Original Article

Evaluation of the Effect of Cardiac Rehabilitation on Left Ventricular Diastolic and Systolic Function and Cardiac Chamber Size in Patients Undergoing Percutaneous Coronary Intervention

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Abstract

Background: *Exercise and rehabilitation are important methods for decreasing the risk factors of coronary artery disease (CAD). We aimed to evaluate the effect of the cardiac rehabilitation (CR) exercise program on the cardiac structure and physiology in patients undergoing percutaneous coronary intervention (PCI).*

Methods: *In this randomized controlled study, 146 patients with CAD were divided equally into two groups: case group (undertaking CR after PCI) and control group (without rehabilitation after PCI). All the patients in the case group underwent echocardiography (before and after CR), and echocardiography was performed for the control group simultaneously. The CR exercise program encompassed 24 sessions, twice or three times a week, with each session lasting between 15 and 45 minutes, depending on the individual patient's tolerance. Left ventricular (LV) ejection fraction, LV diastolic function, LV end-systolic and diastolic diameter, and right ventricular (RV) end-diastolic diameter were measured in the CR group before and after rehabilitation and compared to those in the control group at the same times.*

Results: *In this study, 146 patients (46 female and 100 male) were evaluated: 73 in the rehabilitation group and 73 in the control group. The mean age of the patients in the CR and control groups was 58.05 ± 10.27 and 56.76 ± 10.07 years, respectively. The CR exercise program had useful effects on LV diastolic function after PCI. The distribution of LV diastolic dysfunction after the CR exercise program was changed significantly only in the CR group (p value = 0.043). In the CR group, normal, grade I, grade II, and grade III LV diastolic dysfunction were observed in 20.5%, 69.8%, 6.8%, and 2.7%, respectively. This distribution was changed respectively to 30.1%, 61.6%, 5.4%, and 2.7% following CR, which showed a significant improvement due to CR in LV diastolic function, most prominently in the patients with grade I diastolic dysfunction (p value = 0.390). There was no significant change in LV and RV diameter before and after rehabilitation, while the ejection fraction increased significantly (p value < 0.05) in both groups.*

Conclusion: *The RC exercise program can be effective in the augmentation of LV diastolic dysfunction after PCI, without significant changes in LV diameters.*

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Introduction

The incidence of coronary artery disease (CAD) has been on the increase worldwide. Management of CAD patients is conducted by various techniques such as thrombolytic therapy and percutaneous coronary intervention (PCI) as well as medications such as angiotensin-converting enzyme inhibitors, β-blockers, and statins, all of which affect cardiac function and exercise capacity.

Cardiac rehabilitation (CR) is performed for patients diagnosed with a history of myocardial infarction, CAD, and chronic stable angina and also after PCI.[1, 2] Previous studies have demonstrated that the CR program in various forms, including training and educating, enhanced results in CAD patients and was associated with a reduction in mortality and post-myocardial infarction re-infarction.[3, 4] Nevertheless, the mechanisms of these improvements in certain aspects of cardiac function, either systolic or diastolic,[5] and other related non-cardiac factors are still controversial.[6, 7]

There are only a few studies on the assessment of diastolic function in patients with heart failure after rehabilitation.[8-11] These studies have reported an increase in stroke volume and left ventricular ejection fraction (LVEF) as well as a decrease in heart rate and diastolic arterial pressure. In the present study, we aimed to evaluate the effect of the CR exercise program on CAD patients who underwent PCI by measuring and comparing their diastolic and systolic functions as well as ventricular dimensions with those of un-rehabilitated CAD patients who underwent PCI.

Methods

This study recruited 146 documented cases of CAD (by angiography), who underwent PCI. All of the patients underwent transthoracic echocardiography before and after the CR exercise program. Our exclusion criteria were patients with valvular heart disease, unstable myocardial ischemia, active myocarditis or pericarditis, end-organ failure due to diabetes and hypertension, arterial fibrillation, history of radiation and chemotherapy, and morbid obesity. Also, patients with advanced heart failure or complicated post-coronary artery bypass graft (CABG) patients who underwent PCI or those who could not tolerate rehabilitation due to any other causes were excluded from this study.

The patients were divided into two equal groups: the CR exercise program group and the control group. Both groups were selected from the patients having undergone PCI in the preceding two to four weeks.

The CR exercise program comprised 24 sessions, twice or three times weekly, with each session lasting between 15 and 45 minutes, based on the individual patient's endurance. This rehabilitation program included 5 minutes of stretching and warm up, followed by treadmill, rowing, stepping, and ergometry.

The CR exercise program, as was described before, was comprised of four phases.[12] In brief, phase I was an inpatient rehabilitation program that lasted between seven and fourteen days and was commenced after PCI. Phase II was an outpatient exercise and education program, three times weekly, with each session lasting between two and three months. Each session contained one hour of education followed by two hours of exercise training under electrocardiography (ECG) monitoring. Phase III was a community-based home exercise program between six and twelve months. And phase IV was a long-term follow-up program until the end of the second post-PCI year, which included half-yearly monitoring of lipid profiles. The crux of this phase was the importance of regular exercise and risk factor modification.

All the studied individuals were regularly followed up in our Rehabilitation Clinic. All the procedures were approved by the Ethics Committee of Tehran University of Medical Sciences, and informed consent was obtained from all the patients.

Standard echocardiography was performed for all the patients on days three and seven post PCI and on the termination of the CR exercise program (or simultaneously without rehabilitation for the control group). LVEF was measured using the Simpson method. Resting LV dimensions were measured via two-dimensional guided M-Mode method, and LV end-diastolic dimension (LVEDD) and LV end-systolic dimension (LVESD) were measured at the level of the mitral leaflet tips at one third of the distances along the length of the long axis from the parasternal long-axis view. Left atrial dimension (LAD) was measured at the end of systole, when the atrium is at the largest size. The measurement of right ventricular end-diastolic dimension (RVEDD) was performed at the base of the Right ventricle (RV) from apical four- chamber view.

In this study, LV diastolic dysfunction was classified as (A) normal pattern, defined as early to late mitral inflow velocities (E/A) ≥ 1.5, deceleration time (DT) = 160-240 msec, early mitral annulus velocity (e') ≥ 10 cm/sec, and early mitral inflow velocity to early mitral annulus velocity (E/e') < 8; (B) grade I or mild diastolic dysfunction or abnormal relaxation pattern (ARP), defined as transmitral early to atrial filling velocity ratio (MV-E/A) < one and deceleration time of early filling (MV-DT) > 240 msec; (C) grade II or moderate diastolic dysfunction, defined as E/A

= 1-1.5 and normal DT = 160-240 msec, E/e' ≥ 10, but an abnormal pulmonary venous flow profile with pulmonary venous flow reversal exceeding the duration of the mitral a duration;[13, 14] and (D) grade III-IV or restrictive filling pattern (RFP) with severe diastolic dysfunction, defined as mitral valve inflow velocities (MV-E/A) ratio > 2, MV-DT < 160 msec, and isovolemic relaxation time (IVRT) < 70 msec.[15-17]

The data are expressed as mean ± SD. Changes in the prevalence of LV diastolic dysfunction in normal, grade I, grade II, and grade III, before and after CR, were computed and then compared between the CR and control groups using the $\chi2$ test. Diastolic function before and after the study period in each group was compared using the McNemar-Bowker test. Also, EF, LVEDD, LVESD, LAD, and RVEDD before and after the study period were compared using the paired sample T-test and analysis of covariance. The Kolmogorov-Smirnov test was used to check the normality of data. A one-tailed p value less than 0.05 was considered statistically significant.

Results

The study population comprised 146 patients (46 female and 100 male), who were equally classified into two groups: the CR exercise program group and the control group. A comparison of the baseline characteristics of the CAD patients between the two groups is presented in Table 1. There were no differences in terms of age or gender between the two groups. At the beginning of the study, the LV diastolic dysfunction distribution between the CR and control individuals was not significant (p value = 0.264); however, this distribution after the CR exercise program was changed significantly only in the CR exercise group (p value = 0.03) (Table 2). In the CR exercise group, the LV diastolic dysfunction distribution was normal in 20.5%, grade I in 69.8%, grade II in 6.8%, and grade III in 2.7%; grade IV was not found in any patient. This distribution was changed respectively to 30.1%, 61.6%, 5.4%, and 2.7% after the CR exercise program.

Table 1. Comparison of the baseline characteristics of patients in cardiac rehabilitation (CR) and control groups*

Parameters	CR	Control	P value
Age (y)	58.05±10.27	56.76±10.07	0.446
Gender			0.373
Female	20 (27.3)	26 (35.6)	
Male	53 (72.6)	47 (64.3)	

*Data are presented as mean±SD or n (%)

Table 2. Prevalence of left ventricular diastolic dysfunction before and after cardiac rehabilitation*

	Diastolic dysfunction				P value
	Normal	Grade I	Grade II	Grade III	
CR Group					0.065**
Before	15 (20.55)	51 (69.86)	5 (6.85)	2 (2.74)	
After	22 (30.14)	45 (61.63)	4 (5.48)	2 (2.74)	
Control Group					0.370**
Before	32 (43.84)	38 (52.05)	2 (2.74)	1 (1.37)	
After	33 (45.21)	37 (50.68)	2 (2.74)	1 (1.37)	
CR Vs. Control					0.043***

*Data are presented as n (%)
**P value was computed using the McNemar-Bowker test
***P value was computed using the chi-squared test

Table 3. Changes in echocardiographic parameters in cardiac rehabilitation (CR) and control groups*

	CR group		P-Value	Control group		P value	P value** CR vs. Control
	Before	After		Before	After		
EF (%)	50.54±8.18	52.00±8.03	0.001	49.05±8.69	49.45±8.52	0.040	0.006
LVEDD (mm)	46.84±6.58	46.82±6.45	0.843	47.32±5.57	47.20±5.58	0.210	0.571
LVESD (mm)	30.43±5.41	30.65±5.15	0.169	31.27±4.79	31.15±4.50	0.227	0.070
LAD (mm)	33.39±4.78	33.04±4.75	0.059	32.50±4.40	32.20±4.50	0.061	0.822
RVEDD (mm)	23.98±10.83	23.56±10.59	0.122	24.80±10.67	24.77±10.67	0.843	0.200

*Data are presented as mean±SD
EF, Ejection fraction; LVEDD, Left ventricular end-diastolic dimension; LVESD, Left ventricular end-systolic dimension; LAD, Left atrial dimension; RVEDD, Right ventricular end-diastolic dimension
**P value was computed using the analysis of covariance

Table 3 depicts the LV diameters and EF findings before and after the CR exercise program. Our results showed that in both the CR exercise group and the control group, there was no significant change in the LV and RV diameters before and after rehabilitation, while the EF increased significantly (p value < 0.05) in both groups: this a fact that seems to be related to PCI and not the CR exercise program.

Discussion

This randomized controlled study was conducted to compare changes in cardiac chamber size and LV systolic and diastolic functions before and after the CR exercise program in CAD patients who underwent PCI. Our results demonstrated that LV diastolic function improved significantly after PCI followed by the CR exercise program. Furthermore, LVEF also improved significantly after PCI (with or without the CR exercise program). However, the effect of the CR exercise program on chamber diameters, i.e. LVEDD, LVESD, RVEDD, and LAD, was neutral. Similar studies have demonstrated positive effects of the CR exercise program on physical activity, hypertension, and lipid level of CAD patients.[18-20] In addition, it has been reported that the CR exercise program in individuals who underwent PCI enhanced quality of life, augmented lipid profile state, decreased mortality rates, and reduced admission time.[21, 22]

The existing literature contains only a few studies on the effect of the CR exercise program on the size and function of the cardiac chambers. Whereas some studies have demonstrated improvement in diastolic function after endurance exercise training in normal individuals,[14, 23] there are other studies reporting opposing results.[16, 17] Belardinelli et al.[24] observed betterment with less severe restrictive filling pattern in heart failure patients suffering from dilated cardiomyopathy and severe systolic dysfunction. Also, Yu et al.[11] observed a significant improvement in LV diastolic parameters with less prevalent abnormal relaxation pattern (ARP) after CR training programs in patients with acute myocardial infarction.

Our study showed that in patients with CAD undergoing PCI, the CR exercise program improved diastolic function. After the CR exercise program, the reduction in the prevalence of grade I and grade II diastolic dysfunction and, especially, the rise in normal diastolic function were significant in the CR exercise group but neutral in the control group. Similar to the Yu et al.[11] study on congenital heart disease patients, we found that the CR exercise program had beneficial effects in preventing the development of LV diastolic dysfunction in CAD patients. However, in our grade III diastolic dysfunction subgroup, there was no significant change in LV diastolic indices due to our small sample size.

Variations in EF after CR exercise training are a controversial issue. We found a significant increase after PCI with or without the CR exercise program. No change was reported in the Jensen et al.[23] and Cobb et al.[5] studies on patients with recent myocardial infarction, while other studies reported a mild and significant increment in EF after the CR exercise program.[11, 25] Although these studies[5, 23, 25] were addressed in a small sample size and uncontrolled trials, due to similar and significant variations in both control and CR groups, EF improvement was related to PCI not CR training.

There were no significant changes in chamber diameters after the CR exercise program in the present study. These findings support those of a previous study by Yu et al.[11] in congenital heart disease patients with severe LV systolic dysfunction.

Conclusion

In conclusion, the CR exercise program was effective on the betterment of LV diastolic dysfunction after PCI, without significant changes in the LV diameters, in our CAD patients.

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References

1. Ades PA. Cardiac rehabilitation and secondary prevention of coronary heart disease. N Engl J Med 2001;345:892-902.
2. Balady GJ, Ades PA, Comoss P, Limacher M, Pina IL, Southard D, Williams MA, Bazzarre T. Core components of cardiac rehabilitation/secondary prevention programs: a statement for healthcare professionals from the American Heart Association and the American Association of Cardiovascular and Pulmonary Rehabilitation Writing Group. Circulation 2000;102:1069-1073.
3. Lawler PR, Filion KB, Eisenberg MJ. Efficacy of exercise-based cardiac rehabilitation post-myocardial infarction: a systematic review and meta-analysis of randomized controlled trials. Am Heart J 2011;162:571-584.e2.
4. Ståhle A, Mattsson E, Rydén L, Unden A, Nordlander R. Improved physical fitness and quality of life following training of elderly patients after acute coronary events. A 1 year follow-up randomized controlled study. Eur Heart J 1999;20:1475-1484.
5. Cobb FR, Williams RS, McEwan P, Jones RH, Coleman RE, Wallace AG. Effects of exercise training on ventricular function in patients with recent myocardial infarction. Circulation 1982;66:100-108.
6. Kraus WE, Houmard JA, Duscha BD, Knetzger KJ, Wharton MB, McCartney JS, Bales CW, Henes S, Samsa GP, Otvos JD, Kulkarni KR, Slentz CA. Effects of the amount and intensity of exercise on plasma lipoproteins. N Engl J Med 2002;347:1483-1492.
7. Nishi I, Noguchi T, Iwanaga Y, Furuichi S, Aihara N, Takaki H, Goto Y. Effects of exercise training in patients with chronic heart failure and advanced left ventricular systolic dysfunction receiving β-blockers. Circ J 2011;75:1649-1655.
8. Teffaha D, Mourot L, Vernochet P, Ounissi F, Regnard J, Monpère

C, Dugué B. Relevance of water gymnastics in rehabilitation programs in patients with chronic heart failure or coronary artery disease with normal left ventricular function. J Card Fail 2011;17:676-683.
9. Kargarfard M, Rouzbehani R, Basati F. Effects of exercise rehabilitation on blood pressure of patients after myocardial infarction. Int J Prev Med 2010;1:124-130.
10. Amundsen BH, Rognmo Ø, Hatlen-Rebhan G, Slørdahl SA. High-intensity aerobic exercise improves diastolic function in coronary artery disease. Scand Cardiovasc J 2008;42:110-117.
11. Yu CM, Li LS, Lam MF, Siu DC, Miu RK, Lau CP. Effect of a cardiac rehabilitation program on left ventricular diastolic function and its relationship to exercise capacity in patients with coronary heart disease: experience from a randomized, controlled study. Am Heart J 2004;147:e24.
12. Yu CM, Lau CP, Cheung BM, Fong YM, Ho YY, Lam KB, Li LS. Clinical predictors of morbidity and mortality in patients with myocardial infarction or revascularization who underwent cardiac rehabilitation, and importance of diabetes mellitus and exercise capacity. Am J Cardiol 2000;85:344-349.
13. Vanoverschelde JJ, Essamri B, Vanbutsele R, d›Hondt A, Cosyns JR, Detry JR, Melin JA. Contribution of left ventricular diastolic function to exercise capacity in normal subjects. J Appl Physiol 1993;74:2225-2233.
14. Levy WC, Cerqueira MD, Abrass IB, Schwartz RS, Stratton JR. Endurance exercise training augments diastolic filling at rest and during exercise in healthy young and older men. Circulation 1993;88:116-126.
15. Forman DE, Manning WJ, Hauser R, Gervino EV, Evans WJ, Wei JY. Enhanced left ventricular diastolic filling associated with long-term endurance training. J Gerontol 1992;47:M56-58.
16. Jungblut PR, Osborne JA, Quigg RJ, McNeal MA, Clauser J, Muster AJ, McPherson DD. Echocardiographic Doppler evaluation of left ventricular diastolic filling in older, highly trained male endurance athletes. Echocardiography 2000;17:7-16.
17. Finkelhor RS, Hanak LJ, Bahler RC. Left ventricular filling in endurance-trained subjects. J Am Coll Cardiol 1986;8:289-293.
18. Hevey D, Brown A, Cahill A, Newton H, Kierns M, Horgan JH. Four-week multidisciplinary cardiac rehabilitation produces similar improvements in exercise capacity and quality of life to a 10-week program. J Cardiopulm Rehabil 2003;23:17-21.
19. Dolansky MA, Moore SM. Effects of cardiac rehabilitation on the recovery outcomes of older adults after coronary artery bypass surgery. J Cardiopulm Rehabil 2004;24:236-244.
20. Koivunen K, Isola A, Lukkarinen H. Rehabilitation and guidance as reported by women and men who had undergone coronary bypass surgery. J Clin Nurs 2007;16:688-697.
21. Lisspers J, Sundin O, Ohman A, Hofman-Bang C, Rydén L, Nygren A. Long-term effects of lifestyle behavior change in coronary artery disease: effects on recurrent coronary events after percutaneous coronary intervention. Health Psychol 2005;24:41-48.
22. Malfatto G, Blengino S, Annoni L, Branzi G, Bizzi C, Facchini M. Original articles primary coronary angioplasty and subsequent cardiovascular rehabilitation are linked to a favorable sympathovagal balance after a first anterior myocardial infarction. Ital Heart J 2005;6:21-27.
23. Jensen D, Atwood JE, Froelicher V, McKirnan MD, Battler A, Ashburn W, Ross J, Jr. Improvement in ventricular function during exercise studied with radionuclide ventriculography after cardiac rehabilitation. Am J Cardiol 1980;46:770-777.
24. Belardinelli R, Georgiou D, Cianci G, Berman N, Ginzton L, Purcaro A. Exercise training improves left ventricular diastolic filling in patients with dilated cardiomyopathy. Clinical and prognostic implications. Circulation 1995;91:2775-2784.
25. Verani MS, Hartung GH, Hoepfel-Harris J, Welton DE, Pratt CM, Miller RR. Effects of exercise training on left ventricular performance and myocardial perfusion in patients with coronary artery disease. Am J Cardiol 1981;47:797-803.