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ORIGINAL ARTICLE

Effect of Cardiac Rehabilitation on Left Ventricular Remodeling After Acute Anterior Wall ST-Segment Elevation Myocardial Infarction Treated by Late Percutaneous Intervention Using Three-Dimensional Echocardiography: A Randomized Study

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Abstract

Background: **Cardiac rehabilitation (CR) has emerged as a comprehensive intervention including several facets and disciplines, with the primary objective of inhibiting the advancement of cardiovascular disease in individuals diagnosed with conditions of the heart and promoting overall health restoration. The objective of this research was to assess the effect of CR on the process of left ventricular (LV) remodeling, specifically using three-dimensional echocardiography after an episode of acute ST-segment elevation myocardial infarction (STEMI).**

Patients and methods: **This randomized controlled trial was carried out on 60 patients who suffered recently from acute STEMI and were treated with delayed percutaneous intervention (PCI). Patients were randomized in a parallel manner into two equal groups: group 1: entered a CR program plus the standard medical treatment, and group 2: did not receive the rehabilitation program and followed up only with standard medical treatment. All patients received invasive management and were subsequently referred for PCI and coronary angiography of the infarct-related artery, namely the left anterior descending artery, with the placement of drug-eluting stents within 24 h of symptom onset.**

Results: **Metabolic equivalent and exercise duration were significantly higher in group 1 than group 2 at follow-up. Also, variances among follow-up and baseline metabolic equivalent were significantly higher in follow-up research in group 1, while it was insignificantly variant between follow-up and baseline research in group 2. There was no important variant among heart rate recovery 1 min after exercise among both groups at the baseline, but it was significantly higher in group 1 than group 2 at follow-up. Heart rate recovery 2 min after exercise at follow-up was significantly higher than at baseline in group 1, while it was insignificantly variant among follow-up and baseline in group 2. Left ventricular end systolic volume (LVESV) was insignificantly variant among follow-up and baseline after rehabilitation in group 1 while it was significantly higher at follow-up than at baseline in group 2. There was no important variance in ejection fraction among follow-up and baseline following rehabilitation in group 1, however, in group 2, ejection fraction was considerably greater at follow-up compared to baseline.**

Conclusion: **CR has been shown to have a convenient impact on LV and exercise capacity remodeling in individuals with STEMI who have had delayed PCI. The delayed commencement of CR was shown to be correlated with a higher degree of LV remodeling. The use of three-dimensional ECG has the potential to provide significant insights into LV function and remodeling.**

Keywords: Cardiac rehabilitation, Left ventricular remodeling, Percutaneous intervention, ST-segment elevation myocardial infarction, Three-dimensional ECG

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1. Introduction

Coronary heart disease (CHD) is an essential contributor to both mortality and morbidity. The documented incidence of CHD among adults has shown a fourfold increase over the course of the previous four decades, resulting in a current prevalence rate of more than 10%. This increase is not limited to urban areas, as even rural regions have had a twofold rise in CHD prevalence over the past three decades, reaching a current level of around 4%.[1]

Myocardial infarction (MI) is the primary etiology of heart failure among the adult population of the United States.[2] The process of left ventricular (LV) remodeling after MI is a complicated and multifaceted phenomenon that has therapeutic consequences and important prognostic.[3] The use of drugs aimed at reducing LV remodeling has been shown to develop both overall quality of life and survival rates.[4]

Research studies have demonstrated that exercise training can decrease mortality rates and enhance exercise capacity, hence enhancing the potential efficacy of therapeutic therapies.[5] Moreover, the addition of aerobic exercise has been shown to safely reduce cardiovascular risk factors, enhancing its attractiveness as an adjunctive therapeutic intervention.[6]

It has been suggested that exercise training be used in post-MI patients with LV systolic dysfunction as a helpful addition to the current medical treatment to achieve both functional and symptomatic improvement as well as to stop the development of LV dysfunction and the associated mortality and morbidity.[7]

In recent years, cardiac rehabilitation (CR) has emerged as a comprehensive and interdisciplinary intervention designed to promote wellness and hinder the advancement of cardiovascular disease (CVD) in individuals with cardiac conditions. This multifaceted strategy encompasses a range of therapeutic approaches, such as pharmacotherapy, education on risk factors, and psychological interventions. However, it is important to note that worldwide clinical recommendations consistently identify exercise-based CR as a crucial element of therapy.[8]

Multiple investigations have shown inconclusive results on these findings, indicating that exercise may not have a significant impact on ventricular metrics, even when varying training intensities are used.[9] Previous research has shown that exercise has the potential to reduce ventricular remodeling and maybe reverse this process after a recent acute MI accompanied by systolic dysfunction.[10]

The precision of echocardiographic assessments of LV volumes is crucial for enhancing our understanding of LV function. Multiple research studies have shown that LV ejection fractions (EF) and LV volumes had prognostic value in predicting cardiovascular outcomes among individuals with diverse cardiac diseases. Three-dimensional echocardiography (3DE) has many benefits, including the ability to get full-volume data with established levels of consistency and accuracy. Moreover, research has shown that 3DE exhibits a stronger correlation with volumes obtained using cardiac magnetic resonance, while exhibiting less underestimate.[11]

Heart rate recovery (HRR) is operationally defined as the variance in HR among the highest HR achieved during activity and the HR measured precisely within the first or second minute after the cessation of exercise. An abnormal finding was seen when the HRR value was fewer than 12 beats per minute or less than 22 beats per minute at 1 and 2 min into the recovery phase, respectively.[12]

A diminished HRR during the first minute after incremental exercise is regarded as a robust prognostic indicator for overall mortality in individuals both with and without cardiac illnesses. This association remains significant regardless of the level of exertion, the existence or nonexistence of myocardial perfusion abnormalities, and changes in HR throughout the exercise.[13]

The goal of this research was to assess the impact of CR on LV remodeling using 3D-ECG.

2. Patients and methods

This study was a randomized controlled trial conducted on a sample of 60 patients who arrived at the Emergency Department with anterior wall ST-segment elevation myocardial infarction (STEMI) and were subsequently treated with late percutaneous intervention (PCI). The research was done from March 2019 to January 2023 after approval from the Ethical Committee Bab Al-sharia University Hospital, Al-Azhar University. The patients were provided with an informed written consent.

Exclusion criteria were MI or chronic arterial disease, post-MI angina, uncompensated congestive heart failure, atrial fibrillation, post-MI pericarditis or myocarditis, poor window, recent embolism, thrombophlebitis, uncontrolled diabetes mellitus, severe orthopedic conditions that would prohibit exercise, resting systolic blood pressure (SBP) more than 200 mmHg or resting diastolic blood pressure more than 110 mmHg that should be assessed on a case-by-case basis, orthostatic blood pressure (BP) drops of more than 20 mmHg with symptoms, critical aortic stenosis (i.e. peak systolic blood pressure gradient of >50 mmHg with an aortic valve orifice area of 120 beats per min), resting ST-segment depression or elevation (>2 mm) and contraindication to rehabilitation.

Patients were randomized in a parallel manner by computer-generated numbers into two equal groups: group 1: entered a CR program plus the standard medical treatment and group 2: patients did not receive the rehabilitation program and follow up only with standard medical treatment.

All patients were subjected to sociodemographic characteristics, clinical investigation, usual investigations (complete blood count, complete lipid profile, HBA1c, kidney function, hepatic enzyme, thyroid profile, and 12 lead ECG: done to all patients for diagnosis of STEMI and serial ECG after PPCI for new ECG changes also for rhythm identification) and resolution of ST segment.

The dyspnea assessment was conducted using the NYHA classification, whereas the chest pain evaluation was performed using the Canadian Cardiovascular Society classification.[14] The patient was diagnosed with and treated for an acute STEMI in accordance with the relevant 2017 European Society of Cardiology guidelines. All patients had invasive management and were subsequently referred for coronary angiography and primary PCI of the infarct-related artery, namely the left anterior descending, with the placement of drug-eluting stents within 24 h of symptom onset.

Before the surgery, all individuals were given loading doses of aspirin and clopidogrel, along with intraprocedural administration of unfractionated heparin. The decision to provide IIb/IIIa inhibitor was determined by the operator's judgment. Arterial hypertension was determined to be present when BP measures exceeded 140/90 mmHg on two consecutive occasions during the first hospitalization or if there was a prior diagnosis of hypertension or usage of drugs antihypertensive.[15]

2.1. *Transthoracic echocardiography*

For evaluation of LV end diastolic, dimensions, end systolic volumes and measurements of systolic function were performed by using Philips (Phillis IE 95 ultrasound machine manufacturer, Amsterdam, Netherland) IEX matrix ultrasound machine using S5-1 matrix array transducer ECG-gated examination. Before discharge, after 12 cycles and end of the 18th cycle, a conventional full 3D and 2D transthoracic ECG examination was performed with the patient lying on his left side, and routine views were acquired. According to the last ASE guidelines, standard views are obtained and used to obtain LV volumes and dimensions.

FS is calculated as a ratio between LVIDd-LVIDs and LVIDd.[16] The 2D modified Simpson's method is used to assess LVEF. LVEF was derived as a ratio between the variance among end-diastolic volumes and end-systolic which represents end-diastolic volume and stroke volume. $LVEF = SV/EDV \times 100\%$.[17]

3D full volume of the LV using four or six beats image acquisition was acquired and stored by offline analysis using Q-lab 9, semi-automated measurements of the EF and LV volumes.

The offline analysis Echo-PAC software (PC 6.0.0; GE Medical System, GE (General Electric) Ultrasound Machine Manufacturer, Boston, Massachusetts, USA) was used to perform LV speckle tracking imaging based on the data obtained during discharge TTE. The calculation of the global longitudinal strain of the LV included determining the average longitudinal strain across all 16 segments of the LV. Similarly, the anterior global longitudinal strain was obtained by calculating the average longitudinal strain only for the anterior wall segments (1–2, 7–8, 12–16).[18]

2.1.1. *Exercise ECG*

Before the rehabilitation program and after CR to evaluate functional capacity through metabolic equivalent (METS), HRR, and BP response after first minute and second minutes in the low-risk group after STEMI.

2.1.2. *Cardiac rehabilitation program*

All patients belonging to either the first or second group were released from the hospital after undergoing PCI. The individuals were provided with an orientation session that covered the components and importance of the CR program. A graded exercise test was conducted on individuals aged 12–16. For graded exercise test, the symptom-limited method by modified Bruce protocol was used according to the AACVPR guidelines.

The target HR was determined to be 60% of the maximum HR for the first 2-week period, followed by an elevate to 70% through the subsequent third and fourth weeks, and then raised to 85% during the fifth and sixth weeks. The researchers used a wireless ECG monitoring system, namely the Q-Tel ECG telemetry system developed by Quinton Instrument Co., to observe and record any potential deviations from normal ECG patterns such as myocardial ischemia or arrhythmia, as well as HR. The patients underwent subjective rating using Borg's rate of perceived exertion. The research included the inclusion of patients who engaged in exercise regimens of 50 min, conducted three times per week for a duration of 6 weeks, resulting in a cumulative total of 18 exercise sessions. Each session had a 10-min warm-up period, followed by a 30-min primary exercise segment, and concluded with a 10-min cool-down period. The primary physical activity was a duration of 15 min on the treadmill, followed by an additional 15 min on the ergometer.

2.2. Statistical analysis

The statistical research was conducted using SPSS v26, a software developed by IBM Inc., based in Chicago, Illinois, USA. The normality of the data distribution was assessed using the Shapiro–Wilks test and histograms. The SD and average of the quantitative parametric variables were reported and compared among the two groups using an unpaired Student's t test. The research used quantitative nonparametric data, which were represented using the interquartile range and median. These data were subjected to analysis using the Mann–Whitney test. The qualitative variables were expressed in percentage and frequency and were subjected to analysis using the Fisher's exact or χ^2 test, as deemed suitable. A two-tailed P value less than 0.05 was considered to be statistically important.

3. Results

A total of 83 patients who had experienced acute STEMI and underwent delayed PCI were evaluated for their suitability to participate in the research. Out of these patients, 17 individuals did not match the eligibility requirements, while six patients declined to take part in the research. The remaining patients were assigned into two groups of similar size using a random process, each consisting of 30 patients. Group 1: patients entered CR program plus the standard medical treatment. Group 2: patients did not receive CR program and were treated by the standard medical treatment. All allocated patients were analyzed statistically and followed-up (Fig. 1).

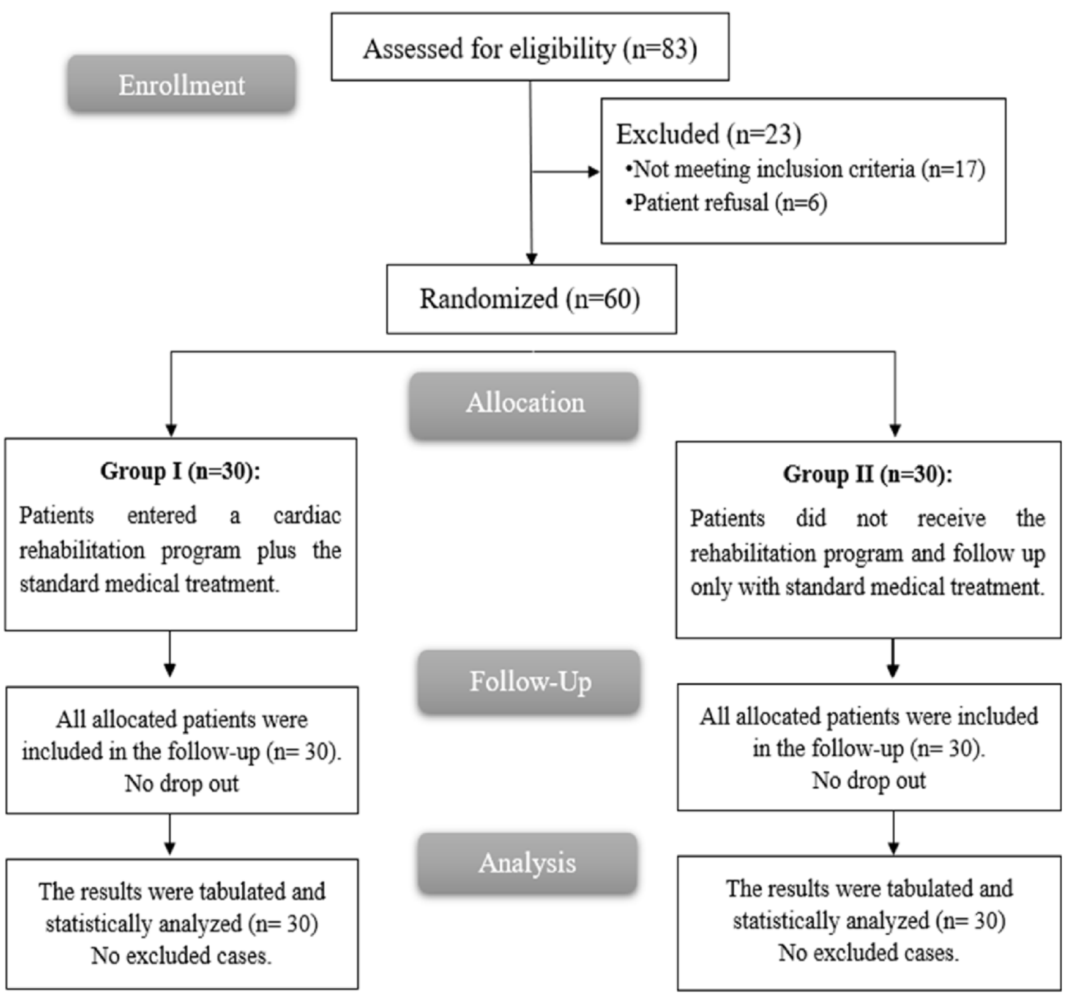

Fig. 1. CONSORT flowchart of the enrolled patients.

There was nonimportant variance among both groups regarding cardiovascular risk factors, demographic criteria, and time to PCI (Table 1).

METS and exercise duration were insignificantly variant among both groups at the baseline, while exercise duration was significantly higher in group 1 than group 2 at follow-up ($P = 0.006$), and METS was significantly higher in group 1 than group 2 at follow-up ($P < 0.001$). METS was significantly higher in follow-up research in group 1 ($P < 0.001$), while it was insignificantly different between baseline and follow-up studies in group 2 (Table 2).

Table 1. Cardiovascular risk factors, demographic criteria and time to percutaneous intervention.

Demographic data			
Age (years)	54.5 ± 8.72	55.07 ± 6.51	0.777
Gender			
Male	21 (70)	18 (60)	0.417
Female	9 (30)	12 (40)	
BMI (kg/m^2)	33.5 ± 2.59	30.03 ± 2.8	>0.05
Smoking	19 (63.33)	15 (50)	0.297
Time to PCI (min)			
	28.6 ± 3.29	28.2 ± 3.04	0.627
Cardiovascular risk factors			
DM	16 (53.33)	16 (53.33)	1.00
HTN	21 (70)	17 (56.67)	0.284
Dyslipidaemia	28 (93.33)	22 (73.33)	>0.05
FH	3 (10)	4 (13.33)	0.688

Data are presented as average ± SD or *n* (%).
DM, diabetes mellitus; FH, familial hypercholesterolemia; HTN, hypertension; PCI, percutaneous intervention.

Data are demonstrated as average ± SD. METS, significant as P value less than or equal to 0.05.

HRR first min after exercise was no important variant among both groups at the baseline and significantly higher in group 1 than group 2 ($P < 0.001$) at follow-up. HRR second minute after exercise was significantly higher follow-up than at baseline rehabilitation in group 1 ($P < 0.001$) while was insignificantly variant among follow-up and baseline in group 2 (Table 3). 2D TTE [left ventricular end-diastolic diameter (LVEDD)/FU, LVESD/FU, EF/FU%, and FS/FU] was insignificantly variant among both groups at follow-up and baseline. left ventricular end systolic volume (LVESV) was insignificantly variant among follow-up and baseline after rehabilitation in group 1, while was significantly higher at follow-up after than baseline in group 2 ($P < 0.001$). EF was insignificantly variant between follow-up and baseline after rehabilitation in group 1, while it was significantly higher at follow-up than at baseline in group 2 ($P = 0.008$) (Table 4).

4. Discussion

CVD is a prevalent contributor to healthcare challenges on a worldwide scale. The yearly

Table 2. Comparison of effort tolerance by metabolic equivalent, exercise duration, at baseline and after follow-up among the studied groups.

	Group 1 ($N = 30$)	Group 2 ($N = 30$)	P value
Exercise duration			
Baseline	3.96 ± 0.98	3.98 ± 0.82	0.924
Follow-up	7.29 ± 1.35	6.37 ± 1.12	0.006*
METS			
Baseline	4.27 ± 0.92	3.88 ± 0.6	0.062
Follow-up	9.15 ± 1.56	3.72 ± 0.73	<0.001*
P value between follow-up and baseline	<0.001*	0.359	

Data are demonstrated as average ± SD.
METS, metabolic equivalent.
*Significant as P value less than or equal to 0.05.

Table 3. Heart rate recovery at after follow-up and baseline among the studied groups.

	Group 1 ($N =$ thirty)	Group 2 ($N = 30$)	P value
HRR first min after exercise (bpm)			
Baseline	13.54 ± 2.85	13.57 ± 3.61	0.965
Follow-up	22.07 ± 5.34	13.67 ± 3.1	<0.001*
P value between before and after	<0.001*	0.915	
HRR second min after exercise (bpm)			
Baseline	24.69 ± 3.52	23.83 ± 2.19	0.257
Follow-up	44.98 ± 7.5	23.88 ± 2.39	<0.001*
P value between before and after	<0.001*	0.919	

Data are demonstrated as average ± SD.
HRR, heart rate recovery.
*Significant as P value less than or equal to 0.05.

Table 4. *Three-dimensional transthoracic echocardiogram and −two-dimensional transthoracic echocardiogram data at baseline and after follow-up among study groups.*

	Group 1 ($N = 30$)	Group 2 ($N = 30$)	P value
LVEDD/FU (mm)			
Baseline	5.32 ± 0.3	5.3 ± 0.29	0.761
Follow-up	5.17 ± 0.58	5.24 ± 0.51	0.623
LVESD/FU (mm)			
Baseline	5.47 ± 7.29	6.54 ± 9.53	0.628
Follow-up	4.93 ± 5.9	5.96 ± 8.05	0.574
EF/FU %			
Baseline	42.83 ± 3.47	40.13 ± 6.63	0.053
Follow-up	47.47 ± 5.76	44.07 ± 7.94	0.063
FS/FU			
Baseline	20.7 ± 2.1	20.27 ± 2.21	0.440
Follow-up	23.2 ± 3.37	21.83 ± 3.33	0.120
LVEDV/FU			
Baseline	115.95 ± 9.82	119.88 ± 11.09	0.151
Follow-up	118.8 ± 18.17	141.16 ± 23.34	<0.001*
P value between before and after	0.408	<0.001*	
LVESV/FU			
Baseline	67.13 ± 7.12	70.47 ± 8.5	0.105
Follow-up	67.66 ± 17.01	94.44 ± 26.76	<0.001*
P value between before and after	0.849	<0.001*	
EF/FU %			
Baseline	42.17 ± 3.14	41.33 ± 3.24	0.308
Follow-up	42.26 ± 7.06	47.36 ± 11.08	0.038*
P value between before and after	0.945	0.008*	

Data are demonstrated as average ± SD.
EF, ejection fraction; FS, fractional shortening; FU, follow up; LVEDD, left ventricular end-diastolic diameter; LVESV, left ventricular end systolic volume; TEE, transthoracic echocardiogram.
*Significant as *P* value less than or equal to 0.05.

incidence of disability morbidity and mortality resulting from CVD is increasing. CVD is responsible for about 30% of all-cause death and 10% of disability worldwide.[19]

The use of transthoracic 2DE has been significant in the characterization and detection of LV remodelling. The use of 3DE offers a higher level of accuracy in the examination of LV function and shape. This method avoids the need to make geometric assumptions and remains unaffected by the issue of foreshortening. In addition, the 3DE technique demonstrated similar outcomes to the established gold standard method of cardiac magnetic resonance imaging, despite its tendency to underestimate volumetric measurements.[17] Nevertheless, the benefits of 3DE include more accessibility, reduced time and expense, and reduced effort.[20]

According to previous research, DM is present in 21–25%[21] or even 35% of patients with a STEMI diagnosis.[22] HRR first minute after exercise was with a mean value (±SD) of 13.54 ± 2.85 bpm in group 1 and 13.57 ± 3.61 bpm in group 2 at the baseline with no important variant among both groups and was with a mean value (±SD) of 22.07 ± 5.34 bpm in group 1 and 13.67 ± 3.1 bpm in group 2 at follow-up research with significantly higher in group 1 than group 2 ($P < 0.001$). HRR first minute after exercise was significantly higher at follow-up than at baseline in group 1 ($P < 0.001$), while it was insignificantly important variant follow-up and baseline in group 2.

HRR second minute after exercise was with an average value (±SD) of 24.69 ± 3.52 bpm in group 1 and 23.83 ± 2.19 bpm in group 2 at baseline with no important variant between both groups and was with an average value (±SD) of 44.98 ± 7.5 bpm in group 1 and 23.88 ± 2.39 bpm in group 2 follow-up with significantly higher in group 1 than group 2 ($P < 0.001$). HRR second minute after exercise was significantly higher follow-up than at baseline rehabilitation in group 1 ($P < 0.001$) while was insignificantly variant important follow-up and baseline in group 2.

This agrees with Khorshid *et al.*,[23] who demonstrated that HRR developed significantly after first and second minutes after completion of the CR program. They also demonstrated an important decline in resting HR after the exercise training program. Our findings are supported by Jolly *et al.*[12] who showed that HRR significantly improved after phase two CR exercise training.

Another research by Giallauria *et al.*,[24] demonstrated that patients who participated in an exercise training program had enhanced HR recovery upon completion of the program. Conversely, patients who received general directions to maintain physical activity upon discharge did not see any improvements in HR recovery.

In our research, exercise duration was insignificantly different between both groups at the baseline, while it was significantly higher in group one than group two at follow-up ($P = 0.006$). METS was insignificantly different between both groups at the baseline study and significantly higher in group 1 than group 2 at follow-up ($P < 0.001$). METS was significantly higher in follow-up study in group 1 ($P < 0.001$) while it was insignificantly variant between baseline and follow-up studies in group 2.

This is in line with Khorshid *et al.*,[23] who reported that the researchers noticed an important boost in functional ability within their study, as shown by a substantial increase in exercise duration and METS after the end of the rehabilitation program ($P < 0.01$).

Another research that agreed with our findings was done by Parvand *et al.*,[25] who demonstrated an important elevate in METS value from secondary post-test to primary ($P < 0.05$).

Similarly, Yang *et al.*[26] demonstrated that the exercise group exhibited enhancements in overall exercise duration and maximal exercise capacity compared to the control group after undergoing PCI.

Regarding 2D TTE parameters, we found that LVEDD/FU, LVESD/FU, EF/FU%, and FS/FU were insignificantly different between both groups at baseline and follow-up. In group 1, there was an important decline in both LVEDD and LVESD values, suggesting some improvement in ventricular function. The EF and FS values also showed improvement at follow-up, with both measures increasing from baseline.

Also, baseline 3D-TTE data showed no important differences between the two groups of LVEDV, LVESV, and EF. However, at follow-up, LVEDV and LVESV were significantly higher in group 2 compared to group 1 ($P < 0.001$), indicating greater LV remodeling in group 2. EF was also significantly higher in group 2 compared to group 1 at follow-up ($P = 0.008$). In group 1, there were no important differences in LVEDV, LVESV, and EF between baseline and follow-up after rehabilitation. In contrast, in group 2, there were significant increases in LVEDV and LVESV at follow-up compared to baseline ($P < 0.001$), indicating greater LV remodeling. However, EF improved significantly in both groups at follow-up after rehabilitation compared to baseline ($P = 0.038$ in group 2 and not significant in group 1).

This is in accordance with Khorshid *et al.*[23] The study demonstrated a statistically significant elevation in EF after the completion of the rehabilitation program ($P < 0.01$). Additionally, a considerably greater improvement in EF was observed among patients with inferior infarction compared to those with anterior infarction ($P < 0.01$).

Furthermore, Zhang and Chang[27] reported that, the LVEF shown a significant enhancement in the patients who engaged in exercise compared to those who did not participate in exercise. No statistically important differences were observed in LVEDD, 6-min walk distance, or coronary artery bypass grafting between the two groups undergoing PCI with or without exercise. LVEF, LVEDD, and 6-min walk distance are often used in the assessment of cardiac function. The patients who underwent exercise rehabilitation 6 months following PIC exhibited a significant improvement in cardiac function as compared to those who received standard care.

Haykowsky *et al.*[28] found that LVEF was significantly improved in 1029 patients with acute MI who had exercise rehabilitation for 3 months.

Poortaghi *et al.*[29] observed that individuals who underwent 45 days of rehabilitation training had more notable improvements in heart function and exercise capacity compared to the control group. Moreover, Yang *et al.*[26] demonstrated a significant enhancement in the exercise group as compared to the control group after PCI.

Giallauria *et al.*[30] confirmed the favorable effects of early exercise-based CR on LV remodeling and myocardial perfusion.

The primary pathophysiological foundation of reverse LV remodeling in early CR patients may include the enhancement of LV diastolic filling and the mitigation of stress-induced myocardial ischemia after an infarction.[31] CRT pacing continues to demonstrate the advantageous characteristic of LV reverse remodeling. There exists a substantial body of research indicating that the volume characteristics of the LV exhibit a reduction in response to CRT pacing. Conversely, the deactivation of the CRT device results in a progressive rise in LV volume.[32]

The facilitation of decline in LVESV by reverse remodeling is influenced by optimum medical treatment, wherein both β-blockers and angiotensin-converting enzyme inhibitors play a role.[33] Additionally, it has been shown that the use of a LVAD leads to a decline in LV volume.[34] In addition, the research by Mitro *et al.*[35] showed that LV strain rate heralded the response to CRT.

The AMICI research provided data supporting the need of reducing ST-segment elevation after PCI as a critical factor LV reverse remodeling.[36] In the Japanese study by Morishita *et al.*[37] The use of LV reverse modelling was seen in 52% of the patient population, even while adhering to the stringent requirement of a minimum of 15% decrease in LVAD.

This research has several limitations: a single-center research with a relatively small sample size, did not include a control group that did not undergo cardia, which limits the ability to make definitive conclusions about the effectiveness of rehabilitation, the follow-up period was relatively short and did not evaluate the impact of other factors, such as medication adherence and lifestyle modification, on LV remodeling and function.

4.1. Conclusion

CR has been shown to have a beneficial effect on exercise capacity and LV remodeling in individuals with STEMI who have had delayed PCI. The delayed commencement of CR was shown to be correlated with a higher degree of LV remodeling. The use of 3D-ECG has the potential to provide significant insights into LV function and remodeling.

Conflicts of interest

No one of the authors has conflict of interest.

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