

## Exercise-based cardiac rehabilitation improves hemodynamic responses after coronary artery bypass graft surgery

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### Abstract

**BACKGROUND:** Cardiovascular disorders are an important public health problem worldwide. They are also the leading cause of mortality and morbidity. Therefore, American Heart Association proposed cardiac rehabilitation program as an essential part of care for cardiac patients to improve functional capacity. The aim of this study was to evaluate the effectiveness of cardiac rehabilitation program on functional status and some hemodynamic responses in patients after coronary artery bypass graft (CABG) surgery.

**METHODS:** Thirty two patients were selected for this study. All patients underwent cardiac surgery two months before admission. They were allocated to two groups. While the rehabilitation group (n =17, mean age: 62 ± 12 years) completed the cardiac rehabilitation program for two months, the reference group (n = 15, mean age: 58.5 ± 12.5 years) did not have any supervised physical activity during this period. Cardiac rehabilitation program consisted of exercise, nutritional, psychological consultation and risk factor management. At the beginning of the study, functional capacity of patients was evaluated by exercise test, 6-minute walking test and echocardiography. Functional capacity was evaluated for a second time after two months of cardiac rehabilitation. Data were analyzed by SPSS<sub>15</sub>. For comparing the mean of outcomes, Mann-Whitney test and Wilcoxon signed ranks test were used.

**RESULTS:** As a result of cardiac rehabilitation, a significant improvement was observed in the distance walked in the rehabilitation group (P < 0.01) compared to the reference group (P = 0.33). It also caused a significant development in hemodynamic responses to exercise such as resting and maximum systolic and diastolic blood pressure, resting and maximum heart rate, ejection fraction and rate pressure product.

**CONCLUSION:** Cardiac rehabilitation significantly improves functional capacity and some hemodynamic responses post coronary artery bypass grafting. Therefore, patients need to be referred to rehabilitation units.

**Keywords:** Cardiac Rehabilitation Program, Hemodynamic Responses, Coronary Artery Bypass Graft Surgery (CABG).

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### Introduction

Cardiovascular disorders are an important public health problem worldwide. They are also the leading cause of mortality and morbidity in the industrialized world. The annual cardiovascular mortality rate was reported as 0.8%.<sup>1</sup> In the United States alone, over 14 million persons suffer from heart disease.<sup>2</sup> In addition, there is evidence of a quick increase in heart disease along the Asian region. It is important to note that the disease accounts for 46% of overall mortality is cardiovascular diseases in Iran.<sup>3,4</sup>

According to the US Public Health Service (USPHS), cardiac rehabilitation (CR) is defined as a program that involves medical evaluation, supervised exercise, education and counseling of patients with cardiac disease.<sup>2</sup> Therefore, CR has been identified as an essential, useful and safe part of the care for patients with coronary artery disease.<sup>5</sup>

As a fundamental part of every cardiac rehabilitation program (CRP), regular physical activity can improve functional work capacity in cardiac patients after coronary artery bypass graft surgery

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(CABG). Training profits in particular have been reported to be cardiovascular and peripheral adaptations including improved blood flow in exercising muscles, enhanced oxidative capacity of the working skeletal muscles and energy use and correction of endothelial dysfunction in the skeletal muscle vasculature.<sup>6</sup> Moreover, habitual physical activity prevents the development of coronary artery disease and reduces symptoms in patients with recognized cardiovascular disease.<sup>7</sup>

Numerous studies signified the benefits of CR and exercise training programs on exercise capacity and coronary risk factors including hypertension, arrhythmia, depression and obesity. They were suggested to generally decrease cardiac morbidity and mortality by more than 40 percent.<sup>4-8</sup>

Since there was not adequate evidence about the effects of CRP on patients after CABG, the purpose of this study was to evaluate the effectiveness of CRP on functional status and some hemodynamic responses such as systolic (SBP) and diastolic blood pressure (DBP), heart rate (HR), ejection fraction (EF) and rate-pressure product (RPP).

### Materials and Methods

This study was conducted in Isfahan Cardiovascular Rehabilitation Research Center. Among all patients that consecutively referred to the rehabilitation center, 32 patients, who had cardiac surgery two months before admission, were selected and assigned to two groups. The rehabilitation group entered and completed a CRP for two months. The reference group had to walk 15-30 minutes two or three times a week. However, they did not have any supervised exercise training during this 2-month period. In this study, routine medications, including aspirin, beta-blockers and statins, were equally prescribed to all patients. The medical treatment did not change during the CR period. Moreover, all patients had suitable conditions for participating in the study, i.e. they were able to endure walking without depending to another person or device and had no chest pain, shortness of breath, angina or musculoskeletal disorders. Before starting the CRP, left ventricular ejection fraction (LVEF) was evaluated by two dimensional and M-mode echocardiography performed by a cardiologist. In addition, the Naughton protocol was followed to conduct exercise tests. Exercise test provided an opportunity to detect body reaction by monitoring HR and blood pressure and observing the electrocardiogram. It also determined functional status by indicating changes in the hemodynamic responses. Afterwards, risk stratification of patients

(low, intermediate, and high risk) was done by the cardiologist on the basis of exercise test and LVEF. Another test which was used to assess the functional status of these patients was 6-minute walking (6-MWT) test. At the first day of CRP, 6-MWT was instructed to each patient. It was performed along the 21-meter straight corridor of the Cardiovascular Research Institute. The researcher was also in the corridor and asked the patients about their physical status during the test. Before and after the test, resting HR and blood pressure (BP) of patients were controlled. Then, the rehabilitation group began the CRP three times a week for 2 months (24 sessions). The CRP included exercise training sessions, nutritional and psychological consultation and risk factor management. Exercise training consisted of combined aerobic and resistance training. It was performed using the treadmills, ergometers, steppers and stair climbing, rowing, jogging and resistance devices in the Cardiac Rehabilitation Center under supervision of a physician, an exercise physiologist and a nurse. Each session lasted up to 90 minutes, including a 20-minute warm-up followed by 60 minutes of aerobic and resistance training and finally a 10-minute cool-down. Based on clinical conditions, the intensity of training was established between 60-85% of maximum HR. During each session, resting and maximum HR, and resting and maximum SBP and DBP of patients were controlled and recorded by a nurse. No events occurred to patients during the CRP. Moreover, the demographic data of the patients were available. After two months and finishing the CRP, echocardiography, exercise test and 6-MWT were repeated and the results were comprised. At the end of the program, all data were collected and analyzed by SPSS<sub>15</sub> in order to evaluate the effects of exercise training. We used independent t-test for showing mean differences of variable between the two groups. For comparing the mean of outcomes, the Mann-Whitney test and Wilcoxon signed ranks test were used. The research was undertaken under medical ethical standards. The level of significance was set at  $P < 0.05$ .

### Results

Thirty two cardiac patients were studied. The rehabilitation group consisted of 17 patients (13 men and 4 women) with the mean age of  $62 \pm 12$  years. The reference group included 15 patients (13 men and 2 women) with the mean age of  $58.5 \pm 12.5$  years. The two independent sample t-test was used to investigate the differences between the two groups at baseline. Since the sample size in this study was too small, we applied the Mann-Whitney test which

provided more significant results. It showed no significant differences in demographic data and hemodynamic responses (Table 1). The baseline and final values of each group were analyzed by Wilcoxon signed ranks test. It illustrated significant development in functional capacity and all hemodynamic responses in the rehabilitation group compared with the reference group (Table 2).

In addition, changes of functional capacity and hemodynamic responses between two groups were compared by Wilcoxon signed ranks test which revealed significant improvement in the distance walked, resting and maximum SBP, maximum DBP, EF and RPP. However, no positive differences were observed in resting DBP and resting and maximum HR (Table 3).

**Table 1.** Baseline hemodynamic responses of the two groups

Hemodynamic Responses	Rehabilitation Group	Reference Group	P
Resting SBP (mmHg)	129.41 ± 10.28	125.00 ± 15.00	0.15
Maximum SBP (mmHg)	135.47 ± 16.04	135.66 ± 23	0.63
Resting DBP (mmHg)	82.35 ± 5.33	79 ± 12.13	0.35
Maximum DBP (mmHg)	82.64 ± 5.33	84.80 ± 13.57	0.81
Resting HR (beat/min)	81.35 ± 14.42	74.73 ± 6.19	0.11
Maximum HR (beat/min)	122.94 ± 24.72	126.13 ± 19.54	0.67
Distance walked (meter)	431.02 ± 92.74	408.42 ± 71.58	0.41
EF (%)	53.82 ± 13.03	57.73 ± 10.68	0.44
RPP	15402.94 ± 20718.56	9298.00 ± 1190.00	0.05

All values are expressed as mean ± SD. Significance level: P < 0.05

SD: Standard deviation; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; HR: Heart rate; EF: Ejection fraction; RPP: Rate pressure product

**Table 2.** Variation of hemodynamic responses from baseline to the end of the program

Hemodynamic Responses	Rehabilitation Group (Mean ± SD)			Reference Group (Mean ± SD)		
	Pre	Post	P	Pre	Post	P
SBP (rest) (mmHg)	129.41 ± 10.28	114.70 ± 15.04	0.006	125.00 ± 15.00	126.33 ± 13.81	0.72
SBP (max) (mmHg)	135.47 ± 16.04	115.00 ± 15.00	0.002	135.66 ± 23.66	123.00 ± 23.05	0.53
DBP (rest) (mmHg)	82.35 ± 5.33	74.70 ± 6.48	0.002	79.00 ± 12.13	78.66 ± 11.87	0.57
DBP (max) (mmHg)	82.64 ± 5.33	75.00 ± 5.59	0.001	84.80 ± 13.57	80.00 ± 75.00	0.20
HR (rest) (beat/min)	81.35 ± 14.42	71.58 ± 10.46	0.006	74.73 ± 6.19	72.80 ± 4.82	0.34
HR (max) (beat/min)	122.94 ± 24.72	111.05 ± 15.99	0.02	126.13 ± 19.54	116.40 ± 10.92	0.03
Distance walked (m)	431.02 ± 92.74	514.21 ± 87.89	0.000	408.42 ± 71.58	416.06 ± 66.75	0.33
EF (%)	53.82 ± 13.03	60.23 ± 9.80	0.049	57.73 ± 10.68	55.53 ± 9.14	0.15
RPP	15402.94 ± 20718.56	8201.17 ± 1544.93	0.001	9298 ± 1190.34	9172.26 ± 951.24	0.53

Significant difference: P < 0.05

SD= Standard Deviation

SBP= Systolic blood pressure

DBP= Diastolic blood pressure

HR= Heart rate

EF= Ejection fraction

RPP= Rate pressure product

**Table 3.** Comparison of changes in hemodynamic responses between the rehabilitation and reference groups

Hemodynamic Responses	Rehabilitation Group	Reference Group	P
Resting SBP (mmHg)	-14.70 ± 4.03	1.33 ± 4.15	0.01
Maximum SBP (mmHg)	-20.47 ± 4.57	-12.66 ± 10.39	0.02
Resting DBP (mmHg)	-7.64 ± 1.77	0.33 ± 3.46	0.15
Maximum DBP (mmHg)	-7.64 ± 1.22	-4.80 ± 3.27	0.04
Resting HR (beat/min)	-9.76 ± 3.61	-1.93 ± 1.88	0.11
Maximum HR (beat/min)	-11.88 ± 4.28	-9.73 ± 4.47	0.74
Distance walked (meter)	83.18 ± 6.54	7.64 ± 9.67	< 0.01
EF (%)	6.41 ± 2.92	-2.20 ± 1.48	0.02
RPP	-7201.76 ± 4904.65	-125.73 ± 367.52	0.001

All values are expressed as mean ± SE. Significance level: P < 0.05

SD: Standard deviation; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; HR: Heart rate; EF: Ejection fraction; RPP: Rate pressure product

### Discussion

The present study demonstrated participation in the CRP and exercise training to provide significant improvements in functional capacity and hemodynamic responses after CABG. Results revealed an increase in functional capacity after the CRP by assessing 6-MWT. However, this favorable difference was not seen in the reference group. Comparison of the two groups confirmed the results.

Many previous studies reported similar results. Nilsson et al. showed walking distance in congestive heart failure (CHF) patients to significantly improve after 32 sessions of high intensity aerobic training. The development was maintained at 1-year follow-up.<sup>9</sup> Another study observed that resistance training improved muscle strength and functional capacity measured by 6-MWT.<sup>10</sup> Likewise, Larsen et al. used 6-MWT and demonstrated a significant improvement in submaximal exercise capacity following 12 weeks of exercise training in patients with heart failure.<sup>11</sup> Some studies suggested combined aerobic and strength training to be positively effective on walking performance and exercise tolerance after CABG and myocardial infarction (MI).<sup>12,13</sup> In addition, Sharma and McLeod studied the effects of CRP on CABG patients. They used exercise test and found improvement in functional tolerance after the program.<sup>14</sup> According to these studies and our results, we concluded different kinds of exercise training such as aerobic and/or resistance training are beneficial for cardiac patients after CHF and CABG.

All previous studies showed a worsened functional status after ischemic heart disease. Using 6-MWT or exercise test (METs) they found exercise training to

be effective role on the progress of functional status. It should be noted that the heart becomes stronger as a result of exercise. Therefore, it can pump more blood through the body with every beat which in turn keeps the blood vessels flexible, ensures proper blood flow, and delivers oxygen to cardiac and skeletal muscles. Finally, it strengthens muscles and increases work capacity.<sup>15,16</sup>

As mentioned above, our results showed the CRP to have significant effects on hemodynamic responses such as resting and maximum SBP, resting and maximum DBP, resting and maximum HR, EF and RPP. Moreover, the comparison between the CRP and reference groups suggested significant improvements in some parameters such as resting and maximum SBP, maximum DBP, EF and RPP.

Although numerous studies confirmed these results, some did not. Hambrecht et al. showed that after 6 months of exercise training, resting HR decreased but maximum HR and LVEF increased in the exercise training group. However, no changes were found in BP at rest.<sup>6</sup> There are some similarities between their findings and ours, i.e. both studies illustrated that exercise training improved work capacity in cardiac patients. Nevertheless, its effects on central hemodynamic function are not well known. On the other hand, another study implied the effect of exercise training on resting BP and reducing SBP and DBP. It did not report a relationship between the weekly training frequency, time per session, or intensity of exercise training and the magnitude of the BP reduction.<sup>7</sup>

Nonetheless, some studies revealed vigorous exercise to reduce SBP for more than 12 hours.<sup>17</sup>

Chicco et al. found that low-intensity exercise training significantly improved survival in female hypertensive heart failure rats without eliciting sustained improvements in BP and cardiac function.<sup>18</sup> Similarly, O'Farrell et al. found that SBP and DBP decreased in both sexes.<sup>19</sup> In contrast, others did not find any changes in resting or maximal exercise SBP.<sup>20,21</sup>

Therefore, according to many studies, there are sparse results in relation to hemodynamic responses to CRP and exercise training. It should be noted that changes in prescribed medications during the exercise program, the intensity of exercise, the age or gender of patients, and even differences in number of samples may be the cause of these variations.

Moreover, one study demonstrated that exercise training is beneficial for patients with angina pectoris. It showed significant reductions in HR and SBP that led to lessened RPP and enhanced work capacity at submaximal exercise.<sup>22</sup> Such findings were in line with our results but we studied CABG patients. Conversely, previous research demonstrated that there were no changes in the values of HR, SBP, DBP, and RPP among CHF patients after the CRP.<sup>23</sup>

At the end, we conclude that regular physical activity (aerobic and resistance training) develops submaximal work tolerance through lessening contractility, reducing cardiac work and myocardial oxygen demand.<sup>7,24</sup> In addition, it enhances hemodynamic responses such as resting and maximum SBP, DBP, and HR, as well as EF and RPP. On the other hand, it is worth mentioning that since exercise training involves large muscle groups, it produces cardiovascular adaptations and improves myocardial perfusion by reducing endothelial dysfunction. Hence, it dilates coronary vessels which in turn leads to increased exercise tolerance, endurance and skeletal muscle strength<sup>7,15,16</sup> evaluated by exercise test and 6-MWT.

Finally, our findings confirm the value of RP with supervised exercise training in patients after CABG since it can possibly lead to a more active lifestyle.

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### Conflict of Interests

Authors have no conflict of interests.

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