Additional Physical Activity During Cardiac Rehabilitation Leads to an Improved Heart Rate Recovery in Male Patients After Coronary Artery Bypass Grafting

Shinji Sato, PhD; Shigeru Makita, MD; Mitsuru Majima, MD

Background Heart rate recovery (HRR) after exercise, which is thought to be a marker of vagal activity, has been reported to improve after cardiac rehabilitation (CR) with exercise in patients with coronary heart disease. The aim of this study was to determine whether or not additional physical activity outside the CR program, would accelerate improvement of the HRR in male patients after coronary artery bypass grafting (CABG).

Methods and Results Twenty male patients were enrolled in a supervised CR program at 2 weeks after CABG, and divided into an active group (walking ≥5,434 steps/day) or a less-active group. The time constant of HRR immediately measured after pedaling exercise was assessed at baseline and after the 2-week CR program. After completion of the CR program, the time constant of HRR improved from 439.7±177 s to 288.6±97.4 s in the active group ($p<0.01$), but no changes were observed in the less-active group.

Conclusions The results suggest that additional physical activity during a CR program may lead to an improved HRR in patients after CABG. Therefore, post-CABG patients should increase their level of physical activity in addition to that in the CR to improve their cardiac autonomic control. (*Circ J* 2005; **69:** 69 – 71)

Key Words: Coronary artery bypass grafting; Heart rate recovery; Physical activity

A prospective cohort study demonstrated that a low value for heart rate recovery (HRR) after exercise testing, which has been shown previously to be a marker of decreased vagal reactivity, is a powerful and independent predictor of overall mortality in patients with known or suspected coronary heart disease (CAD).[1,2] Exercise-based cardiac rehabilitation (CR) is an effective solution to improving an inadequate HRR in patients with CAD.[3–5]

A recent report showed maximum health benefits with physical activity in addition to that of the CR, achieved by exercise such as walking and stair-climbing.[6] To date, the association between HRR and physical activity outside a formal CR program in patients with CAD has not been studied, so the present study was designed to investigate the hypothesis that additional physical activity during CR would result in an improvement of HRR in patients with CAD.

Methods

Patient Population

The study population consisted of 20 male patients who were admitted to the Department of Rehabilitation Medicine in Saitama Medical School Hospital between July 1999 and August 2001. All patients had previously undergone coronary artery bypass grafting (CABG) at the Cardiovascular Surgery Department of this hospital. It is standard practice for almost all patients to be referred to the Department of Rehabilitation Medicine by their surgeon after CABG. The patients were admitted to the Department during an approximate 2-week post-CABG period and underwent initial screening that included a symptom-limited exercise test with direct measurement of oxygen uptake and a HRR test after performing pedaling exercise at the anaerobic threshold (AT) level. All of these evaluations were repeated after 2 weeks of a CR program. Patients were excluded if they were older than 80 years, used β-blockers, or had heart failure, insulin-dependent diabetes, arterial fibrillation or abnormal sinus node function. The purpose and risk of this study were explained to each patient before written informed consent was obtained.

Cardiac Pulmonary Exercise Testing

Symptom-limited cardiac pulmonary exercise testing (CPX) was performed in the upright position on a bicycle ergometer with an initial workload of 0 W, with subsequent increments of 15 W every minute until exhaustion. A 12-lead ECG and the HR were monitored throughout the test using the Stress test system (ML-6500, Fukuda Denshi). The blood pressure was measured every minute with an automatic indirect manometer (STBP-760, Colin Denshi). Oxygen consumption and carbon dioxide production were measured with a metabolic cart (Oxycon Alpha, Jaeger). The exercise test variables analyzed in the study included oxygen consumption at AT and peak oxygen uptake. The AT was determined from the gas exchange data by the V-slope method.[7]

Measurement of HRR

The HRR was measured 18–24 h after the CPX and exercise training session to avoid the acute effects of exercise. The HRR was estimated using the time constant of post-exercise HR decay on conventional electrocardiography as described previously.[8] In subjects who rested immediately after pedaling exercise at the AT intensity level for 5 min,

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Department of Rehabilitation Medicine, Saitama Medical School, Saitama, Japan

Mailing address: Shinji Sato, PhD, Department of Rehabilitation Medicine, Saitama Medical School, 38 Morohongo, Moroyama-cho, Iruma, Saitama 350-0495, Japan. E-mail: sshinji@poem.ocn.ne.jp

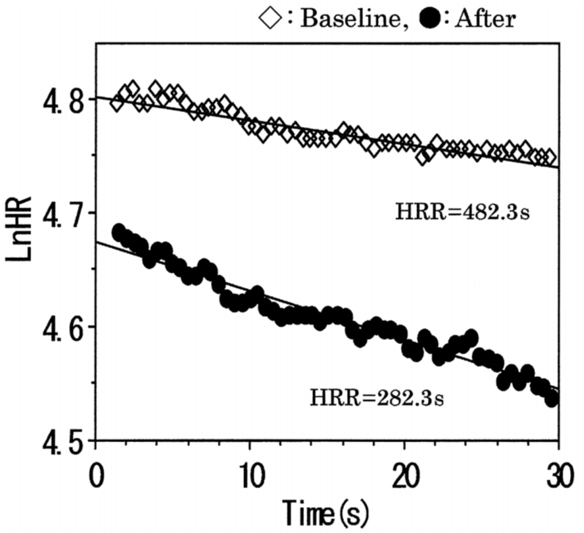

Fig 1. Post-exercise heart rate recovery in one subject who undertook additional physical activity at baseline and after cardiac rehabilitation. HRR, time constants of the heart rate recovery for 30 s.

we measured the interval between heart beats during a 30 s period. When the natural logarithm of HR was plotted against the time elapsed after exercise, the time constant of HRR was determined as the negative reciprocal of the slope of the regression line (Fig 1).

Assessment of Physical Activity

We used the data from each patient's pedometer (Lifecorder, Suzuken) to obtain the mean of recorded movements over the final 3 days of the rehabilitation program in order to determine the amount of physical activity[9] The pedometer, which was worn at the waist, had an internal lever that was deflected with vertical acceleration of the hip, each instance of which was interpreted as a step and recorded on-line. Subjects reporting more than the median value of walking steps were classified as the active group, and the others were classified as the less-active group.

Cardiac Rehabilitation Program

The patients participated in a training program (14.6±4.3 days) during the hospital admission. The program consisted of 2 daily 30-min sessions of stationary cycling for 6 days per week. Training intensity was adjusted to the AT. In addition to their cycling exercise, the patients were encouraged to increase their level of activity when they are not attending the structured program.

Statistical Analysis

All values were expressed as mean ± standard deviation. In all patients, group changes in the reported variables between the baseline and 2 weeks after CR were evaluated by the paired t-test. Differences between the active group and the less-active group were analyzed using one-way ANOVA with the Scheffe post hoc test. A probability level of <0.05 was considered statistically significant.

Results

The baseline characteristics of all patients are presented in Table 1 and the effects of 4 week CR are shown in Table 2. The median value for steps walked per day was 5,434±2,699. There was no significant difference in the baseline HRR between myocardial infarction (MI) and non-MI patients (410.7±126 vs 523.3±200 s). Of the 20 patients, 10 were classified as active and 10 were classified as less active (Table 1). The 2 groups were matched for cardiac pathology, age, height and weight, and exercise program. None of the other characteristics, including treatment and all of the characteristics of cardiopulmonary exercise testing at baseline, was significantly different between the groups. Cardiac rehabilitation improved peak oxygen uptake in both groups; however, mean HRR significantly improved in the active group (from 439.7±177 to 288.6±97.4 s; p<0.01), but was unchanged in the less-active group (from 505.6±178. to 480.1±246 s) (Fig 1).

Discussion

Rapid HRR after exercise, a marker of vagal reactiva-

Table 1 Physical Activity and Clinical Characteristics of Patients

Case no.	*Physical activity (steps/day)*	*Group*	*Age (years)*	*Diagnosis*	*EF (%)*	*No. of grafts*
1	12,760	Active	62	Ap	66	2
2	8,417	Active	49	MI	50	4
3	7,966	Active	59	Ap	66	4
4	7,040	Active	57	Ap	58	3
5	6,999	Active	57	MI	76	2
6	6,973	Active	58	MI	67	4
7	6,478	Active	56	MI	78	4
8	6,353	Active	66	Ap	47	4
9	5,837	Active	64	MI	49	4
10	5,518	Active	65	Ap	57	3
11	5,256	Less-active	46	Ap	63	3
12	5,109	Less-active	61	Ap	47	3
13	4,807	Less-active	60	MI	56	2
14	4,148	Less-active	61	MI	47	3
15	3,633	Less-active	63	Ap	71	1
16	3,377	Less-active	58	MI	43	3
17	3,224	Less-active	57	MI	42	4
18	2,302	Less-active	75	Ap	58	3
19	1,637	Less-active	69	Ap	55	3
20	839	Less-active	67	Ap	71	4

Ap, angina pectoris; MI, myocardial infarction; EF, ejection fraction.

Table 2 Cardiovascular, Metabolic, and Autonomic Results at Baseline and After Cardiac Rehabilitation Program

	All patients		*Active group*		*Less-active group*	
	Baseline	*After*	*Baseline*	*After*	*Baseline*	*After*
Rest HR (beats/min)	*95.7±10.4*	*87.7±15.2***	*96.6±9.7*	*86.4±16.1*	*94.7±11.3*	*88.9±14.8*
Rest SBP (mmHg)	*118.4±15.9*	*117.9±17.4*	*117.3±19.6*	*119.4±20.1*	*119.5±12.2*	*116.3±15.1*
Peak oxygen up take (ml/kg per min)	*13.2±2.6*	*15.2±2.9***	*13.7±2.0*	*15.4±2.1***	*12.7±3.2*	*15.1±3.7**
Time constant of HRR (s)	*475.9±172*	*384.4±207***	*439.7±177*	*288.6±97.4**,#*	*505.6±178*	*480.1±246*

HR, heart rate; SBP, systolic blood pressure; HRR, heart rate recovery.
**p<0.05, **p<0.01 vs baseline, #p<0.05 vs Less-active.*

tion, has been reported after CR with exercise in patients with coronary heart disease[3–5] and the present study demonstrated that HRR was accelerated in patients after CABG by physical activity in addition to that of the CR program. These results indicate that an increase in ordinary physical activity accelerates improvement in the vagally mediated HRR in post-CABG patients.

Vagally mediated cardiac autonomic control is commonly impaired after CABG.[10,11] The time constant of HRR in the present post-CABG patients (475.9±172 s) was prolonged in comparison with that of middle-aged men (176.0±60.0 s), suggesting diminished post-exercise vagal reactivation. Mechanical injury to the autonomic nerve fibers during surgery might interfere with the vagal cardiac reflex.[10] Moreover, bed-rest deconditioning may lower the parasympathetic tone in the early phase of CR,[12] but the mechanism by which vagally mediated HRR is blunted in post-CABG patients remains unclear.

It is generally accepted that structured exercise training enhances the vagal contribution to the cardiac autonomic control in patients with CAD.[13–15] The results of the present study, in which increasing the out-of-program activity resulted in marked improvement of the HRR, suggest that lifestyle activity can effect an adequate increase in vagal reflex. Indeed, CR staff should advise sedentary post-CABG patients to increase their level of ordinary physical activity when they are not attending the structured program.

The mechanism by which physical activity induces changes in the vagally mediated HRR remains obscure. Evidence for a central mechanism, considered to be a release of inhibitory commands from the motor cortex to the parasympathetic center,[16] or afferent stimulation from baroreflex or chemoreflex functions,[17] has typically utilized the initial R-R interval changes during the post-exercise recovery periods. Imai et al demonstrated that a release of inhibitory central command rather than baro- or chemoreceptor stimulation may play an important role in post-exercise vagal reactivation, because the HR during the first 30 s of recovery minimally depends on the exercise intensity.[8] We therefore hypothesize that the improved vagally mediated HRR resulting from physical activity may be associated with changes in central command mechanisms.

Study Limitations

This was a retrospective survey, and the number of patients was small. In addition, it is not yet known whether the vagally mediated HRR has any prognostic significance in patients following CABG.

Conclusion

According to our study results, additional physical activity during CR may lead to an improved HRR in patients after CABG. As a result, post-CABG patients should increase their level of additional physical activity outside that of the CR program in order to improve their cardiac autonomic control.

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