Original article

Effects of a cardiac rehabilitation program on systolic function and left ventricular mass in patients after myocardial infarction and revascularization

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BACKGROUND: Supervised exercise-based cardiac rehabilitation programs (CRP) have been suggested to all patients, especially after myocardial infarction. However, the effects of cardiac rehabilitation on systolic function are controversial. The aim of this study was to examine the effects of an 8-week cardiac rehabilitation on left ventricular systolic function and left ventricular mass in patients with myocardial infarction (MI) and revascularization. **METHODS:** This study included 29 men with MI after reperfusion therapy, i.e. coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI). The patients were randomized into a training group (n = 15, mean age: 54.2 ± 9.04 years) and a control group (n = 14, mean age: 51.71 ± 6.98 years). The training group performed 8 weeks of CRP with an intensity of 60-85% of maximum heart rate, 3 times a week. Each session lasted for 60 minutes. Before and at the end of the study, all patients underwent 2-dimentional echocardiography for left ventricular systolic function and left ventricular mass to be assessed. **RESULTS:** After 8 weeks of CRP, left ventricular ejection fraction (LVEF) increased significantly in the training group (48.53 ± 10.41 vs. 59.13 ± 5.90; $p < 0.001$). Moreover, the difference in LVEF between the training and control groups were significant after the course (59.13 ± 5.90 vs. 55.90 ± 9.60; $p < 0.001$). In addition, stroke volume increased significantly (57.22 ± 7.84 ml vs. 64.03 ± 12.80 ml; $p < 0.001$) while left ventricular systolic volume decreased significantly (42.89 ± 17.32 ml vs. 31.00 ± 8.34 ml; $p < 0.001$) in the training group. CRP was decreased left ventricular mass in the training group (229 ± 42 vs. 196 ± 34; $p < 0.05$). **CONCLUSIONS:** A 2-month CRP in post-MI patients led to improvements in systolic function and reductions in left ventricular mass and thus cardiomegaly.

KEYWORDS: Rehabilitation, Systolic Function, Left Ventricular Mass, Post-Myocardial Infarction

BACKGROUND

Coronary heart disease (CHD) is the leading cause of death worldwide and has reached epidemic proportions.[1,2] The prevalence of CHD has increased markedly in Iran during recent years.[3] Myocardial infarction (MI) has tremendous impacts on public health. It is still ranked as the third leading cause of death in the U.S. and is also the leading cause of serious, long-term disability.[4] Current treatment of patients after MI often includes exercise training as an element of cardiac rehabilitation program (CRP). Physical activity has been shown to have substantial benefits for patients after MI, and may reduce the risk of mortality after a heart attack by 20%.[5] It has also been shown to impact CHD risk factors by reducing resting blood pressure, management of body weight, improving lipid profile, increasing insulin sensitivity and fibrinolytic activity, decreasing blood clotting, and helping as part of smoking cessation.[6-9]

Nevertheless, the effects of exercise training on left ventricular (LV) systolic function have remained controversial.[10-15]

Cardiac hypertrophy in response to hypertension or MI is a pathological indicator associated with heart failure.[10] Physical activity is known to affect LV structure and induce hypertrophy and dilation as normal physiologic adaptations whose relative magnitude depends on the type and intensity of the exercise.[16-18] Exercise of relatively low to moderate intensity and duration has been shown to decrease blood pressure[6] and possibly cause regression of LV mass (LVM) among hypertensive subjects.[19] Recent evidence in animal subjects has indicated that exercise training can attenuate or reverse pathological remodeling and create a physiological phenotype.[10] However, the effects of physical activity on LVM in patients after MI has not been established. The aim of this study was to examine the effects of a CRP on LV systolic function and mass in patients with MI and revascularization.

METHODS

This was a randomized, controlled trial to examine the effects of a 2-month CRP on LV function in patients following MI with coronary intervention

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during 2009-10 in Chamran Hospital (Isfahan, Iran). Our study comprised 29 male patients with a history of S-T elevation MI who were treated with primary percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG). After undergoing baseline testing, the subjects were allocated to the training group (15 patients aging 54.2 ± 9.04 years) and the control group (14 patients aging 51.71 ± 6.98 years). The training group participated in an 8-week supervised exercise program, whereas the control group was instructed to maintain their current lifestyle. The training group referred to the cardiac rehabilitation center in Chamran Hospital and completed 24 sessions of CRP. All the study subjects were regularly followed up in the cardiac rehabilitation clinic. Clinical characteristics of the two groups are outlined in table 1.

Patients were excluded if they had unstable angina, resting blood pressure > 200 mmHg and resting diastolic blood pressure > 100 mmHg, acute systemic illness, or uncontrolled tachycardia and bradycardia. All patients with PCI started outpatient CRP after 4 weeks of intervention. In CABG patients, the duration between surgery and the start of CRP was 8 weeks. The study protocol was reviewed and approved by the Ethics Committee of Isfahan Cardiovascular Research Center (Isfahan, Iran) and a written informed consent was obtained from every patient. This study was registered in the Iranian Registry of Clinical Trials (No. IRCT201011085136N1).

A checklist was completed for the patients at the time of admission according to medical history and physical examination by trained general practitioners, physiotherapists, and nurses. To determine functional capacity, patients performed an exercise test (Naughton protocol) under the supervision of a cardiologist without withholding medication.[20] Resting systolic and diastolic blood pressure was measured in sitting position before exercise for all patients in the training group.

The CRP

The rehabilitation program comprised 24 exercise sessions, scheduled over 8 weeks in the cardiac rehabilitation center of Chamran Hospital. Each session took 60-90 minutes and included 10-20 minutes of warm-up followed by 20-40 minutes of aerobic exercise and a final 10-minute cool-down. In addition, there was a 20-minute relaxation at the end of each session. According to the determined risks, the intensity of the exercise was calculated as 60-85% of the maximum heart rate (HR) achieved on the exercise test.[21] The exercise was performed under electrocardiographic monitoring if the patient was at high risk. All patients received psychological, nutritional, and smoking cessation consultations. In addition, there were weekly educational sessions during the 8 weeks of CRP, for both patients and their families. It consisted of explanations on cardiovascular diseases, introducing risk factors, diagnoses and treatment approaches, medications and their complications, stress reduction methods, and advices on healthy lifestyle including smoking cessation, nutrition, and physical activity. For all patients who completed the whole CRP, the tests were re-conducted at the end of the study.

Echocardiography

Echocardiographic measurements were performed before and after 24 sessions of CRP by VIVID 3 Ultrasound Machine (General Electric). LV dimensions, ejection fraction (EF), stroke volume (SV), and LV volumes were measured in the supine position by 2-dimentional M-mode echocardiography according to the guidelines of American Society of Echocardiography.[22] Ejection fraction and stroke volume were measured using Simpson's biplane method.

LVM was measured via M-mode and dimensional echocardiography with the following formula:

$$LVM = (1.04)[(LVEDD + PWT + IVS)3 - (LVEDD)3]$$

in which LVEDD = left ventricular end diastolic dimension, PWD = posterior wall thickness, and IVS = interventricular septal thickness.[23]

Statistical analysis

All data is expressed as mean ± standard deviation (SD). Paired student's t-test was used to compare significant differences of the same variables within the groups before and after the CRP period. Differences between the two groups were analyzed using analysis of covariance.

The statistical package for social sciences version 16.0 (SPSS Inc., Chicago, IL, USA) for Windows was used for data analysis. P values less than 0.05 were considered to be statistically significant.

RESULTS

Baseline characteristics of the study population are listed in table 1. There were no significant differences between the training and control groups in baseline clinical variables and therapy. Table 2 presents echocardiographic indices of LV systolic including LV end diastolic dimension (LVEDD), LV end systolic dimension (LVESD), LV end diastolic volume (LVESV), LV end systolic volume (LVEDV), EF, SV, and LVM.

Table 1. Baseline characteristics of participants in the training and control groups

Characteristics	Training group	Control group	P-value
Number	15	14	NS
Age (Years)	9.04 ± 54.20	51.71 ± 6.98	NS
Height (m)	167.66 ± 4.62	172.64 ± 6.58	NS
Weight (kg)	75.16 ± 11.69	78.75 ± 10.84	NS
SBP at rest	131.00 ± 16.80	121.78 ± 17.49	NS
DBP at rest	76.00 ± 11.80	75.71 ± 12.22	NS
Myocardial Infarction			
Anterior	9	7	NS
Inferior	6	7	
CABG	8	7	NS
PCI	7	7	NS
Risk factors:			
*Hypertension**	2	3	NS
*Hyperlipidemia**	8	9	
*Diabetes**	2	3	
*Positive family history**	7	6	
Smoking	5	6	NS
Medications:			
Beta blockers	15	14	
ACE inhibitors	15	14	NS
Statins	15	14	
Anticoagulants	15	14	

Data is expressed as mean ± SD or numbers. NS: Not significant; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; CABG: Coronary artery bypass grafting; PCI: Percutaneous coronary intervention; ACE: Angiotensin-converting-enzyme *History of, or being on treatment for the risk factor

Table 2. Echocardiographic indices of left ventricular systolic function and left ventricular mass before and after the cardiac rehabilitation program

Variables	training group				Control group			
	Pretest	Post test	t	P-value	Pretest	Post test	f	P-value
LVEDD (cm)	5.11 ± 1.16	5.03 ± 1.10†	-4.47	NS	4.61 ± 0.51	5.10 ± 0.63	10.70	0.001
LVESD (cm)	3.39 ± 1.04	3.40 ± 1.03	-1.29	NS	3.23 ± 0.61	3.50 ± 0.72	0.55	NS
LVEDV (ml)	84.65 ± 28.24	76.53 ± 19.24	1.63	NS	80.50 ± 32.25	85.90 ± 39.40	3.98	NS
LVESV (ml)	42.89 ± 17.32	31.00 ± 8.34**	2.82	0.001	42.07 ± 26.70	38.40 ± 23.50	3.60	NS
EF	48.53 ± 10.41	59.13 ± 5.90†**	-3.54	0.001	50.70 ± 13.25	55.90 ± 9.60	2.30	0.001
SV (ml)	57.22 ± 7.84	64.03 ± 12.80**	-3.84	0.001	56.60 ± 14.25	57.25 ± 17.64	2.04	NS
LVM (g)	229.00 ± 42.00	196.00 ± 34.00*	3.32	0.050	253.92 ± 82.66	218.50 ± 74.00	0.17	NS

LVEDD: Left ventricular end diastolic dimension; LVESD: left ventricular end systolic dimension; LVEDV: Left ventricular end diastolic volume; LVESV: Left ventricular end systolic volume; EF: Ejection fraction; SV: Stroke volume
NS: Not significant
***:** Significant difference between pre and post test values in the training group ($p \le 0.05$)
**: Significant difference between pre and post test values in the training group ($p \le 0.001$)
†: Significant difference in changes of the mean values between the two groups ($p \le 0.001$)

Table 3. Comparison of left ventricular mass (LVM) between patients with coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI)

Groups		LVM-pre	LVM-post	Δ	P-value
Training group (n = 15)	PCI (n = 7)	218.00 ± 42.03	190.14 ± 36.69	-12.78%	0.114
	CABG (n = 8)	239.50 ± 42.30	201.75 ± 34.80	-10.34%	0.031
Control group (n = 14)	PCI (n = 7)	246.00 ± 87.35	220.57 ± 51.09	-15.76%	0.311
	CABG (n = 7)	261.86 ± 83.83	216.57 ± 97.38	-17.29%	0.028

Comparisons of the effects of CRP on systolic function and LVM in patients with PCI and CABG revealed no significant differences between the two groups. Table 3 shows that patient with CABG in the training and control groups had lower LVM than patients with PCI.

DISCUSSION

The aim of this study was to investigate the effects of an 8-week CRP on systolic and diastolic function and LVM in post-MI patients. The results of the current study showed that 8 weeks of CRP had positive effects on LV systolic function and decreased LVM in the participants.

CRP and systolic function

Physical training is currently recommended for patients after acute MI.[6-14,24] It is also suggested for patients with other cardiac conditions since some studies have reported the possibility of improving ventricular function through physical training in selected patients with coronary disease.[14] However, the available data is limited and often contradictory.[5-9,24,25]

The present controlled trial was specifically designed to address whether regular exercise influences LV function in patients with MI. Our data confirmed 2 months of CRP to be effective on improving systolic function in these patients. The major findings of the present study were the observed significant improvements in SV and EF in the training group. Moreover, while LVESV decreased significantly, LVEDV, LVESD, and LVEDD had no significant changes in the training group. On the other hand, LVEDD increased significantly in the control group.

Similar results were reported in patients with acute MI,[12] mild heart failure,[14] heart failure,[24] and chronic heart failure,[26] as well as men with reduced LV function.[28] However, the findings of Yu et al.[27] and Gondoni et al.[28] are inconsistent with our results. Shorter course of regular exercise (3 weeks compared with 8 weeks in our study) or less intensity of exercises may have caused the differences between these results.

The results of this study suggested that in patients with acute MI, a 2-month CRP was associated with significant reduction in afterload. This beneficial effect of training leads to a small but significant improvement in SV and reduces cardiomegaly.[12,13] Significant improvements in SV might be due to reduction in peripheral resistance and improvement in endothelial function after regular exercise.[26] Our results also showed significant decrease in end systolic volume or afterload which improve SV.

CRP and LVM

Findings of this study showed that CRP significantly decreased LVM in the training group. In contrast, the changes were not significant in the control group. We also found that patients with CABG in both the training and control groups had lower LVM than patients with PCI. However, the mechanism causing this difference is unclear.

Rodriguez et al. showed reduced LVM in patients with high physical activity. They also reported the risk of stroke to progressively decrease with increasing the duration of physical activity. They found a significant decrease in mean LVM with increasing duration of exercise.[19]

Erbs et al. suggested that exercise training in heart failure patients decreased cardiomegaly.[29] In animal subjects, aerobic endurance training has been found to attenuate the ventricular and cellular hypertrophy in failing hearts. Furthermore, training consistently restored contractile function, intracellular Ca^{+2} handling, and Ca^{+2} sensitivity in cardiomyocytes from rats with MI.[30]

CONCLUSIONS

In conclusion, CRP had no significant effects on diastolic function but improved systolic function. Therefore, supervised CRP can be of value for post-MI patients. CRP in patients with myocardial infarction results in significant improvements in EF and SV and reduces cardiomegaly.

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