An Evaluation of Training Responses Using Self-regulation in a Residential Rehabilitation Program

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■ BACKGROUND: The efficacy of exercise training for patients with cardiovascular disease is well established. Given recent changes in reimbursement patterns for cardiac rehabilitation and therefore a greater need for self-monitoring, home programs, and the like, a need exists to determine the capability of patients to regulate their own exercise intensity and assess the efficacy of self-regulated exercise. This study assessed the training responses of a group instructed to train at an intensity they perceived as "somewhat hard," and compared their responses to standardized methods of exercise prescription.

■ METHODS: A total of 78 patients (86% male; mean age, 56 ± 10 years; mean ejection fraction, 64% ± 12%) referred to a residential rehabilitation program after myocardial infarction or bypass surgery were randomized to three different groups, for which exercise intensity was prescribed using different methods. For group 1, 70% of heart rate reserve was maintained using precise, continuous electronic heart rate-controlled resistance on a cycle ergometer. Group 2 gauged their own exercise intensity according to a level they perceived as "somewhat hard" (13 on the Borg scale) and were given no feedback in terms of heart rate or work rate. For group 3, exercise intensity was determined using both objective (heart rate reserve and work rate targeted to 60% to 80% of maximal exercise) and subjective (Borg scale 12 to 14) indices. The subjects exercised daily for 1 month. Training frequency, duration, and mode were equivalent between the groups.

■ RESULTS: The exercise capacity of the three groups was increased significantly after the training period: 33.7% in group 1, 22.9% in group 2, and 31.2% in group 3 ($P < .005$ for all). Other measures of the training response also were similar between the groups, including a significant increase in work rate at a perceived exertion of 13 and maximal watts achieved. The magnitude of the training response was not different between the groups. There were no complications during training.

■ CONCLUSIONS: The training response was similar between the three methods used to monitor exercise intensity. Thus, patients are able to gauge their own exercise intensity reasonably when instructed to exercise at a perceived exertion of 13. This suggests that close heart rate monitoring may not always be necessary for many stable patients with cardiovascular disease to achieve the benefits of a rehabilitation program.

K E Y W O R D S

exercise training

cardiac rehabilitation

exercise prescription

exercise testing

myocardial infarction

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This study was supported in part by grants from RAHN-Medizinfonds, Zurich, Schweizerische Herzstiftung, Switzerland, and the Instituto National De Cardiologia, Ignacio Chavez, Mexico City.

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The benefits of exercise training for patients who have sustained a myocardial infarction (MI) and those who have undergone coronary artery bypass surgery (CABS) are well established.[1] The foundation of exercise training in cardiac rehabilitation is the exercise prescription: the mode, intensity, duration, and frequency of exercise. By convention, one of several methods is used to prescribe training intensity such that the patient's heart rate falls within a target range. Historically, it was thought that maintaining an exercise intensity within a specific heart rate range provides a training effect that is optimal, individualized, and safe. A large empirical body of literature has demonstrated the effectiveness of this approach over several decades. During this time, cardiac rehabilitation has become established as an effective therapeutic modality after an MI or CABS.[2]

Despite the benefits associated with cardiac rehabilitation, however, formal programs remain elusive for most patients.[1,3] Between 80% and 90% of eligible US patients do not receive formal cardiac rehabilitation services. Furthermore, because of changes in reimbursement patterns, many patients do not get cardiac rehabilitation or receive only brief recommendations on home exercise after discharge. Moreover, an increasing number of patients are referred to cardiac rehabilitation without entry exercise testing,[4] making heart rate-based exercise prescription difficult. Studies also have shown that dropout rates for exercise programs range from 25% to 50%,[5,6] with excessive exertion demands and lack of confidence cited as two of the most important deterrents to a sustained exercise program. Finally, from a public health perspective, the emphasis has shifted recently from exercise "intensity" to "physical activity."[7] This view has evolved in part from an awareness that a specific intensity is less important during an exercise program than the development of habits and a knowledge base that lead to a more physically active lifestyle in the long term.[7,8]

For these reasons, there exists a need to determine exercise intensity, safety, and training efficacy on the basis of a patient's self-regulated effort in the absence of close surveillance or equipment. The current study specifically investigated whether patients enrolled in a rehabilitation program achieve training benefits when asked to exercise at an intensity commensurate with what they perceive as "somewhat hard."[9] This group was provided no feedback in terms of heart rate or work load, and was compared with groups that trained within strict heart rate ranges, including one that used continuous electronic heart rate-controlled resistance on a cycle ergometer. The study objective was to determine whether a self-regulated program would yield training benefits similar to those of more traditional, heart rate-based approaches.

METHODS

The study participants were 78 consecutive patients (86% male; mean age, 56 ± 10 years) referred to a residential rehabilitation center in Seewis, Switzerland. This residential center is one of several in Switzerland to which patients come from an outlying area to reside for a 1-month period after a myocardial event (usually MI or CABS).

The clinical characteristics of the three groups in this study are outlined in Table 1. As shown, 39 participants (50%) had sustained an MI; 39 (50%) had undergone percutaneous transluminal coronary angioplasty; and 41 (52%) had undergone CABS.

Table 1 • CLINICAL AND DEMOGRAPHIC CHARACTERISTICS AT BASELINE

Characteristics	Group 1 *Mean ± SD Number (%)*	Group 2 *Mean ± SD Number (%)*	Group 3 *Mean ± SD Number (%)*
Demographics			
Number	24	27	27
Age	54.3 ± 11.6	60.9 ± 10.2	55.4 ± 9.1
Male	21 (87)	23 (85)	23 (85)
Height, cm	1.73 ± 0.07	1.72 ± 0.06	1.72 ± 0.08
Weight, kg	83.5 ± 12.6	77.9 ± 11.4	79.2 ± 12.1
Ejection fraction, %	68.6 ± 12	60.8 ± 13	60.8 ± 14
Myocardial infarction	8 (33)	15 (55)	13 (48)
PTCA	12 (50)	15 (55)	12 (44)
Medications			
Beta blocker	19 (79)	22 (81)	23 (85)
Nitrates	2 (8)	3 (11)	2 (7)
Calcium antagonist	2 (8)	4 (15)	4 (15)
Aspirin	22 (92)	27 (100)	24 (89)
Anticoagulant	2 (8)	3 (11)	11 (41)
ACE /AT II	5 (21)	6 (22)	7 (26)
Diuretics	8 (33)	11 (41)	11 (41)
Statins	22 (92)	26 (96)	24 (89)
Digoxin	0 (0)	0 (0)	0 (0)
Antiarrythmics	6 (24)	6 (22)	6 (22)

PTCA, percutaneous transluminal coronary angioplasty; ACE, angiotensin-converting enzyme inhibitor; AT II, angiotensin II receptor blocker.

After their coronary event, the patients were stabilized for approximately 2 weeks. The mean number of days between the patients' hospital admission and their initiation into the study was 15.5 ±12 days. All the patients had stable symptoms at baseline, and none had evidence of heart failure, as determined by clinical or echocardiographic criteria. All the patients were limited by fatigue, dyspnea, or both at baseline exercise testing, and none had clinical evidence of pulmonary disease. After informed consent was obtained, baseline exercise testing was performed, and the subjects were randomized into one of the three study groups.

Exercise Training

The rehabilitation center chosen for this study is located in an area isolated in the mountains at an elevation of 3500 feet. The center has its own staff of physicians including a medical director and three medical residents. The program components included education, exercise, and low-fat meals prepared daily by the center's cook. Details of the rehabilitation program have been described previously.[10]

Training frequency, mode, and duration were the same for all three groups. Only the method for monitoring exercise intensity was altered. Five indoor cycling sessions were performed weekly for 30 minutes, and all the participants walked outdoors for 45 minutes twice daily. The duration of training was 1 month.

For group 1, exercise intensity was determined using a standard heart rate reserve method: (maximal heart rate-rest heart rate × 0.70) + rest heart rate.[11] During indoor cycling sessions, resistance was controlled using a heart rate feedback mechanism. A specific target heart rate was entered into the system, and resistance was adjusted at 10-second intervals to maintain a desired heart rate. During walking sessions, a Polar heart rate device (Polar, Inc., Woodbury, NJ) was used to monitor heart rate, and walking pace was adjusted such that heart rate was kept within ±5 beats/minute of the target. Perceived exertion data were not acquired for this group.

For group 2, indoor and outdoor exercise intensities were determined using only the patient's perceived Borg scale rating of 12 to 14 ("somewhat hard")[9] irrespective of heart rate or work rate.

For group 3, exercise intensity was determined using both objective (heart rate reserve and work rate targeted to 60% to 80% of maximal exercise) and subjective (Borg scale 12 to 14) responses, and work rate was manually adjusted accordingly.

Use of Perceived Effort

For group 1, perceived exertion data were not recorded. In groups 2 and 3, the Borg 6 to 20 scale was carefully explained to the participants before they began their exercise training sessions. For group 2, the first two training sessions were "learning" sessions, in which the participants were taught to exercise using a self-regulated intensity between a rating of 12 and 14. Thereafter, the participants were instructed to exercise at this intensity and provided with no other feedback in terms of exercise programming. Heart rate was recorded only for retrospective comparison with the heart rate reserve method, and no feedback was provided to the patient regarding heart or work rate. The participants in both of these groups were asked to provide perceived exertion levels at 10-minute intervals during exercise. For the outdoor walking sessions, walking pace was adjusted to elicit the desired heart rate or perceived exertion responses. All the indoor cycling sessions were supervised directly by a medical resident, and the outdoor walking sessions were supervised by exercise physiologists.

Exercise Testing

On the day of testing, the participants in both groups were asked to abstain from food, coffee, and cigarettes for 3 hours before the test. Standard pulmonary function tests were performed. Maximal exercise testing was performed on an electrically braked cycle ergometer using an individualized ramp protocol.[12] Briefly, this test entails choosing an individualized ramp rate that will yield a test duration of approximately 10 minutes. A 12-lead electrocardiogram (ECG) was monitored continuously, and blood pressure was measured manually every minute during the exercise and throughout the recovery period. The patient's subjective level of exertion was quantified every minute using the Borg 6-20 scale.[9] All the tests were continued to volitional fatigue/dyspnea. No test was terminated because of an untoward event or inappropriate sign or symptom.

Echocardiography

Ejection fraction and left ventricular end-diastolic dimensions were determined at baseline and after training using standard M-mode and two-dimensional echocardiography (VingMed CFM-725; GE Medical Systems, Horten, Norway). All echocardiograms were performed by the same cardiologist using the parasternal window with long- and short-axis views. The ejection fraction was calculated using the Teicholz method.[13]

Statistical Analysis

Multivariate ANOVA procedures between patients randomized to the three training groups were performed using NCSS software (Salt Lake City, UT). Main effect analyses were performed initially for each of the exercise test responses to compare before and after training. Post hoc procedures (within group before and after comparisons) were performed using the Bonferoni method. Data are presented as mean ± standard deviation.

RESULTS

No differences were observed between the three groups initially in terms of clinical or demographic data including age, height, weight, pulmonary function, and medication status (Table 1). No untoward events occurred during any of the exercise testing or training procedures. Retrospective assessment of heart rate recordings showed no differences between the groups in terms of training intensity expressed by the heart rate reserve method. The training intensities were 65% in group 1, 64% in group 2, and 69% in group 3. The mean heart rates during all the exercise training sessions also were similar: 107 ± 13 beats per minute (bpm) in group 1, 105 ± 10 bpm in group 2, and 106 ± 8 bpm in group 3. The mean perceived exertion during the training sessions in the self-regulated group (group 2) was 12.8 ± 0.47, and the value for group 3 was 12.6 ± 0.79.

The exercise testing responses before and after the study period are presented in Table 2. All the groups achieved mean maximal perceived exertion levels that exceeded 18 or 19, suggesting that maximal efforts were generally achieved. Submaximally, the work rate (in watts) at a perceived exertion of 13 was higher after training in each group (ranging from 28 to 36 watts higher; $P < .05$), although the heart rate at 5 minutes of exercise (matched individualized work rate in watts) was not significantly different after training. At maximal exercise, the heart rate increased significantly in groups 1 and 3 ($P < .05$), but not in group 2. The peak watts increased by 31% ($P < .01$) in group 1, by 23% ($P < .01$) in group 2, and by 31% ($P < .01$) in group 3 after training, and similar increases were observed in all the groups for exercise time ($P < .005$). The magnitude of the change in exercise capacity was not significant between groups. The changes in ejection fraction and left ventricular end-diastolic dimensions were not significant within or between groups after the training period.

DISCUSSION

The present findings show that patients in a rehabilitation program who self-regulated their exercise intensity at a level commensurate with "somewhat hard" achieved training benefits (as measured by an increase in exercise tolerance) that did not differ from those of patients whose exercise program was prescribed using more traditional methods, including a group whose heart rate was tightly controlled via a heart rate-work rate feedback cycle ergometer.

These findings suggest that an exercise intensity that is less formal and self-determined can be effective in

Table 2 • EXERCISE TEST RESPONSES BEFORE AND AFTER TRAINING

	Group 1		Group 2		Group 3		
Variable	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*	*P*‡
Rest							
Heart rate, beats/min	76 ± 10	73 ± 15	77 ± 15	71 ± 14	76 ± 12	72 ± 11	.84
Systolic BP, mmHg	126 ± 14	125 ± 13	118 ± 16	119 ± 14	121 ± 15	126 ± 20	.64
RPP ($\times 10^3$)	9.7 ± 1.8	9.2 ± 1.9	9.1 ± 2.2	8.6 ± 2.1	9.3 ± 2.0	9.2 ± 2.0	.86
Submaximal exercise							
Heart rate at PE 13	104 ± 17	115 ± 18	101 ± 17	107 ± 17	99 ± 13	110 ± 13	.71
Watts at PE 13	82.6 ± 36	116.4 ± 40 *	76.8 ± 28	105.1 ± 40*	79 ± 31	115.3 ±37†	.84
Heart rate at 5′	102 ± 11	99 ± 13	100 ± 12	94 ± 14	100 ± 13	97 ± 13	.74
Maximal exercise							
Heart rate, beats/min	125 ±17	141 ± 19 *	119 ± 20	129 ± 18	116 ± 14	132 ± 18 *	.52
Systolic BP, mmHg	186 ± 29	200 ± 23	169 ± 35	177 ± 30	168 ± 25	186 ± 33	.68
RPP ($\times 10^3$)	23.4 ± 5.4	28.4 ± 5.9	20.7 ± 7.3	23.2 ± 6.5	19.5 ± 3.8	24.9 ± 6.1 *	.43
Workload (watts)	129.2 ± 39	169.1 ± 41 *	123.3 ± 37	151.2 ± 42	124.5 ± 38	163.3 ± 46 †	.70
PE	18.2 ± 1	18.8 ± 0.8	18.3 ± 0.9	19.2 ± 0.8 †	18.3 ± 1	18.9 ± 0.8	.69
Exercise time, min	8.3 ± 1.5	11.1 ± 1.4 †	8.3 ± 1.8	10.2 ± 2.0†	8 ± 1.8	10.5 ± 2.4 †	.45
Echocardiography							
EF (%)	68.6 ± 12	73 ± 11	60.8 ± 13	63.4 ± 12	60.8 ± 14	67.2 ± 14	.77
LVEDD, mm	49.2 ± 8	52.3 ± 7	52.8 ± 8	52.3 ± 7	50.9 ± 8	52.6 ± 7	.49

* $P < .05$, †$P < .01$ pre versus post within group.
‡ *P* values from between-group comparison.
BP, blood pressure; RPP, rate pressure product; PE, perceived exertion; EF, ejection fraction; LVEDD, left ventricular end-diastolic dimensions.

achieving a training effect, at least in stable, low-risk patients. Although the magnitude of the training response was somewhat lower for the self-regulated patients than for the other groups, the response to rehabilitation (23% increase in exercise capacity) was commensurate with an accepted training effect, and did not differ significantly from that in the heart rate-regulated groups. The residential rehabilitation program provided ideal conditions in which to perform such a study because other factors affecting the training response, such as duration, frequency, mode, and compliance, were kept uniform between the groups.

Whereas close supervision of exercise intensity, including ECG monitoring during cardiac rehabilitation, was once more widely used, current guidelines suggest that such close surveillance is not necessary for most individuals, and that direct ECG monitoring should be reserved for selected high-risk patients.[14] This is largely because of the changing perception about exercise prescription, including the view that moderate exercise is remarkably safe for most patients,[15,16] making close scrutiny of heart rate targets unnecessary. In addition, reimbursement patterns have changed such that many patients receive less surveillance than in previous decades.[17] The current observation that stable patients can train effectively after MI, percutaneous transluminal coronary angioplasty, or CABS when limited to the use of perceived exertion as a guideline has implications for training among patients who need less monitoring, participate in home programs, or cannot afford or otherwise do not have access to traditional outpatient programs.

The current results should not be interpreted to suggest that traditional methods of exercise prescription may be discarded or safety ignored. The “art” of exercise prescription involves applying a combination of several objective and subjective indices.[8,18,19] Heart rate has been the foundation of exercise prescription because it closely parallels myocardial oxygen demand[20] and total body oxygen uptake.[19] The former is important in that heart rate reflects a reproducible myocardial oxygen demand that can be associated with ischemia, and the latter is important in that “training” ultimately reflects the extent to which total body oxygen uptake is increased relative to its maximum. However, the current results do suggest that for patients considered by established criteria to be at low risk (eg, stable patients who do not demonstrate signs or symptoms of ischemia during exercise or clinically important arrhythmias), a training program early after a coronary event can be effective without specific heart rate or work rate targets. Because a great deal of effort has been directed toward increasing the proportion of patients who receive cardiac rehabilitation services[21] (estimated to be only 80% to 90% of eligible patients), the current findings have applications for those who do not have monitoring facilities available or those who participate in a home program.

Previous Studies

Advantages and limitations of using heart rate alone for prescribing exercise have been described over the years. Maximal and submaximal heart rate shows considerable variation even for individuals the same age,[22] and both are influenced by emotional states, medications, and environment. In addition, the strength of the association between heart rate during exercise and oxygen uptake can be altered by disease, mode of exercise, exercise intensity, and motor skills.[2] Studies using heart rate and perceived exertion in combination more accurately achieve targeted work rates than either measure alone,[23,24] and targeted intensities are more accurately achieved with learning and feedback.[23,25,26]

Smutok et al[27] observed that self-regulated exercise intensity is accurately achieved at high, but not low, metabolic rates. Strzelczyk et al[28] recently reported that patients with congestive heart failure who exercise at a perceived exertion of 11 to 13 more often fall within the targeted ±10% of the ventilatory threshold than those who follow the heart rate reserve method. However, at a perceived exertion of 11 to 13, only half of the patients were exercising within the ±10% ventilatory threshold range. Dishman et al[23] observed that subjects who attempted to produce a training heart rate based on perceived exertion had a mean difference of only 3 beats/min, as compared with the prescribed heart rate, and that the difference was reduced after they received feedback about their training heart rate over three exercise sessions.

Several studies have shown that errors associated with reproducing submaximal oxygen consumption from perceived exertion are not greater than the errors observed from the use of target heart rate.[23,29-31] Other studies have shown significant errors with exercise prescribed using self-regulation only. Chow and Wilmore[32] reported that during self-paced treadmill jogging without feedback, subjects remained in a target heart rate range (60% to 70% heart rate reserve) only 25% of the time. Allowing subjects to monitor pulse rate periodically increased accuracy to 55%, whereas using the rate of perceived exertion increased accuracy similarly to 48%.

Among the participants in the current study who used self-regulation (without feedback) to gauge their exercise intensity, the mean percentage of heart rate reserve was 64%, which was not different from the 65% and 69% intensities, respectively, in the two groups monitored by heart rate and given feedback. Although it should be noted that most of the aforementioned studies were conducted in a different context (eg, repeat treadmill tests among healthy individuals), the current results suggest that most patients in a cardiac rehabilitation setting will achieve an acceptable exercise intensity by self-regulation.

Ventricular Function

Baseline echocardiograms are routinely taken at referral to the authors' rehabilitation center. For the purposes of this study, echocardiograms also were measured at discharge. Although not the focus of this study, it is noteworthy that, like the majority of studies in similar populations (post-MI and post-CABS), no differences were observed in ejection fraction after training.[1] The program at Seewis also uses a comparatively concentrated training stimulus (high frequency of training sessions over a 1-month period), and this type of training has generated concerns about further ventricular damage or volume expansion among post-MI patients in the recent past.[33] Notably, the current results provide further evidence that training does not cause further ventricular expansion (ie, left ventricular end-diastolic dimensions) or changes in ejection fraction in such patients. It should be noted that the 1-month duration of the study represents only a small period in the overall time course of the remodeling process.[34]

Limitations

The rehabilitation facility used in this study is remote, and cardiopulmonary exercise testing equipment was not available. Therefore, exercise responses were not quantified using these more precise techniques. Because exercise prescribed on the basis of perceived exertion alone does not permit the same surveillance as that using ECG monitoring, heart rate, work load, or their combination, it is reasonable to suggest that such an approach should be limited to stable, low-risk patients. In this regard, none of the patients in the current study had reduced ventricular function or clinically significant arrhythmias during exercise, and none met the American College of Cardiology criteria for direct ECG monitoring. The duration of training also was relatively short (1 month). However, this approach is typical of residential programs in central Europe, and it has been demonstrated that most of the increase in exercise capacity occurs during the first month of training in these[10] and other programs.[1]

SUMMARY

Significant training effects occur using both traditional heart rate and non-heart rate methods for exercise intensity in a residential rehabilitation program characteristic of those in central Europe. Patients are able to self-regulate their exercise intensity reasonably when instructed to exercise at a perceived exertion of 13. This suggests that at least in terms of gains in exercise capacity, close heart rate monitoring is less necessary for many stable patients after MI or CABS. These findings may be useful for the relatively large proportion of patients in the United States who participate in home programs or otherwise do not have access to a traditional rehabilitation facility.

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