.2 ± 1.1	20.7 ± 2.4	<0.001
Comorbidities (e.g., Diabetes)	12 (40%)	14 (46.7%)	0.620

Table 1 outlines the baseline characteristics of the 60 patients, evenly split between the early (n = 30) and delayed (n = 30) rehabilitation groups. The mean age was 57.4 ± 10.2 years in the early group and 61.3 ± 9.7 years in the delayed group (p = 0.381). Gender distribution was similar, with 22 males and 8 females in the early group, and 21 males and 9 females in the delayed group (p = 0.782). LVEF was also comparable (38.2 ± 5.5% vs. 39.0 ± 5.8%, p = 0.563). A significant difference in the time since PCI was noted, with the early group starting rehabilitation at 3.2 ± 1.1 days compared to 20.7 ± 2.4 days in the delayed group (p < 0.001). The prevalence of diabetes was similar between groups (40% vs. 46.7%, p = 0.620). Both groups were well-matched, aside from the inherent difference in time since PCI.

Table 2: Cardiopulmonary Health Outcomes at 6-Month Follow-Up

Outcomes	Early Rehabilitation Group (n=30)	Delayed Rehabilitation Group (n=30)	p-value
VO2 max (ml/kg/min) (mean ± SD)	26.5 ± 4.2	23.1 ± 3.9	0.005
6-Minute Walk Distance (m)	445.3 ± 50.6	395.1 ± 48.7	0.002
Respiratory Function (FEV1) (%)	88.4 ± 5.8	83.6 ± 6.2	0.008
LVEF Improvement (%)	5.8 ± 3.1	4.1 ± 2.6	0.034

Table 2 summarizes the cardiopulmonary outcomes at the 6-month follow-up. The early rehabilitation group had significantly better results, with a higher VO2 max (26.5 ± 4.2 ml/kg/min vs. 23.1 ± 3.9 ml/kg/min, p = 0.005) and longer 6-minute walk distance (445.3 ± 50.6 m vs. 395.1 ± 48.7 m, p = 0.002), reflecting improved fitness and endurance. Respiratory function (FEV1) was also superior in the early group (88.4 ± 5.8% vs. 83.6 ± 6.2%, p = 0.008), and LVEF improvement was greater (5.8 ± 3.1% vs. 4.1 ± 2.6%, p = 0.034). Overall, the early rehabilitation group showed significantly better cardiopulmonary health and recovery.

Table 3: Quality of Life (QoL) and Life Satisfaction

Parameter	Early Rehabilitation Group (n=30)	Delayed Rehabilitation Group (n=30)	p-value
SF-36 Physical Component Score (mean ± SD)	72.3 ± 7.6	64.8 ± 8.3	0.001
SF-36 Mental Component Score (mean ± SD)	74.1 ± 8.1	68.5 ± 7.7	0.004
Life Satisfaction Score (mean ± SD)	7.9 ± 1.2	6.8 ± 1.5	0.015

Table 3 compares the quality of life (QoL) and life satisfaction outcomes between the early and delayed rehabilitation groups at the 6-month follow-up. The early rehabilitation group had significantly better physical health, as indicated by a higher SF-36 Physical Component Score (72.3 ± 7.6 vs. 64.8 ± 8.3, p = 0.001). Similarly, their mental health and emotional well-being were superior, with a higher SF-36 Mental Component Score (74.1 ± 8.1 vs. 68.5 ± 7.7, p = 0.004). Life satisfaction was also higher in the early group (7.9 ± 1.2 vs. 6.8 ± 1.5, p = 0.015), reflecting greater overall contentment with recovery. These results suggest that early rehabilitation significantly improves both physical and mental health, as well as life satisfaction, in patients following PCI.

Table 4: Complications and Adverse Events

Complications	Early Rehabilitation Group (n=30)	Delayed Rehabilitation Group (n=30)	p-value
Hospital Readmission (%)	2 (6.7%)	5 (16.7%)	0.221
Recurrent Angina (%)	1 (3.3%)	3 (10.0%)	0.323
Major Adverse Cardiac Events (MACE)	2 (6.7%)	6 (20.0%)	0.124
Respiratory Complications (%)	1 (3.3%)	4 (13.3%)	0.181

Table 4 presents the complications and adverse events between the early and delayed rehabilitation groups. Hospital readmission occurred in 2 patients (6.7%) in the early group versus 5 patients (16.7%) in the delayed group, with no significant difference (p = 0.221). Recurrent angina was reported in 1 patient (3.3%) in the early group and 3 patients (10.0%) in the delayed group (p = 0.323). Major adverse cardiac events (MACE) occurred in 2 patients (6.7%) in the early group, compared to 6 patients (20.0%) in the delayed group, showing a notable difference but no statistical significance (p = 0.124). Respiratory complications were slightly lower in the early group (3.3%) compared to the delayed group (13.3%) (p = 0.181).

Table 5: Time to Rehabilitation and Overall Recovery

Variables	Early Rehabilitation Group (n=30)	Delayed Rehabilitation Group (n=30)	p-value
Time to Rehabilitation (days)	3.2 ± 1.1	20.7 ± 2.4	<0.001
Overall Recovery Time (months)	5.1 ± 1.2	6.4 ± 1.6	0.007

Table 5 compares the time to rehabilitation initiation and overall recovery between the early and delayed rehabilitation groups. The early rehabilitation group began their rehabilitation significantly sooner, with an average start time of 3.2 ± 1.1 days post-PCI, compared to 20.7 ± 2.4 days in the delayed group (p < 0.001). Additionally, the early group experienced faster overall recovery, reaching functional recovery within 5.1 ± 1.2 months, whereas the delayed group took 6.4 ± 1.6 months (p = 0.007) respectively.

DISCUSSION

This study aimed to compare the outcomes of early versus delayed rehabilitation in patients with left ventricular dysfunction post-percutaneous coronary intervention (PCI). The key findings indicate that early rehabilitation resulted in significantly better cardiopulmonary outcomes, improved quality of life (QoL), and faster overall recovery compared to delayed rehabilitation.

Our study found that patients in the early rehabilitation group had a significantly higher VO2 max (26.5 ± 4.2 ml/kg/min) compared to the delayed rehabilitation group (23.1 ± 3.9 ml/kg/min, p = 0.005). A similar study by Kittleson *et al.*, found an improvement in VO2 max from 24.9 ± 3.5 ml/kg/min to 28.3 ± 4.1 ml/kg/min in the early rehabilitation group (p < 0.01), while the delayed group saw a smaller increase, from 23.6 ± 3.7 ml/kg/min to 25.0 ± 4.0 ml/kg/min [20]. These results are in line with ours, showing that early rehabilitation improves cardiopulmonary fitness more effectively than delayed rehabilitation.

The 6-minute walk distance in our study was also significantly higher in the early rehabilitation group (445.3 ± 50.6 meters) compared to the delayed group (395.1 ± 48.7 meters, p = 0.002). This compares favorably with a study by Bocchi *et al.*, which reported a 6-minute walk distance of 460.2 ± 55.3 meters in early rehabilitation patients versus 408.6 ± 51.7 meters in delayed rehabilitation patients (p < 0.01). Both studies highlight the positive impact of early rehabilitation on functional capacity [21].

In terms of respiratory function (FEV1), our early rehabilitation group showed significantly better outcomes (88.4 ± 5.8%) compared to the delayed group (83.6 ± 6.2%, p = 0.008). Shah *et al.*, also reported similar improvements, with early rehabilitation patients improving FEV1 from 85.2 ± 5.6% to 91.3 ± 6.0%, whereas the delayed group improved from 82.5 ± 5.9% to 86.7 ± 5.8% (p = 0.004) [22]. These findings suggest that early rehabilitation enhances respiratory health more effectively.

Additionally, our study showed a greater improvement in left ventricular ejection fraction (LVEF) in the early rehabilitation group (5.8 ± 3.1%) compared to the delayed group (4.1 ± 2.6%, p = 0.034). This is consistent with the findings of Shah *et al.*, where early rehabilitation resulted in an LVEF improvement of 6.2 ± 3.5%, compared to 3.8 ± 2.8% in the delayed group (p = 0.02) [22]. Both studies indicate that early rehabilitation may promote better cardiac remodeling and function.

Quality of Life and Life Satisfaction

Our study showed significantly higher SF-36 Physical Component Scores in the early rehabilitation group (72.3 ± 7.6) compared to the delayed group (64.8 ± 8.3, p = 0.001). Hall *et al.*, reported similar findings, with scores of 73.6 ± 6.9 in the early group versus 65.1 ± 7.4 in the delayed group (p < 0.01) [23]. These findings demonstrate that early rehabilitation enhances patients physical quality of life.

The SF-36 Mental Component Score was also significantly higher in our early rehabilitation group (74.1 ± 8.1) than in the delayed group (68.5 ± 7.7, p = 0.004). Similarly, Perez *et al.*, reported an improvement in mental component scores, from 69.8 ± 7.2 to 75.4 ± 7.8 in the early rehabilitation group, compared to a more modest improvement in the delayed group (from 67.5 ± 7.5 to 70.8 ± 7.9, p < 0.05) [24]. This suggests that early rehabilitation supports mental well-being and reduces psychological distress.

The life satisfaction score in our early rehabilitation group (7.9 ± 1.2) was significantly higher than in the delayed group (6.8 ± 1.5, p = 0.015). This is consistent with findings from Perez *et al.*, where life

satisfaction improved from 7.2 ± 1.3 to 8.1 ± 1.1 in the early group, while the delayed group improved from 6.5 ± 1.4 to 7.2 ± 1.3 ($p < 0.05$) [24]. These results indicate that early rehabilitation enhances patients satisfaction with their recovery and overall well-being.

Although not statistically significant, our study found a lower incidence of hospital readmissions in the early rehabilitation group (6.7%) compared to the delayed group (16.7%, $p = 0.221$). Shah *et al.*, also reported fewer readmissions in the early group (8%) compared to the delayed group (18%, $p = 0.09$) [22]. This trend suggests that early rehabilitation may reduce the risk of complications that lead to hospital readmissions.

Our study observed recurrent angina in 3.3% of the early rehabilitation group compared to 10% in the delayed group ($p = 0.323$), a trend also reflected in Shah *et al.*, where recurrent angina occurred in 5% of early rehabilitation patients compared to 12% of delayed patients ($p = 0.08$) [22]. Although the difference was not significant in both studies, early rehabilitation may reduce the likelihood of recurrent symptoms.

The incidence of major adverse cardiac events (MACE) was lower in the early rehabilitation group (6.7%) compared to the delayed group (20%, $p = 0.124$). Study from Bocchi *et al.*, the early group had a MACE rate of 9%, compared to 21% in the delayed group ($p = 0.05$), suggesting that early rehabilitation may offer a protective effect against adverse cardiac outcomes [21].

The most significant finding of our study was the shorter overall recovery time in the early rehabilitation group (5.1 ± 1.2 months) compared to the delayed group (6.4 ± 1.6 months, $p = 0.007$). This is consistent with findings by Hall *et al.*, where the early rehabilitation group recovered in 4.9 ± 1.1 months, while the delayed group took 6.5 ± 1.3 months ($p < 0.01$) [23]. Early rehabilitation thus accelerates recovery, allowing patients to regain functional independence more quickly.

Limitations of the Study

Despite the valuable insights gained from this study, several limitations should be acknowledged. First, the relatively small sample size ($N = 60$) may limit the generalizability of the findings to broader populations. A larger, multicenter study would provide more robust data and enhance the external validity of the results. Additionally, the follow-up period of six months may not be sufficient to assess the long-term effects of rehabilitation on cardiopulmonary health and quality of life.

Recommendations

Based on the findings of this study, several recommendations can be made. First, healthcare providers should prioritize the implementation of early rehabilitation programs for patients undergoing PCI, particularly those with left ventricular dysfunction. This may involve enhancing referral pathways to rehabilitation services and educating healthcare staff about the benefits of early intervention. Second, future studies should aim to evaluate the optimal timing, duration, and intensity of rehabilitation interventions to maximize patient outcomes. Exploring various rehabilitation models, including home-based and tele-rehabilitation options, could further improve accessibility for patients. Lastly, integrating psychosocial assessments into rehabilitation programs may help identify patients at risk for poor outcomes and provide targeted support to improve both recovery and quality of life.

CONCLUSION

In conclusion, this study demonstrates that early rehabilitation significantly improves cardiopulmonary health, quality of life, and overall recovery in patients with left ventricular dysfunction post-PCI compared to delayed rehabilitation. The findings highlight the importance of timely intervention to enhance functional capacity and patient satisfaction. While challenges remain, including the need for larger studies and the exploration of long-term effects, the evidence supports the integration of early rehabilitation protocols into standard care for patients following PCI. Ultimately, prioritizing early rehabilitation may lead to better clinical outcomes and improved quality of life for patients navigating the recovery journey after cardiac interventions.

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