ORIGINAL ARTICLE

Cardiac Rehabilitation in Chronic Heart Failure: Effect of an 8-Week, High-Intensity Interval Training Versus Continuous Training

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ABSTRACT. Freyssin C, Verkindt C, Prieur F, Benaich P, Maunier S, Blanc P. Cardiac rehabilitation in chronic heart failure: effect of an 8-week, high-intensity interval training versus continuous training. Arch Phys Med Rehabil 2012;93: 1359-64.

Objective: To compare the effects of an 8-week, high-intensity interval training protocol versus continuous training.

Design: Randomized controlled trial.

Setting: Cardiac rehabilitation center.

Participants: Patients (N=26; mean age ± SD, 54±12y) with chronic heart failure were enrolled in a cardiac rehabilitation program for 8 weeks.

Interventions: Patients were randomly assigned into 2 groups that performed either interval training (IT) or continuous training (CT). IT consisted of 3 sessions of 12 repetitions of 30 seconds of exercise at very high intensity, followed by 60 seconds of complete rest. The CT group performed CT exercises, which consisted of 45 minutes of aerobic exercise.

Main Outcome Measures: Parameters of gas exchanges: peak oxygen consumption ($\dot{V}O_2$peak), first ventilator threshold (VT1), distance at six-minute walk test (6MWT), and level of anxiety and depression were measured.

Results: The IT group increased significantly their $\dot{V}O_2$peak, the duration of the exercise test, the oxygen pulse, oxygen consumption at the VT1, and the distance walked during the 6MWT. The CT group only increased the time at the VT1 and the distance performed at the 6MWT. The improvement in the time at the VT1 was significantly higher for the IT group than for the CT group.

Conclusions: This study shows that IT at very high intensity for patients with heart failure appears to be more effective than CT in improving indices of submaximal exercise capacity.

Key Words: Heart failure; Rehabilitation.

PRIOR TO 1980, congestive heart failure was a contraindication to exercise. This concept has been abandoned and many randomized studies have demonstrated that an adapted physical activity program leads to an improvement in exercise tolerance, which is an important prognosis marker for patients with heart failure.[1] Thus, exercise training in cardiac patients increases exercise duration, the first ventilatory threshold (VT1), and peak oxygen consumption ($\dot{V}O_2$peak) by 15% to 30% without any increase in morbidity and mortality.[2-4] Improvement of the VT1 is of important clinical relevance, because it leads to an improvement in the ability to tolerate submaximal exercise and in quality of life perception. Chronic exercise also improves some symptoms of chronic heart failure.[1] It was thus shown that physical exercise induced a regression of the left ventricular dysfunction markers,[5] a decrease in vascular resistance,[6] a reduction in the endothelial dysfunction,[7] and an increase in the oxidative capacity of peripheral muscles.[8] The management of patients with heart failure and their treatment have evolved significantly over the last decade and the benefits of cardiac rehabilitation are well-documented in the literature. Physical exercise and cardiac rehabilitation are associated with a reduction in mortality and rehospitalization.[9,10] Therefore, training is now part of the recommendations in the management of heart failure.

Several types of training protocols are currently used in rehabilitation, but there is still debate regarding the intensity and type of exercise training that can provide optimal effects for chronic heart failure.[11] It has been demonstrated that aerobic interval training (IT) is feasible even in elderly patients with heart failure and severely impaired cardiovascular function.[12] IT can induce significant and clinically important physiologic adaptations in a population of coronary artery disease, and it was reported that improvements were to a greater extent after IT than after moderate-intensity continuous training (CT).[13]

To our knowledge, studies on the effects of IT in patients with chronic heart failure were performed using 4 repetitions of high-intensity intervals (80%–95% of $\dot{V}O_2$peak) of a relatively long duration (2–5min), separated by moderately intense recovery periods (50%–70% of $\dot{V}O_2$peak).[13] It was suggested that the fluctuations of high oxygen requirements during IT sessions would maximize the training induced adaptations.[14] Therefore,

List of Abbreviations

CT	continuous training
HADS	Hospital Anxiety and Depression Scale
IT	interval training
MET	metabolic equivalent task
MCID	minimal clinical important difference
rpm	revolutions per minute
6MWT	six-minute walk test
$\dot{V}O_2$	oxygen consumption per unit time
$\dot{V}O_2$peak	peak oxygen consumption
VT1	first ventilatory threshold

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IT performed with more repetitions of exercise of shorter duration and at higher intensities could be more efficient in improving exercise capacity in patients with heart failure. Moreover, the duration of the training program in previous studies was between 10[15] and 40 weeks,[16] which is longer than current rehabilitation programs. Consequently, it seems interesting to consider IT programs of lower duration performed at a higher intensity level with increased repetitions of shorter exercise periods, interspaced with periods of complete rest. In this context, we hypothesize that such an IT protocol could be more efficient to improve physical capacity and exercise tolerance than CT at the VT1, which is the intensity recommended by the French Cardiological Society[17] and the most often used in clinical practice. Therefore, the aim of this study was to compare the benefits of an 8-week high-intensity IT with a CT in a population of patients with chronic heart failure with regard to variables commonly used in cardiac rehabilitation.

METHODS

Participants

Twenty-six patients (mean age ± SD, 54±12y) with chronic heart failure were enrolled in an 8-week tailored multidisciplinary cardiac rehabilitation program at the Sainte Clotilde Cardiovascular Rehabilitation Center (Reunion Island, France). Criteria for inclusion were stable chronic heart failure and a left ventricular ejection fraction less than 40%. Patients have an optimized medical treatment. They received a beta-blocker, diuretic therapy. Patients were randomly assigned to 2 groups: 1 group (n=12) performed rehabilitation with interval training (IT) and 1 group (n=14) performed rehabilitation with continuous training (CT).

Study participants were matched at the beginning of the rehabilitation, according to age, sex, anthropometric criteria (weight), physical capacity ($\dot{V}O_2$peak, distance at the six-minute walk test [6MWT]), and smoking history (table 1). The protocol complied with the Helsinki Declaration and was approved by our local ethics committee. Informed consent was obtained from all patients.

Table 1: Baseline Characteristics of Patients Entering the Rehabilitation Program

Characteristics	CT Group	IT Group	*P*
Age (y)	55±12	54±9	.08
Sex ratio (men/women)	7/7	6/6	
Body mass index (kg/m²)	24.1±5.4	24.8±4.0	.99
Diabetics type 2 ratio	5/14	3/12	
Smoker			
Nonsmoker ratio	7/14	7/12	
Former smoker ratio	4/14	4/12	
Current smoker ratio	3/14	1/12	
Ejection fraction (%)	30.7±7.8	27.8±4.7	.25
$\dot{V}O_2$ (mL·min·kg)	10.6±4.1	10.7±2.9	.90
Oxygen pulse at maximal exercise (mL/beat)	6.6±3.3	6.2±2.4	.66
$\dot{V}O_2$ at the VT1 (mL·min·kg)	7.3±2.4	7.7±2.3	.79
Maximal workload steep ramp test (W)	–	183±34	
6MWT distance (m)	423±78	423±98	1.00
Depression, HADS Scale	9.4±4.8	8.8±3.5	.74
Anxiety, HADS Scale	7.7±2.3	6.6±1.8	.37
Systolic blood pressure (mm Hg)	110±17	114±22	.61
Diastolic blood pressure (mm Hg)	71±14	76±12	.33
Cause of chronic heart failure			
Ischemic ratio	12/14	10/12	
Alcoholism ratio	1/14	0/12	
Primary ratio	1/14	2/12	
Medications			
Betablockers ratio	14/14	12/12	
Antiplatelet ratio	10/14	7/12	
Diuretic ratio	14/14	12/12	
ACE ratio	12/14	10/12	
Antiarrhythmic ratio	8/14	6/12	
Statins ratio	9/14	9/12	

NOTE. Values are mean ± SD or as otherwise noted.
Abbreviation: ACE, angiotensin converting enzyme.

Cardiac Rehabilitation Program

The rehabilitation program was conducted according to previously published guidelines of the French Cardiological Society.[17] It was preceded by a consultation inclusion directed by a cardiologist and a clinical examination including measurement of blood pressure, echocardiography, stress testing, and blood tests. It was a multidisciplinary program of 8-weeks, and it consisted of physical activity and educational sessions. The physical activity program included 13 hours of exercise per week (2–3h/d, 5d/wk), conducted under the supervision of a physiotherapist or a sports teacher and nurse. It included 6 sessions of 71 minutes of IT or 61 minutes of CT, 4 hours of gymnastics, and 3 hours of balneotherapy (gymnastics in water). Gymnastic training consisted of a 5-minute warm-up followed by 45 minutes of strengthening exercises, stretching, and relaxation. The program also included therapeutic educational sessions on risk factors and physical practice.

After a 10-minute warm-up phase at 5W, IT consisted of 12 repetitions of 30 seconds of cycling exercise, followed by 60 seconds of complete rest. The exercise intensity was 50% and 80% of the maximal power reached during a steep ramp test during the first 4 weeks and the last 4 weeks, respectively. Each training session consisted of 3 series (12 repetitions of 30s of exercise), separated by 5 minutes of rest. Half of the CT was performed on a treadmill and half on a cycle ergometer (for practical and organizational reasons). CT was composed of a 10-minute warm-up followed by 45 minutes of aerobic exercise corresponding to the heart rate at the VT1 and a final 5 minutes of active recovery. Patients in the IT group practiced 168 minutes of exercise weekly, and patients in the CT group practiced 360 minutes of exercise weekly.

Tests

The cardiopulmonary test consisted of an exercise stress test performed on a treadmill with gas exchange measurements. The same test was performed at the beginning (t1) and the end (t2) of training on a treadmill,[a] using a ramp protocol. After a 10-minute warm-up on the treadmill, the work load was increased progressively by 1.07km/h per minute, and the slope was increased by 1.9% per minute. The criteria used to end the exercise test stress were: symptoms of fatigue, dyspnea, or leg fatigue/pain.

A steep ramp test[18] on a cycle ergometer was performed at the beginning of the rehabilitation, 1 day after the exercise stress test, only for patients in the IT group, to determine the intensity of training. After 10 minutes of cycling at 5W, the

Table 2: Evolution of Functional Capacity and Syndrome of Anxiety and Depression

Parameters	CT Group t1	CT Group t2	CT Group Change (%)	IT Group t1	IT Group t2	IT Group Change (%)	ANOVA Group Effect (*P*)	ANOVA Training Effect (*P*)	ANOVA Interaction Effect (*P*)
Functional capacity									
$\dot{V}O_2$ (mL·min·kg)	10.6±4.1	10.8±4.1	2	10.7±2.9	13.6±3.2‡	27	.272	<.001	.001
Exercise test duration (min)	3.5±0.6	3.9±0.6	12	3.3±1.2	4.9±0.6‡	47	.673	<.001	.002
Oxygen pulse at maximal exercise (mL/beat)	6.6±3.3	6.3±3.5	–3	6.2±2.4	7.3±2.1*	18	.854	.292	.033
$\dot{V}O_2$ at the VT1 (mL·min·kg)	7.3±2.4	7.5±3.4	2	7.7±2.3	9.4±2.4†	22	.240	.022	.059
Time at the VT1 (min)	1.1±0.5	1.6±0.7†	45	1.3±2.0	2.7±0.8‡	111	.043	<.001	.003
6MWT distance (m)	423.0±78.0	451±72*	6	423.0±98.0	475.0±52.0‡	12	.648	<.001	.218
Symptoms of anxiety and depression									
Depression, HADS Scale	7.3±2.3	3.1±1.3*	58	6.6±1.8	3.4±2.5*	48	1.000	.080	.501
Anxiety, HADS Scale	9.4±4.8	6.7±3.8*	29	8.8±3.5	6.5±3.1*	26	.910	.003	.792

NOTE. Values are mean ± SD or as otherwise indicated.
Abbreviation: ANOVA, analysis of variance.
**P*<.05.
†*P*<.01.
‡*P*<.001.

load was increased by 25W every 10 seconds until exhaustion. The subject was instructed to cycle at a pedal frequency between 60 and 80 revolutions per minute (rpm). A physiotherapist supervised this test and encouraged patients. The test ended when the pedal frequency fell below 50 rpm and when the patient was exhausted.

The functional capacity was assessed at t1 and at t2 using a 6MWT. It was conducted following a standardized protocol described by guidelines and in a 20-m flat obstacle free corridor.[19] This test assesses the submaximal level of functional capacity. It was performed 1 day after the stress test.

Measurements

Gas exchanges were measured during the exercise stress test.[b] It provided measurement of VO_2peak and the VT1.[20] Peak $\dot{V}O_2$ was determined as the $\dot{V}O_2$ achieved at the patient's peak work load, an average over the last 15 seconds. The VT1 was determined by visual inspection of the breakpoints in the pulmonary ventilation $\dot{V}O_2$. Gas analyzers and flow probes were calibrated before each test.

The level of anxiety and depression was measured using the Hospital Anxiety and Depression Scale (HADS)[21] by a psychologist, the same day of the stress test. The HADS Scale can screen for the most common psychological disorders: anxiety and depression. This test can validate the existence of symptoms and evaluates their severity.[22]

Statistical Analysis

Results were expressed as mean ± SD. For baseline characteristics, means of continuous variables were compared by paired Student *t* test. The sample size of the study was calculated to detect a mean difference of at least $3mL \cdot kg^{-1} \cdot min^{-1}$ between the groups, with a common SD of $2.5mL \cdot kg^{-1} \cdot min^{-1}$, with 80% power and a significance level of .05. A two-way, repeated-measures analysis of variance with group and time as factors was employed. When a significant effect of factors or interaction (group × time) was observed, a post hoc test (Tukey) was performed for each variable in order to identify the differences. In case of a significant difference in a variable in both groups, the variation (t2–t1) was compared using a Student *t* test. $P<.05$ was considered statistically significant. All analyses were performed using SigmaStat software.[c]

RESULTS

At baseline of cardiac rehabilitation, disease etiology and medications were similar for both groups, and no more therapeutic changes had occurred in the rehabilitation program (see table 1). The pharmacologic treatment was comparable between the groups.

Peak $\dot{V}O_2$, exercise test duration, oxygen pulse at maximal exercise, and $\dot{V}O_2$ at the VT1 increased significantly after 8 weeks of IT, while no significant change was observed after CT for these variables (table 2). The time corresponding to the VT1 and the distance at the 6MWT were significantly improved after IT and CT. This increase in the time at the VT1 was, however, significantly higher with IT than with CT (fig 1). Lastly, the level of anxiety and depression was significantly improved by both training methods. This improvement was not significantly different between IT and CT.

The adherence to the training was 100% with no dropouts. It should be noted that no cardiac event and no major decompensation were observed.

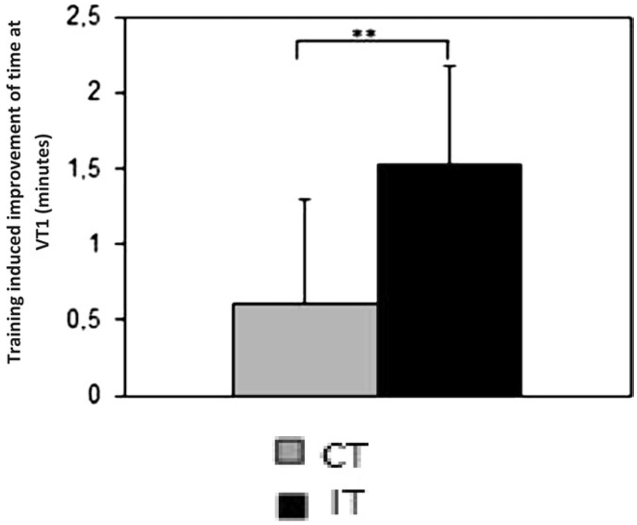

Fig 1. Improvement in time at the VT1. **$P<.01$: difference between IT and CT.

DISCUSSION

The major finding of the present study was that a short IT program performed at high intensity induced significant improvement in the functional physical capacity in patients with chronic heart failure, while CT had fewer effects on this capacity. Indeed, in CT we observed an increase in the time at the VT1 but no significant change in VO_2peak, exercise test duration, and $\dot{V}O_2$ at the VT1, while we found that IT significantly increased VO_2peak, exercise test duration, time at the VT1, and $\dot{V}O_2$ at the VT1, indicating an improvement in exercise tolerance. The VT1 reflects the degree of deconditioning, and the increase of time and $\dot{V}O_2$ at the VT1 suggest a delayed intervention of the anaerobic pathways for energy production.[23] Indeed, VO_2peak and $\dot{V}O_2$ at the VT1 were improved by 27% and 22%, respectively, which is similar to previous studies in patients with coronary artery disease (17%–46% for the increase in VO_2peak and 23%–42% for the increase in $\dot{V}O_2$ to the VT1[12,15,16,24-26]). The increase in VO_2peak was approximately 1 metabolic equivalent task (MET) in IT. This increase appears to be considerable, because according to the dose-response analyses, a 1 MET higher level of maximal aerobic capacity is associated with 13% and 15% decrements in risk of all mortality and coronary heart disease.[27] Tabet et al[28] showed that a lack of increase in exercise capacity with training (evaluated by VO_2peak) in patients with chronic heart failure has strong prognostic value for cardiac events. Patients that do not respond to rehabilitation, as defined by an improvement of less than 6% in the ratio of VO_2peak, were 8 times more likely to have a cardiac event over the next 16 months.[28]

Currently, there is no consensus on the optimal intensity of exercise for rehabilitation in patients with heart failure.[29] IT used in our study is innovative, because the exercise intensity was higher than the previously used protocols. Indeed, IT was performed with exercises at 50% and 80% of the maximal power reached during a steep ramp test during the first 4 weeks and the last 4 weeks, respectively. According to the method proposed by De Backer et al,[30] we calculated that these intensities corresponded to about 80% and 120% of the maximal power reached during the stress test. Therefore, IT can be actually considered as a very high-intensity IT. In most of the previous studies on the effects of IT in cardiac failure populations, the intensity of exercises was between 80% and 95% of VO_2peak during 2 to 5 minutes, and these exercise periods were separated by moderate-intensity exercises between 40% and 70% of VO_2peak.[11,12,15,16,24-26] The duration of exercise of our protocol was also shorter (30s), and exercises were separated by 1 minute of complete rest. The short periods of exercise as well as the long periods of rest (about two thirds of rest in a training session) proposed in our study seemed more achievable for very deconditioned patients, as suggested earlier by Meyer et al.[18] Lastly, it should be noted that previous studies reported changes after 10 to 52 weeks of training.[11,15,24] We studied the effect of a training period of only 8 weeks of rehabilitation, performed 5 days per week. This corresponds to the period of rehabilitation commonly prescribed in France.

The distance performed during the 6MWT is an objective measure of functional capacity. Previous studies have qualified the 6MWT as a valid and reliable test to measure the functional capacity in patients with chronic heart failure.[31,32] Our results show that IT and CT significantly increased the distance at the 6MWT. The 6MWT globally evaluates the responses of all the systems involved during exercise, including the pulmonary and cardiovascular systems.[19] The minimal clinical important difference (MCID) in the 6MWT is 43m in patients with chronic heart failure.[19] Our results show that IT generates an average improvement of 52m, and CT an average improvement of 28m. IT induced an MCID, while CT did not induce this improvement. Moreover, the 6MWT is a fairly accurate predictor of increased mortality and morbidity of heart disease.[19,33] Therefore, in accordance with our results on exercise tolerance, it suggests higher adaptations after IT.

It was already established that a rehabilitation program contributes to diminished levels of anxiety and depression.[34,35] In accordance with that, IT and CT groups of the present study showed significant improvements in the symptoms of anxiety and depression. No difference between IT and CT was found, indicating that the modalities of training had no effect on these symptoms. This result put forward the significant contribution of physical training programs associated with multidisciplinary support in the improvement of anxiety and depression levels of patients in cardiovascular rehabilitation programs.

It was shown in healthy subjects that IT seems optimal in maximizing both peripheral muscle and central cardiorespiratory adaptations.[14] Indeed, the constant submaximal oxygen requirement during CT would be mainly associated with greater oxygen extraction by muscles, while the fluctuation of a high oxygen requirement during IT would induce improvements in cardiac output and oxygen extraction.[14] In patients with heart failure, interval exercise would allow more intense exercise stimuli on peripheral muscles with no greater left ventricular stress than when using a steady state training method.[26] Because the intensity of exercise may be an important factor for reversing left ventricular remodeling,[12] this method of training is interesting for patients with heart failure. The IT at very high intensities in these patients could have induced central and peripheral adaptations. Future investigations should address the acute responses of intermittent exercise in patients with chronic heart failure; this will help support the findings from the present study.

Study Limitations

The number of patients in the present study was small, and subjects were predominantly men. This study clearly demonstrates that this short IT program was sufficient to induce a significant effect on the functional physical capacity in patients with chronic heart failure. However, our study gives no information about the long-term consequences of such a short IT program. In addition, further studies seem necessary to determine the optimal duration of training using an IT program.

CONCLUSIONS

The present study demonstrates that a rehabilitation program of 8 weeks with very high-intensity IT in patients with chronic heart failure can result in considerable improvements in physical capacity. These parameters are considered prognostic markers of chronic heart failure. CT programs seem to have lower impact on this capacity. These results can contribute to improve the workout training intervals used for these patients. Moreover, this type of protocol is much more feasible and accessible by such patients. However, with regards to the size of population and number of parameters studied, our results remain to be confirmed by more extensive studies.

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