Original Article

Effect of Cardiac Rehabilitation Program on Heart Rate Recovery after Percutaneous Coronary Intervention and Coronary Artery Bypass Grafting

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Abstract

Background: *The objective of this study was to evaluate the effect of a hospital-based cardiac rehabilitation program on heart rate recovery (HRR) in patients who received percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG).*

Methods: *Two hundred forty patients, who completed 24 sessions of a cardiac rehabilitation program (phase 2) after PCI (n=62) or CABG (n=178) at the rehabilitation department of Tehran Heart Center were included in the present study. Demographic and clinical characteristics and exercise capacity at baseline and at follow-up were compared between the two groups. The main outcome measurements were: Resting heart rate, peak heart rate, and HRR.*

Results: *All the patients showed significant improvements in heart rate parameters from the baseline to the last sessions. The profile of atherosclerotic risk factors (except for diabetes mellitus) was similar between the PCI and CABG subjects. After eight weeks of cardiac rehabilitation, HRR increased averagely about 17 and 21 bpm among the CABG and PCI patients, respectively (p=0.019).*

Conclusion: *The results of the present study were indicative of an increase in HRR over 1 minute in patients irrespective of their initial revascularization modality (i.e. PCI or CABG) after the completion of cardiac rehabilitation. Be that as it may, the PCI patients achieved greater improvement in HRR by comparison with the CABG patients.*

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Introduction

Cardiac rehabilitation is a well-established treatment in patients with coronary artery disease. Meta-analysis of pooled data from clinical trials and cohort studies has demonstrated significant reductions in all-cause and cardiovascular mortality of patients enrolled in cardiac rehabilitation programs.[1-4] It has been shown that exercise training modifies

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the autonomic control of cardiovascular function. An early fall in the heart rate after exercise is thought to result from increased vagal activity. Recently, heart rate recovery (HRR) was demonstrated to be a powerful predictor of all-cause mortality.[5,6] Cardiac rehabilitation has been associated with an improvement in HRR in patients with heart failure, coronary artery bypass graft (CABG), or prior myocardial infarction.[7-14] However, there is a paucity of data on Percutaneous coronary intervention (PCI). PCI and CABG, as two revascularization approaches for the relief of angina in patients with coronary artery disease, have been compared in several randomized trials for the past decades. Overall, clinical results from these trials are consistent in that the frequency of death and myocardial infarction is similar in both arms. The purpose of the present study was to evaluate and compare the effects of a hospital-based cardiac rehabilitation program on HRR in PCI and CABG patients and to clarify whether exercise training could result in different improvements by certain approaches.

Methods

Our study population comprised 240 patients (58.08±10.42 years; males: 74.2%) with a recent revascularization procedure who had enrolled in and completed a 24-session hospital-based cardiac rehabilitation program between July 2004 and January 2006. The investigation was approved by the institutional review board governing the participation of human subjects in research at the Tehran University of Medical Sciences. Also, it conforms to the principles outlined in the Declaration of Helsinki.

The inclusion criteria were selected subjects with coronary artery disease who had: 1) no neurologic impairments such as stroke, peripheral neuropathy, traumatic brain injury, and severe musculoskeletal diseases such as fracture or amputation, and 2) no complications during hospitalization such as severe infection, shock, arrhythmia, or prolonged ventilator dependence. Patients were excluded if they displayed uncontrolled dysrhythmia such as atrial flutter, fibrillation, or continuous ventricular tachycardia, observed during exercise training.

HRR was defined as the decrease in the heart rate from the end of peak exercise to the first minute of the recovery and cool-down period (peak heart rate subtracted by post-exercise heart rate). The complete cardiac rehabilitation program was 20 minutes of cardiovascular exercise on a treadmill for 8 weeks, with a total of 24 exercise sessions (3 per week). There were approximately 20 minutes of stretching and calisthenics for warm-up, and the session finished with 20 minutes of stretching and calisthenics for cool-down. The total duration of a session was approximately 1 hour. The intensity of the aerobic exercise was patient-dependent. The training intensity was increased as tolerated by the patients. Heart rate, blood pressure, and exercise intensity were monitored and supervised by a senior cardiopulmonary physical therapist during the exercise session. All the patients received psychological and dietary counseling. During the psychological sessions, the patients were offered coping strategies to accept and live with their cardiac incident. During the dietary counseling, the subjects received education sessions on healthy nutrition and were included into a food program.

The subjects were categorized into two groups: those who received CABG (n=178) and those who underwent PCI (n=62). For the categorical variables, the statistical significance of difference among the subjects in the two groups was evaluated at baseline and after cardiac rehabilitation using the chi-square or Fisher's exact tests. The continuous variables were expressed as mean±standard deviation. The baseline and post-training exercise parameters were defined as the values of the first session (i.e., resting heart rate1, peak heart rate1, post-exercise heart $rate_1$, and HRR_1) vs. the last session (i.e., resting heart $rate_2$, peak heart $rate_2$, post-exercise heart $rate_2$, and HRR_2) in which the patients had attended. The main outcome measures, namely resting heart rate, peak heart rate achieved during treadmill exercise, post-exercise heart after 1 minute, and HRR between and within the two groups, were analyzed and compared using the Student's t-test and paired t-test. The analyses were performed using the Scientific Package for Social Sciences (version 13; SPSS, Chicago, IL). A p value≤0.05 was considered statistically significant.

Results

The baseline demographic and clinical characteristics of the two groups are presented in Table 1. The mean ages of the patients enrolled in phase 2 cardiac rehabilitation were 59.53±10.23 and 54.67±9.23 years in the CABG and PTCA groups, respectively (p<0.001). Both groups had a similar male to female ratio. Except for diabetes mellitus, the risk factors, namely hypertension, hyperlipidemia, family history of CAD, and current cigarette smoking habit, were not significantly different between the two groups. The mean of left ventricular ejection fraction (LVEF) was significantly lower in the CABG group than that in the PCI group. In the PCI patients, the use of anti-hyperlipidemia agents and calcium channel blockers was more common, but other medications were similarly prescribed for the two groups.

Table1. Clinical and demographic characteristics of patients in phase II cardiac rehabilitation*

	CABG group (n=178)	PCI group (n=62)	P value
Age (yr)	59.53±10.23	54.67±9.23	0.001
Male	130(73.9)	48(77.4)	0.615
Hypertension	73(41.0)	29(46.8)	0.458
Diabetes mellitus	49(27.5)	8(12.9)	0.024
Current smoker	43(24.2)	16(26.2)	0.864
Hyperlipidemia	95(53.4)	36(58.1)	0.556
Family history	77(44.3)	24(38.7)	0.554
LVEF (%)	50.51±10.81	56.21±6.62	0.001
Aspirin	168 (94.4)	58(93.5)	1.000
Warfarin	13(7.3)	2(3.2)	0.206
β blockers	147(82.6)	44(71.1)	0.067
Calcium channel blockers	25(14.0)	33(53.2)	<0.001
ACE inhibitors	55(30.9)	22(35.5)	0.530
Antihyperlipidemia	87(48.9)	45(72.6)	0.002

*Data are presented as mean±SD. Numbers in parenthesis show the related percentage
CABG, Coronary artery bypass grafting; PCI, Percutaneous coronary intervention; LVEF, Left ventricular ejection fraction; ACE, Angiotension-converting enzyme

The descriptive statistics of the resting heart rate, peak heart rate, end-exercise heart rate, HRR, and systolic and diastolic blood pressures at baseline and post-training are listed in Table 2. There was no significant difference in the mean resting or end-exercise diastolic and systolic blood pressures between the groups. The CABG group had higher resting heart rate1, peak heart rate1, and post-exercise heart rate1 in comparison with the PCI group, but there was no significant difference in HRR at baseline between the CABG and PCI groups (8.48±6.34 and 8.71±7.21 bpm; p=0.815). After eight weeks of rehabilitation, both groups showed significant improvement in peak heart rate, end-exercise heart rate, and HRR. Within the CABG group, resting heart rate was significantly reduced between the first and the last session (82.18±0.95 and 76.74±0.82 bpm; p<0.001). However, resting heart rate of the PCI group demonstrated no significant change from the first to the last session (75.03±1.75 and 74.98±1.56 bpm; p=0.976). The mean value of HRR was significantly higher for the PCI group (29.82±10.69 bpm) when compared with that of the CABG group (25.63±12.48 bpm) at the last session (p=0.019) Figure 1.

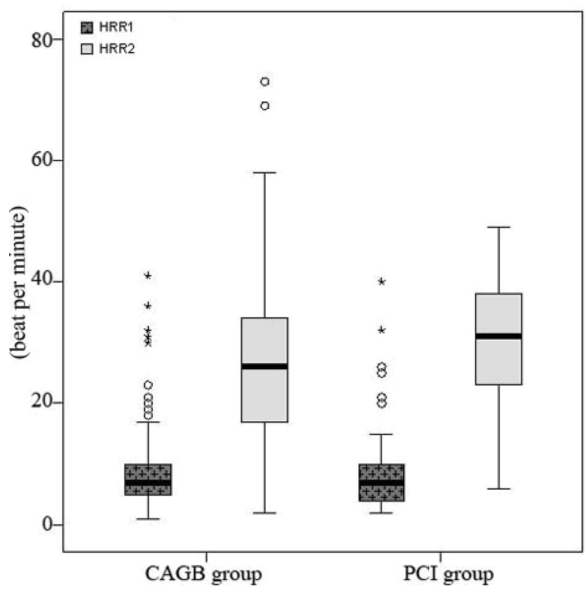

Figure 1. Heart rate recovery patients in phase II cardiac rehabilitation HRR1, Heart rate recovery at baseline; HRR2, Heart rate recovery at the last session; CABG, Coronary artery bypass grafting; PCI, Percutaneous coronary intervention

Table 2. Baseline and post-exercise cardiovascular parameters of patients in phase II cardiac rehabilitation*

Values of cardiovascular parameters	CABG group (n = 178)	PCI group (n= 62)	p value
Resting systolic BP_1 (mmHg)	129.53±16.58	126.90±15.64	0.276
Post- exercise systolic BP_1 (mmHg)	126.04±17.12	129.76±18.24	0.121
Resting diastolic BP_1 (mmHg)	82.47±9.48	83.58±9.26	0.426
Post- exercise diastolic BP_1 (mmHg)	85.31±9.26	83.25±9.03	0.119
Resting systolic BP_2 (mmHg)	128.08±16.98	129.66±17.27	0.530
Post- exercise systolic BP_2 (mmHg)	136.34±18.31	133.73±18.12	0.333
Resting diastolic BP_2 (mmHg)	82.39±10.15	81.73±13.35	0.683
Post- exercise diastolic BP_2 (mmHg)	83.59±11.13	85.080±12.1	0.378
Resting heart $rate_1$ (bpm)	82.18±12.63	75.03±13.76	<0.001
Peak heart $rate_1$ (bpm)	99.36±13.09	92.18±15.23	<0.001
Post-exercise heart $rate_1$ (bpm)	90.88±12.17	83.47±13.66	<0.001
Resting heart $rate_2$ (bpm)	76.74±10.90	74.98±12.25	0.293
Peak heart $rate_2$ (bpm)	122.32±17.51	125.82±14.38	0.158
Post- exercise heart $rate_2$ (bpm)	96.63±12.77	96.00±12.46	0.738
HRR (bpm)	8.48±6.34	8.71±7.21	0.815
HRR (bpm)	25.63±12.48	29.82±10.69	0.019
Mean change in HRR (bpm)	17.14±13.21	21.11±13.48	0.044

*Data are presented as mean±SD.
CABG, Coronary artery bypass grafting; PCI, percutaneous coronary intervention; BP, Blood pressure; HRR, Heart rate recovery

Discussion

Over the last several years ,HRR after treadmill exercise testing and training has been the subject of much interest in respect to clinical evaluation of healthy subjects ,athletes, and patients with cardiovascular disease .HRR is a simply and readily obtainable clinical parameter which has shown to be a strong predictor of all-cause mortality among various populations including patients with heart failure and those with coronary artery disease[8-14]. The ability of the heart rate to recover after exercise is related to the capacity of the cardiovascular system to reverse the autonomic nervous system (withdrawal of vagal activity) and baroreceptor (detection of changes in blood pressure and inhibition of sympathetic discharge) adaptations that occur during exercise, often termed vagal reactivation. Because of the strong association between HRR and mortality, and the link between HRR and exercise capacity or physical activity patterns, HRR has the potential to be an additional marker of training efficacy and risk stratification in patients undergoing cardiac rehabilitation. [5,6,15,16]

Our study extends current information on HRR to patients with coronary revascularization who undergo exercise training inasmuch as we sought to examine the effects of cardiac rehabilitation on heart rate parameters in both CABG and PCI patients. Previous works have focused on heart rate variability and baroreflex sensitivity as markers of the vagal tone and also evaluated the effect that cardiac rehabilitation has on HRR in patients with prior myocardial infarction, heart failure, and CABG.[7-14] In light of the previous studies on patients with coronary artery disease, we showed that exercise training in a structured hospital-based cardiac rehabilitation program was associated with significant improvements in peak heart rate and HRR over 1 minute. This effect was witnessed in both CABG and PCI subjects, who attended the cardiac rehabilitation program within two to four weeks after discharge and completed all the 24 sessions. However, the effect of exercise training on HRR and the change in HRR in the PCI patients were comparable to those of the CABG patients. After 8 weeks of rehabilitation, we observed that HRR had increased averagely about 17 and 21 bpm among our CABG and PCI patients, respectively.

By comparison with the results of previous studies, improvements in HRR after rehabilitation in our patients were remarkable. Tiukinhoy et al.[13] reported that HRR was 18 bpm faster 1 minute into recovery after 12 weeks of rehabilitation among patients after a cardiac event. Tsai et al.[8] observed that the mean value of HRR over 1 minute increased from 4.15±3.74 to 16.38±6.32 bpm at follow-up among the cardiac rehabilitation group. Hao et al.[17] reported modest (3-6 bpm) improvements in HRR 1 minute into recovery among both elderly and younger patients referred to a 12-week rehabilitation program. Kligfield et al.[9] demonstrated that 1-minute post exercise HRR was more rapid (by 2-4 beats/min) in response to submaximal activity after 12 weeks of rehabilitation. Wu et al.[8] showed that the mean value of HRR improved from 9.2±4.5 to 19.1±6.2 bpm after cardiac rehabilitation among CABG patients.[18] Streuber et al.[7] reported that HRR 1 minute post exercise improved by 5 bpm after 12 weeks. Similarly, Giallauria et al.[12] reported that HRR 1 minute post exercise improved by approximately 6 bpm after 3 months of training after myocardial infarction.

Training resulted in a significant increase in peak heart rate by 23 bpm and 33 bpm in our CABG and PCI groups, respectively. Although the CABG group demonstrated significantly higher resting heart rate and peak heart rate at baseline, these parameters were similar between both groups after the completion of the 8-week exercise training. The improvement in resting heart rate in the CABG group may be due to longer time to the onset of training, which increases the parasympathetic activity and decreases the sympathetic activity directed to the human heart at rest, thus decreasing resting heart rate.[8,11,19] It was reported that exercise conditioning over a 12-week period improved heart rate variability, reduced resting heart rate in cardiac patients, and lowered the risk of sudden cardiac death via an increased vagal tone.[19] Therefore, it seems reasonable that our CABG patients developed improvement in resting heart rate as they passed a longer interval-to-program entry compared with the PCI group.

A comparison of HRR in the present study revealed that it tended to improve more in the PCI patients as opposed to the CABG patients. Few studies have directly examined this issue. This improvement is impressive, given that our CABG patients attending the cardiac rehabilitation program began with a higher baseline peak heart rate and would have been expected to have equaled to gain. Chiming in with our results, Feuerstadt et al.[20] reported that patients with recent PCI had significantly greater entry and exit metabolic equivalent level capacity than did patients with recent CABG or with stable angina. Similarly, in a cohort study by Ades et al.,[21] at all ages and in both men and women, patients who underwent CABG had lower age-adjusted values of peak VO_2 than did patients treated medically or with PCI. This is may be due to the fact that the patients undergoing CABG are generally hospitalized longer and require a longer convalescence than do patients treated medically.

In our series, both CABG and PCI groups were similar with respect to sex and cardiovascular risk factors, while patients in the CABG group tended to be older and also to have a higher proportion of diabetes mellitus and a lower LVEF. Although previous studies have demonstrated that the vagal modulation of the heart rate during exercise is independent of age or workload and unaffected by β-blockers, one study showed that the proportional increase in HRR after training in older patients was greater than that found in younger patients, suggesting that older patients derived much benefit from exercise training.[17,22-24] Therefore, the difference in HRR between the CABG and PCI groups may be attributable at least in part to the potential influence of age, functional capacity, LVEF, and some differences in the exercise protocol for the patients training in hospital-based rehabilitation.

One limitation of this study is its retrospective design and its concomitant inherent bias. Although heart rate, blood pressure, and exercise intensity were monitored and supervised by a senior cardiopulmonary physical therapist for all the patients, baseline and follow-up exercise stress tests were not performed and the data were recorded during treadmill exercise training. Nevertheless, these findings seem to be indicative of the parameters of exercise stress test. Ideally, because of a lack of data concerning the association between the study outcomes and subsequent mortality, this relation requires further investigation, specifically using a prospective study design. Our clinical data do not permit clarification of the reasons underlying the major differences in survival between our patients, who entered cardiac rehabilitation after CABG or PCI. Also, it is worthy of note that our groups were not assigned randomly to treatment, but rather came for exercise training after original treatment options had been made individually by their referring physicians.

Conclusions

our findings suggest that patient after exercise training in a hospital-based cardiac rehabilitation significantly benefit in respect to heart rate recovery and peak heart rate regardless of revascularization modalities. However, patients with PCI may achieve greater improvements of heart rate parameter in comparison with those undergoing CABG, possibly due to being younger, having higher LVEF and being less diabetic.

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Reference

1. O'Connor GT, Buring JE, Yusuf S, Goldhaber SZ, Olmstead EM, Paffenbarger RS Jr, Hennekens CH. An overview of randomized trials of rehabilitation with exercise after myocardial infarction. Circulation 1989;80:234-244.

2. Fletcher GF, Balady GJ, Amsterdam EA, Chaitman B, Eckel R, Fleg J, Froelicher VF, Leon AS, Piña IL, Rodney R, Simons-Morton DA, Williams MA, Bazzarre T. Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. Circulation 2001;104:1694–1740.

3. Jolliffe JA, Rees K, Taylor RS, Thompson D, Oldridge N, Ebrahim S. Exercise-based rehabilitation for coronary heart disease (Cochrane Review). Cochrane Database Syst Rev 2001;1:CD001800.

4. Oldridge NB, Guyatt GH, Fischer ME, Rimm AA. Cardiac rehabilitation after myocardial infarction: combined experience of randomized clinical trials. JAMA 1988;260:945-950.

5. Cole CR, Blackstone EH, Pashkow FJ, Snader CE, Lauer MS. Heart rate recovery immediately after exercise as a predictor of mortality. N Eng J Med 1999;341:1351-1357.

6. Nishime EO, Cole CR, Blackstone EH, Pashkow FJ, Lauer MS. Heart rate recovery and treadmill exercise score as predictors of mortality in patients referred for exercise ECG. JAMA 2000;284:1392-1398.

7. Streuber SD, Amsterdam EA, Stebbins CL. Heart rate recovery in heart failure patients after a 12-week cardiac rehabilitation program. Am J Cardiol 2006;97:694-698.

8. Tsai SW, Lin YW, Wu SK. The effect of cardiac rehabilitation on recovery of heart rate over one minute after exercise in patients with coronary artery bypass graft surgery. Clin Rehabil 2005;19:843-849.

9. Kligfield P, McCormick A, Chai A, Jacobson A, Feuerstadt P, Hao SC. Effect of age and gender on heart rate recovery after submaximal exercise during cardiac rehabilitation in patients with angina pectoris, recent acute myocardial infarction, or coronary bypass surgery. Am J Cardiol 2003;92:600-603.

10. Duru F, Candinas R, Dziekan G, Goebbels U, Myers J, Dubach P. Effect of exercise training on heart rate variability in patients with new-onset left ventricular dysfunction after myocardial infarction. Am Heart J 2000;140:157-161.

11. Oya M, Itoh H, Kato K, Tanabe K, Murayama M. Effects of exercise training on the recovery of the autonomic nervous system and exercise capacity after acute myocardial infarction. Jpn Circ J 1999;63:843-848.

12. Giallauria F, De Lorenzo A, Pilerci F, Manakos A, Lucci R, Psaroudaki M, D'Agostino M, Del Forno D, Vigorito C. Long-term effects of cardiac rehabilitation on end-exercise heart rate recovery after myocardial infarction. Eur J Cardiovasc Prev Rehabil 2006;13:544-550.

13. Tiukinhoy S, Beohar N, Hsie M. Improvement in heart rate recovery after cardiac rehabilitation. J Cardiopulm Rehabil 2003;23:84-87.

14. Myers J, Hadley D, Oswald U, Bruner K, Kottman W, Hsu L, Dubach P. Effects of exercise training on heart rate recovery in patients with chronic heart failure. Am Heart J 2007;153:1056-1063.

15. Cole CR, Foody JM, Blackstone EH, Lauer MS. Heart rate recovery after submaximal exercise testing as a predictor of mortality in a cardiovascularly healthy cohort. Ann Intern Med 2000;132:552-555.

16. Imai K, Sato H, Hori M, Kusuoka H, Ozaki H, Yokoyama H, Takeda H, Inoue M, Kamada T. Vagally mediated heart rate recovery after exercise is accelerated in athletes but blunted in patients with chronic heart failure. J Am Coll Cardiol 1994;24:1529-1535.

17. Hao SC, Chai A, Kligfield P. Heart rate recovery response to symptom-limited treadmill exercise after cardiac rehabilitation in patients with coronary artery disease with and without recent events. Am J Cardiol 2002;90:763-765.

18. Wu SK, Lin YW, Chen CL, Tsai SW. Cardiac rehabilitation vs. home exercise after coronary artery bypass graft surgery: a comparison of heart rate recovery. Am J Phys Med Rehabil 2006;85:711-717.

19. Pardo Y, Merz CN, Velasquez I, Paul-Labrador M, Agarwala A, Peter CT. Exercise conditioning and heart rate variability: evidence of a threshold effect. Clin Cardiol 2000;23:615-620.

20. Feuerstadt P, Chai A, Kligfield P. Submaximal effort tolerance as a predictor of all cause mortality in patients undergoing cardiac rehabilitation. Clin Cardiol 2007;30:234-238.
21. Ades PA, Savage PD, Brawner CA, Lyon CE, Ehrman JK, Bunn JY, Keteyian SJ. Aerobic capacity in patients entering cardiac rehabilitation. Circulation 2006 13;113:2706-2712.
22. Tulppo MP, Makikallio TH, Seppanen T, Laukkanen RT, Huikuri HV. Vagal modulation of heart rate during exercise: effects of age and physical fitness. Am J Physiol 1998;274:424-429.
23. Morise AP. Heart rate recovery: predictor of risk today and target of therapy tomorrow? Circulation 2004;110:2778-2780.
24. MacMillan JS, Davis LL, Durham CF, Matteson ES. Exercise and heart rate recovery. Heart Lung 2006;35:383-390.