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Original Article

Influence of β-blockers on heart rate recovery and rating of perceived exertion when determining training intensity for cardiac rehabilitation

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Abstract

Background: The influence of β-blockers on heart rate recovery (HRR) and rating of perceived exertion (RPE) during Phase I cardiac rehabilitation (CR) for patients with a recent episode of acute myocardial infarction (AMI) is not clear.
Methods: From October 2009 to July 2011, 105 patients with a recent episode of AMI who received a successful percutaneous coronary intervention were recruited into this study. Before entering Phase II CR, each patient underwent a cardiopulmonary exercise test (CPET), where RPE was assessed every minute and related parameters were recorded.
Results: The participants entering CR had relatively low mean peak oxygen consumption (VO_{2max}). However, the peak heart rate and VO_{2max} were lower in those taking β-blockers. The RPE value at the ventilatory threshold (VT) was significantly higher (12.7 ± 1.7) in participants who were taking β-blockers relative to those who were not (11.5 ± 1.4). The HRR value was lower (12.5 ± 8.8) in participants who were taking β-blockers relative to those who were not (17.0 ± 9.1).
Conclusion: These findings suggest that use of β-blockers increased the RPE value at the VT. In addition, HRR was attenuated by β-blockers. In patients who do not undergo CPET, the use of β-blockers should be taken into consideration when using RPE for the initial exercise prescription to determine training intensity.

Keywords: acute myocardial infarction; cardiac rehabilitation; rating of perceived exertion; β-blocker

1. Introduction

Exercise-based cardiac rehabilitation (CR) reduces the total and cardiovascular mortality rates as well as risk factors associated with myocardial infarction. It also provides improvements in heart rate recovery (HRR), health-related quality of life, and exercise capacity.[1–4] The symptom-limited or maximal cardiopulmonary exercise test (CPET) is customarily considered the gold standard to determine the ventilatory threshold (VT), peak oxygen consumption (VO_{2max}), and peak heart rate (HR_{peak}). To more effectively improve aerobic capacity or VO_{2max}, several initial training intensities were suggested as follows: (1) training at or just above the lactate threshold or VT, (2) training initially at 50% of VO_{2max}, or (3) training at 40–80% of the maximal heart rate using the heart

Conflicts of interest: The authors declare that there are no conflicts of interest related to the subject matter or materials discussed in this article.

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rate reserve or the Karvonen method, which should be based on the CPET results.[5] Patients with an acute myocardial infarction (AMI) are candidates for entering a CR program.[6] Because most patients with an AMI receive β-blocker therapy, the use of heart rate to monitor or guide exercise may not be applicable in clinical practice due to the attenuation of the heart rate caused by the β-blockers themselves.[7,8] Other methods, such as rating of perceived exertion (RPE), may be necessary alternatives for monitoring exercise progression or termination.

The 6−20 Borg RPE Scale is a reliable and commonly used tool for assessing perceived effort during exercise.[9−12] The relationships between the RPE and exercise physiological markers, such as the VT and oxygen uptake (VO_2), are markedly strong in healthy people.[11,13,14] Although the RPE is a valuable and reliable indicator of exercise tolerance in healthy people, only limited data focusing on the relationships between the RPE and other indicators of the CPET exist; furthermore, the effect of β-blockers on this association in post-AMI patients has not been clearly demonstrated.[15−17]

HRR, defined as the difference from HR_{peak} to HR measured at 1 minute after peak exercise, is associated with mortality in cardiovascular disease.[18] However, little is known about the effects of β-blockers on the HRR of patients with a recent episode of AMI.[19]

Patients with a recent episode of AMI who were entering a CR program were enrolled in this study. The aim of this study was to determine whether β-blockers affected the RPE value close to the VT, to disclose the effect of β-blockers on HRR, and other variables obtained during the CPET.

2. Methods

2.1. Participants

From October 2009 to July 2011, patients with AMI at Taichung Veterans General Hospital, Taichung, Taiwan who received a successful percutaneous coronary intervention and completed a Phase I CR program were selected for recruitment into this study. Before discharge, the benefits of exercise were explained by physical therapists, and the patients were encouraged to participate in Phase II of the CR program. Data were excluded if neurological or musculoskeletal disorders were evident, if participants failed to complete the CPET procedure, or if exercise termination was due to clinical criteria for an absolute stop as outlined by the American College of Sports Medicine (e.g., chest tightness or S-T depression on an electrocardiogram during the CPET).[5] In total, 113 patients were recruited, of whom 105 completed the CPET and were thus included in the analysis. Informed consents were obtained from the recruited participants before their study entry. The study protocol was approved by the Ethics Committee for Human Research of Taichung Veterans General Hospital.

2.2. RPE Scale

Before undergoing the exercise test, the Borg 6−20 RPE Scale was explained to the participants so they could correctly report their overall feelings of exertion. The participants were asked to provide their subjective RPE by pointing to a number during the last 5 seconds of each minute of the CPET from the resting phase to the recovery phase. The RPE recorded at the end of the exercise session was defined as the maximal RPE. After the VT had been determined by the V-slope method, the RPE values associated with the VT (VT RPE) and the associated workload (VT workload) were defined according to the time of VT.

2.3. Exercise testing protocol

The procedures were fully explained to all participants before the test. They were continuously monitored using a 12-lead electrocardiogram and a blood pressure gauge while in an upright position throughout the exercise testing period. The participants exercised using a MasterScreen CPX (CareFusion Respiratory Care, San Diego, CA, USA) with a cycle ergometer according to the procedure described in a previous report.[20] In brief, after a 3-minute rest period, the participants initially cycled for 3 minutes at 10 W for the baseline warm-up. Subsequently, the exercise load was increased at increments of 10 W/min. The pedal rate was set at 60 revolutions/min during the whole CPET period. The participants were encouraged to continue exercising until exhaustion or until achieving the following criteria: (1) RPE > 17, (2) respiratory exchange ratio (RER) > 1.10, (3) plateau in VO_2 despite increasing workload, and (4) >85 age-predicted maximal HR. After the peak exercise period, the participants were required to undergo a 3-minute cool-down phase at 10 W. The parameters such as resting HR, HR_{peak}, maximal oxygen consumption (VO_{2max} mL/min/kg), and differences between HR_{peak} and resting HR ($HR_{peak-rest}$) were measured. At the time point of exactly 1 minute into the recovery phase, HRR was collected.

2.4. Statistical analysis

The Chi-square and Student *t* tests were used to compare the basic characteristics and proportions between participants with or without β-blockers. Multiple lineal regression analysis was used to analyze the influence of different factors and variables on VT RPE. Pearson correlation coefficient was used to compare the association between variants. The data are presented as mean ± standard deviation. Analyses were performed using SPSS (version 13.0; SPSS Inc., Chicago, IL, USA). The differences were considered statistically significant when $p < 0.05$.

3. Results

3.1. Descriptive statistics of the participants and RPE measured during the exercise tests

The participants' characteristics, including age, sex, medical history, and medication (β-blockers) use, are summarized in Table 1. Among these 105 participants, the VT could be

Table 1
Baseline clinical and demographic characteristics of the study participants.

	β-blocker (n = 52)	No β-blocker (n = 42)	p
Variable			
Age (y)	58.2 ± 12.3	57.6 ± 10.0	0.81
Male	46	37	0.96
Smoking	9	10	0.44
Diabetes mellitus	6	6	0.70
Hypertension	33	21	0.19
Calcium channel blocker	12	11	0.80
ACEI/ARB	31	28	0.50
Antiplatelet	44	35	>0.99
Nitrate	24	15	0.40
Hyperlipidemia	32	24	0.58
NYHA classification			0.08
NYHA Class 1	6	7	
NYHA Class 2	21	23	
NYHA Class 3	21	11	
NYHA Class 4	5	0	
BMI (kg/m^2)	25.4 ± 3.0	25.1 ± 2.8	0.69
LVEF (%)	47.2 ± 10.5	50.1 ± 7.8	0.16

Data are presented as n or mean ± SD, unless otherwise indicated.
ACEI/ARB = angiotensin-converting enzyme inhibitor/angiotensin receptor blocker; BMI = body mass index; LVEF = left ventricular ejection fraction; NYHA = New York Heart Association.

determined in 94 of the participants (83 male and 11 female participants). These 94 participants were selected for the analysis of VT RPE and VT workload. The mean VT RPE value was 12.3 ± 1.7, and the mean VT workload was 54.5 ± 17.6. There were no differences in the following variables: age, sex, diseases, body mass index (BMI), and left ventricular ejection fraction (LVEF) between participants with or without β-blockers.

3.2. Variables significantly affecting the VT RPE score

The effects of factors and covariates on VT RPE were analyzed using multiple lineal regression analysis. The study results showed that after adjustment for age, sex, diabetes mellitus, hypertension, New York Heart Association class, hyperlipidemia, smoking, resting heart rate, ejection fraction rate, BMI, calcium channel blocker, and antiplatelets, β-blocker remains statistically significantly associated with VT RPE (Table 2).

3.3. Effects of β-blockers on the physiological parameters

The effects of β-blockers on the physiological parameters obtained from CPET were analyzed by Student t test and the details are summarized in Table 3. The mean RER at the end of exercise was 1.06 ± 0.07. The results of the t test analyses showed that the resting HR, HR_{peak}, VO_{2max}, RER, and metabolic equivalents were lower in the participants taking β-blockers. The VT RPE was significantly higher (12.7 ± 1.7) in the participants taking β-blockers compared with those not taking them (11.4 ± 1.4; Fig. 1). HRR was attenuated in the participants taking β-blockers (Fig. 2).

Table 2
Estimated VT RPE modeling results for selected independent factors by multiple linear regression analysis.

Parameter	Estimate	Standard error	p
Intercept	8.40	3.11	0.01*
β-blockers	1.399	0.38	<0.001**
BMI (kg/m^2)	0.15	0.07	0.04*
Age (y)	−0.003	0.02	0.88
Sex (male)	0.69	0.61	0.27
LVEF (%)	−0.01	0.02	0.79
Diabetes mellitus	0.63	0.60	0.29
Hypertension	−0.10	0.42	0.82
Hyperlipidemia	−0.47	0.38	0.22
Smoking	0.27	0.48	0.58
Calcium channel blocker	0.55	0.39	0.16
ACEI/ARB	−0.39	0.40	0.33
Antiplatelets	−0.31	0.46	0.51
Nitrate	0.11	0.36	0.77
Resting HR (bpm)	−0.01	0.02	0.48
NYHA classification	0.17	0.28	0.54

Data are presented after adjustment for age, ACEI/ARB, antiplatelets, BMI, calcium channel blocker, diabetes mellitus, sex, hypertension, hyperlipidemia, LVEF, NYHA classification, resting HR, and smoking.
*$p < 0.05$.
**$p < 0.01$.
ACEI/ARB = angiotensin-converting enzyme inhibitor/angiotensin receptor blocker; BMI = body mass index; bpm = beats/min; HR = heart rate; LVEF = left ventricular ejection fraction; NYHA = New York Heart Association; RPE = rating of perceived exertion; VT = ventilatory threshold.

The HRR did not correlate with LVEF and resting HR. There was a significant negative correlation between HRR and age ($p < 0.01$). In addition, HRR significantly correlated with HR_{peak} and $HR_{peak-rest}$ ($p < 0.01$). The relationship between $HR_{peak-rest}$ and HRR is shown in Fig. 3.

Table 3
Effects of β-blockers on the independent parameters and values obtained from the CPET.

Variable	Mean ± SD		p
	β-blocker	No β-blocker	
Resting HR (bpm)	73.1 ± 10.9	78.5 ± 11.2	0.02*
HR_{peak} (bpm)	115.0 ± 14.8	132 ± 17.1	<0.01**
$HR_{peak-rest}$ (bpm)	41.9 ± 14.2	53.5 ± 17.4	<0.01**
VO_{2max} (mL/kg/min)	17.9 ± 4.6	20.3 ± 4.6	0.02*
Metabolic equivalents (3.5 mL/kg/min)	5.1 ± 1.3	5.8 ± 1.3	0.01*
VT RPE	12.7 ± 1.7	11.5 ± 1.4	<0.01**
VT workload (W)	56.7 ± 17.2	51.7 ± 17.9	0.17
RER	1.04 ± 0.1	1.07 ± 0.1	0.05
HRR (bpm)	12.5 ± 8.8	17.0 ± 9.1	0.02*
HR 1 min into the cool-down phase (bpm)	102.5 ± 12.2	115.1 ± 14.1	<0.01**

Data are presented as mean ± SD.
*$p < 0.05$.
**$p < 0.01$.
bpm = beats/min; CPET = cardiopulmonary exercise test; HR = heart rate; HRR = heart rate recovery; HR_{peak} = peak heart rate; $HR_{peak-rest}$ = difference between HR_{peak} and resting HR; RER = respiratory exchange ratio; RPE = rating of perceived exertion; SD = standard deviation; VO_{2max} = peak oxygen consumption; VT = ventilatory threshold.

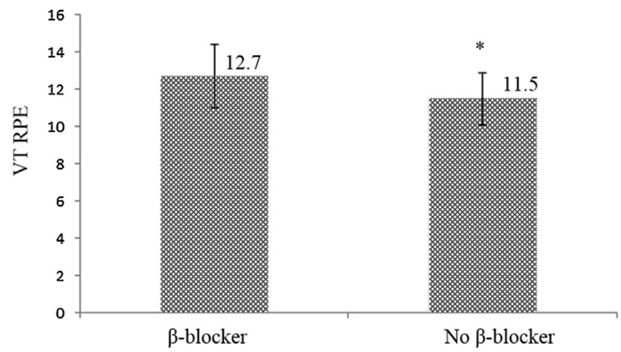

Fig. 1. Effect of β-blockers on the rating of perceived exertion (RPE) values associated with the ventilatory threshold (VT RPE). $^{*}p < 0.05$.

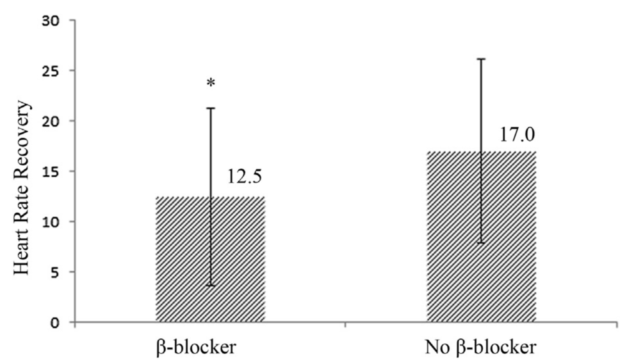

Fig. 2. Use of β-blockers attenuates heart rate recovery. $^{*}p < 0.05$.

4. Discussion

Before entering CR, a symptom-limited CPET is usually performed. Among the various CPET parameters, the HR_{max} and VO_{2max} are typically measured directly in the CPET to generate guidelines for an individualized exercise prescription. Through the heart rate-lowering effect of β-blockers, the interpretation of the heart rate response to exercise based on an age-predicted maximum heart rate is confounded. As expected, we found a significantly higher HR_{peak} in participants

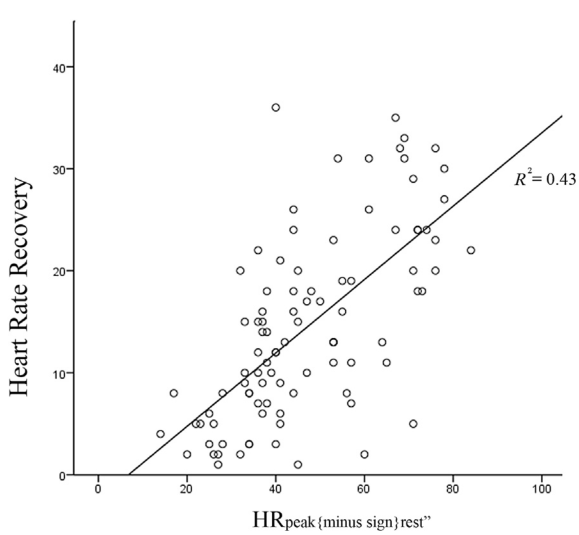

Fig. 3. Heart rate recovery correlated significantly with $HR_{peak-rest}$ ($R^2 = 0.43$, $p < 0.01$). HR = heart rate.

without β-blockers, which is similar to results reported previously.[7] This lower HR_{peak} corresponded to a reduced VO_{2max} in those individuals taking β-blockers.

One important parameter that is used to guide exercise intensity is the RPE. The role of the RPE in the prescription of exercise intensity for participants with *coronary artery disease* (CAD) is unclear, especially for those taking β-blockers. Although several studies have discussed the use of the RPE Scale for exercise prescription, most cohorts were healthy adults. In participants without an entry exercise test, the recommended exercise intensity based on the RPE is 11−14. The Borg 6−20 RPE Scale was designed to assess exertion. In participants entering CR without an exercise test, the RPE Scale is also one of the most common methods used to monitor exercise tolerance.[14,21] The correlation between the RPE and VT is important because the VT is used for the prescription of exercise intensity.[22] Scherr et al[23] showed that in healthy people, the lactate thresholds [either before the onset of lactate accumulation (LT1) or at a lactate concentration of 1.5mM above LT1] corresponded to RPE values of 10.8 ± 1.8 and 13.6 ± 1.8, respectively. They suggested that when prescribing exercise intensity, RPE 11−13 is better suited for more novice participants, whereas RPE 13−15 is more appropriate for trained participants. In another study on a cohort of untrained adults, Rynders et al[13] showed that RPE 9−12 was correlated with maximal fat oxidation and lactate threshold, and was thus suggested as the ideal exercise intensity. Our study further clarified the role of RPE in prescribing exercise intensity for patients with a recent episode of AMI entering CR programs. In this study, an important finding is that the VT RPE was influenced by the use of β-blockers. Zanettini et al[24] showed that in patients taking β-blockers after cardiac surgical revascularization, the self-regulation of exercise training intensity between Grade 4 (somewhat hard) and Grade 5 (hard) of the 10-point category-ratio Borg Scale is effective but may promote overtraining in some patients without significant functional advantages. The "somewhat hard" (Grade 4) exercise training intensity of the 10-point category-ratio Borg Scale is compatible with Grade 13 of the 20-point category-ratio Borg Scale. These results suggest that in patients with a recent episode of AMI and taking β-blockers, a training intensity of RPE 13 (or RPE 4 of the 10-point category-ratio Borg Scale) is appropriate. For those with a recent episode of AMI but not taking β-blockers, RPE 11 is suggested to be appropriate.

Many clinical trials have shown that β-blockers are considered a cornerstone therapy in patients with acute coronary syndrome for reducing mortality after AMI.[25,26] It is hypothesized that β-blockers achieve their clinical effects through their heart rate-lowering capability. Despite a high rate of the use of β-blockers in outpatients with stable CAD, patients often have resting HR > 70 beats/min (bpm).[27] In our study, the average resting HR in participants taking β-blockers was 74.4 bpm. This is consistent with a prior observation which showed that the average HR was 74 bpm in patients with postacute coronary syndromes taking β-blockers.[28] Although a targeted HR of 50−60 bpm was recommended,[29] only a minority of patients achieved this therapeutic goal.[27,28] Further studies are necessary to validate this therapeutic goal.

HRR is an independent prognostic factor related to overall mortality associated with cardiovascular diseases,[30] and is thought to be a reflection of vagal tone.[31,32] In our study, an attenuated response of HRR was observed in patients taking β-blockers. Ushijima et al[33] demonstrated that HRR is correlated with the increment in HR from rest to peak exercise ($HR_{peak-rest}$), which was consistent with the result of this study. As the use of β-blockers attenuated $HR_{peak-rest}$, this may explain the attenuated HRR observed in this study.

4.1. Limitations

There were several limitations of this study. First, cycling was used as the testing instrument in our institution. Compared with treadmill exercise, the results of exercise tests using a cycle ergometer yielded a 5–25% lower VO_{2max}.[34] Therefore, it is unclear whether our findings can be applied to a CR program using a treadmill or running exercise. Second, this observational study may not fully reflect regional differences in clinical characteristics and patterns of care of stable CAD patients, and the data were collected from a single center that served communities located in central Taiwan. Thus, the data may not reflect the actual conditions in Western countries. As the VO_{2max} obtained in our study was consistent with that reported by Ades et al[35] (who used a treadmill), we think that RPE 11 or 13 can still provide a valid method for home exercise prescription in patients with or without β-blocker use. Further clinical investigations comparing the training effect between different RPE levels are necessary to support our findings.

In conclusion, the results of this study indicate that in patients with a recent episode of AMI entering CR programs, the VO_{2max} is relatively low. It would appear that the prognostic marker HRR is attenuated by β-blockers. Finally, in patients who do not undergo a CPET, when using RPE for the initial exercise prescription to determine training intensity, the use of β-blockers should be taken into consideration.

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