

ORIGINAL ARTICLE

Continuous Aerobic Training and High Intensity Interval Training Increase Exercise Tolerance in Heart Failure Patients: A Retrospective Study

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Abstract

Background: Conventional aerobic training is the first choice in cardiac rehabilitation for patients with chronic heart failure (CHF). However, high-intensity interval training (HIIT) may be an alternative, although it has little evidence.

Objectives: To evaluate the effect of continuous aerobic training (CAT) or HIIT on exercise tolerance in CHF patients.

Methods: Retrospective study with 30 patients, of both genders, members of a 10-week CAT or HIIT program. The control group (CON) consisted of patients who did not participate voluntarily in the program. Peak oxygen uptake (VO_{2peak}), thresholds (LV1 and LV2), and ventilatory efficiency in the production of dioxide (VE/ VCO_2 slope), oxygen uptake efficiency (OUES), and VO_2 recovery kinetics were analyzed. A two-way or repeated measures ANOVA was used, followed by Fisher's post-hoc test ($p < 0.05$).

Results: After 10 weeks of training, the CAT group increased the treadmill speed at LV1 ($p = 0.040$), while the HIIT increased both the speed ($p = 0.030$) and incline of the treadmill ($p < 0.001$) for VO_{2peak} and LV2, as well as the total time of the cardiopulmonary test. The VE/ VCO_2 slope was lower than that predicted for CAT ($p = 0.003$) and HIIT ($p = 0.008$). There was no change in VO_{2peak} , recovery of heart rate (HR), and VO_2 , VE/ VCO_2 , and OUES in both groups.

Conclusions: After 10 weeks, both CAT and HIIT increased the tolerance to physical exercise. However, HIIT showed improvement in more parameters, differently from CAT. (Int J Cardiovasc Sci. 2021; [online].ahead print, PP.0-0)

Keywords: Heart Failure; Exercise. Physical Exertion; Exercise Therapy; Rehabilitation; Exercise Movement Techniques.

Introduction

Chronic heart failure (CHF) is a multifactorial syndrome characterized by cardiovascular and ventilatory abnormalities associated with the increase in the neurohumoral systems.^{1,2} The cycle generated between physical deconditioning and disorders is associated with classic CHF pathophysiological mechanisms. Nevertheless, this condition is pinpointed as the main problem of the reduction in tolerance to physical exercise in this population.^{1,2}

International guidelines have voiced concern over the theme and have highlighted the heart rehabilitation

programs with emphasis on regular physical exercise, and under professional supervision, as being forms of safe, non-pharmacological treatment in adjunct therapy for CHF patients.³ The benefits of physical exercise are demonstrated in studies that observe improvements in the variable relation to exercise tolerance, functional capacity, and ventilatory efficiency of these patients.⁴⁻⁶ Improvement in one's cardiorespiratory fitness, illustrated by increases in the VO_{2peak} and in the total duration of the cardiopulmonary exercise test, present strong prognostic values in CHF, thus confirming the benefits and safety of physical exercise.

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Mild-intensity continuous aerobic training (CAT), maintaining an intensity between 60% and 80% (VO_2 peak or reserve heart rate),⁷ has been described as the most successful style of training, due to its efficacy and safety.⁷⁻⁹ Nonetheless, studies have used greater intensities of physical exercise in CHF patients with promising results and, in some cases, even greater than the CAT.¹⁰⁻¹² In this context, interest concerning increasing intensity (75 to 90% VO_2 peak) of physical exercise is growing, especially as regards safe training for this population¹². Some justifications for this type of conduct would be a greater aerobic and cardiovascular adaptation that could be achieved by using this type of strategy,¹⁰ in addition to improvements in exercise capacity, endothelial function, left ventricular function, and ejection fraction.¹² These conclusions, however, seem rather uncertain, since the impacts upon the difference in prognoses, the length of training, and the diversity of protocols, with different durations, recoveries, and intensities used in the studies, make the defense of clinical training standards for CHF patients difficult; thus, a larger body of evidence is needed.

Faced with the continuing key question about which aerobic training method should be ideally prescribed in heart rehabilitation programs, the search for this type of evidence is necessary. Hence, this study sought to evaluate the potential benefits of mild-intensity CAT and high-intensity interval training (HIIT), through the medical records of Class II and III (NYHA) CHF patients who participated in a heart rehabilitation program.

Methods

This study was conducted in accordance with that set forth in the Helsinki Declaration and CNS 466/12. All patients read and signed the Free and Informed Consent Form provided by the Clinical Center where the data were collected upon entrance into the program. The project was approved by the Research Ethics Committee from Universidade Federal de Ciências da Saúde de Porto Alegre (logged under protocol number 3.055.126).

Through a retrospective cohort, this study assessed the records of data referent to the physical training sessions of patients with CHF and who agreed to participate in the heart rehabilitation program of the Sports Medicine Unit of the Clinical Center of Universidade de Caxias do Sul, RS, Brazil, between 2016 and 2017.

Samples and Groups

This study included medical records from 30 CHF patients (64 ± 9 years of age), from both genders, left

ventric (CON) consisted of patients who opted not to participate in the heart rehabilitation program at that moment.

The exclusion criteria were: incomplete medical records and patients who did not present reference values during the strength test ($R < 1.0$ to reach the VO_2 peak or submaximal heart rate).

Heart Rehabilitation Program

Once the patients had been admitted to the program, a clinical anamnesis was performed by the doctor of the program. After, the patients were referred for initial physical assessments and were distributed randomly (<https://www.randomizer.org/>) for supervised training in the different methods: CAT (n=10) and HIIT (n=10). Patients that chose not to participate in the rehabilitation program were allocated to the control group (CON, n=10).

Cardiopulmonary Exercise Test

After warming up for 10 minutes, the VO_2 peak was evaluated by the gas analyzer (VO2000, Medical Graphics Diagnostics Corporation, USA), using a Super ATL 300 treadmill (Imbramed, Porto Alegre, RS, Brazil). A Ramp protocol was used, beginning at 3 km/h and with no slope. The speed was then increased by 0.3 km/h, and the slope by 1.6%, for each minute of exercise, until patient exhaustion. The exhaled gases were quantified every 20 seconds, obtaining ventilator flows and volumes. The patient's blood pressure (BP), heart rate (HR), minute ventilation (VE), oxygen uptake (VO_2), carbon dioxide production (VCO_2), and respiratory exchange ratio (R), as well as the ventilator equivalents for oxygen (VE/VO_2) and carbon dioxide (VE/VCO_2), were analyzed during the evaluation. Based on this data, the VO_2 peak, the first ventilatory threshold (LV1), the second ventilatory threshold (LV2), among other ventilatory and metabolic measures described in the literature, were determined.¹³

Evaluation of Ventilatory Efficiency

The ventilatory equivalent for CO_2 was calculated by means of the ratio between the instantaneous ventilation rate (VE) and the release of CO_2 (VE/VCO_2). For this, the present study used the data recorded in the cardiopulmonary exercise test, from the beginning to the LV2. The slope (VE/VCO_2 slope) was used to analyze the ventilatory efficiency.¹⁴ The predicted values for this variable were obtained by means of the equation described in the literature.¹⁵

Evaluation of Oxygen Uptake Efficiency

The *oxygen uptake efficiency slope* (OUES) is represented by the rate of increase of VO_2 in response to VE, and was calculated by measuring the relationship between VO_2 and the VE logarithm.¹⁶ The predicted value for this variable has already been described in the literature.¹⁶

Recovery Kinetics of Oxygen Uptake and Heart Rate

At the end of the cardiopulmonary exercise test, the patients were instructed to remain seated for three minutes while the metabolic and ventilatory variables continued to be recorded. The data during this period served to analyze and determine the recovery kinetics of VO_{2r} in the following manner: the magnitude of the recovery through the relationship of VO_2 regarding time (VO_2/t slope), calculated by the linear regression model and adjusted to a simple exponential curve.¹⁷ The slope equation was calculated considering the time needed to reach the VO_2 peak and recovery in the first three minutes; the established value of the VO_2 recovery was obtained by determining the difference between the value of the VO_2 peak and that of VO_2 in the first, second, and third minutes after the end of the VO_2 peak test.¹⁸ In addition, the recovery kinetics for HR were calculated by subtracting the HR value at the end of the test from the values of minutes 1, 2, and 3 in the recovery test.¹⁴

Protocols of the Heart Rehabilitation Training Program

The CAT consisted of a mild-intensity continuous training (70-75% HRreserve) for 47 minutes per session. The time was calculated and duly controlled to guarantee that the training protocols were isocaloric.¹² A fingertip pulse oximeter (NoninOnix 9500, United Kingdom) was used to monitor the patients' HR and peripheral saturation of oxygen (SpO_2). The speed was adjusted continuously to guarantee that each session would be performed in the HR target.

The HIIT consisted of 38 minutes, beginning with the 10-minute warm-up, between 50-60% HRreserve, followed by 4 series of 4 minutes between 90-95% HRreserve. Each series was staggered, with an active pause of 3 minutes (light walk). The training session was finished with a period of 3 minutes of cool down (50% HRreserve).

Data Collection

This study was conducted by consulting the data recorded in the medical records of each patient who

trained three times per week, during 10 consecutive weeks. These medical charts were used in the routine of the heart rehabilitation program. After the previous study of the feasibility of the medical records, the data were tabulated within a databank put together in Excel 2013 (*Microsoft Office*).

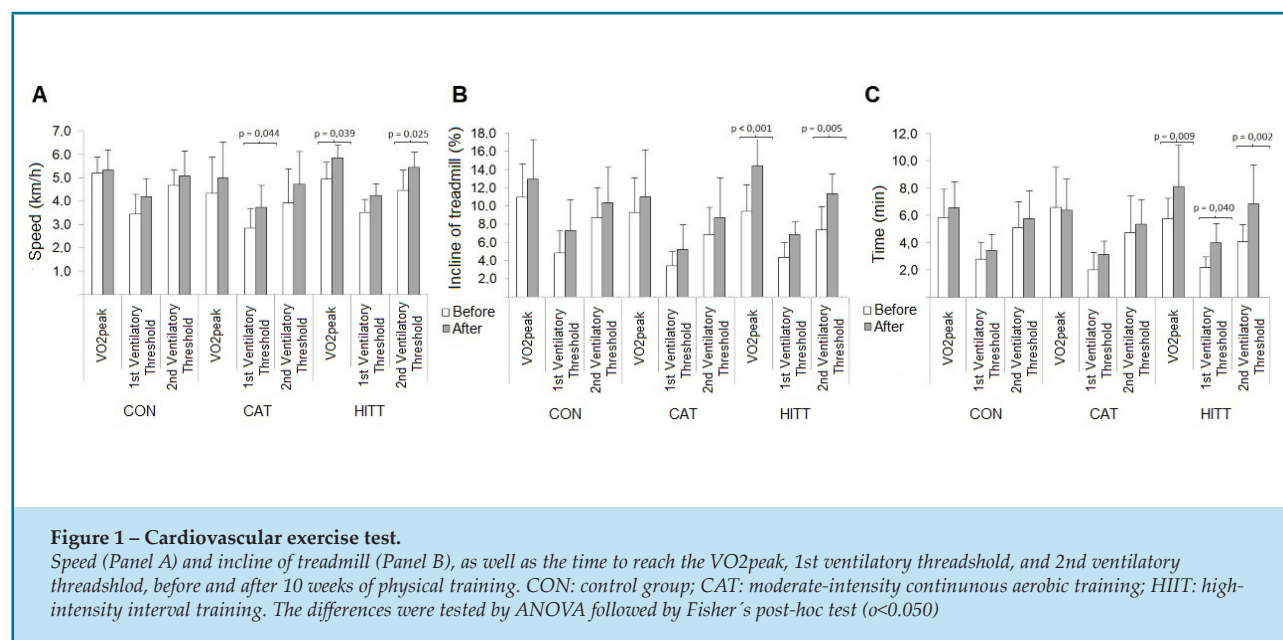
Statistical Analysis

The normality of the data was evaluated using the Shapiro-Wilk test. The data were expression as average \pm standard deviation. The two-way ANOVA was used, together with Fisher's *post-hoc* test. By contrast, the comparison of the data of the VO_2 recovery kinetics and HR between the 1, 2, and 3 minute intra-groups was performed using the repeated measures ANOVA, together with Fisher's *post-hoc* test. The *GraphPad Prism 6* program (*GraphPad Software*, San Diego, California, USA) was used as a computational tool for data analysis, considered significant for a $\alpha=0.05$.

Results

This study analyzed the medical records of 30 patients with CHF, with LVEF <40%, who voluntarily chose to participate in the heart rehabilitation program between August 2016 and December 2017. One patient was over 80 years of age, nine were between 70 and 80 years of age, eleven were from 60 to 70 years of age, and nine were between 50 and 60 years of age. Of these, five patients were using a pacemaker. All of the patients were hemodynamically stable, with optimized treatment, including β -blockers and antiplatelet aggregation over the past 12 months, even during the period of physical training. No event related to the sessions of physical training occurred in the patients in either group. The presence of participants reached 100% of the scheduled sessions (10 weeks).

Figure 1 presents parameters of intensity (speed and slope) and time to reach the VO_2 peak referent to the cardiopulmonary test. After ten weeks of physical training, the CAT group presented improvement in exercise tolerance for LV1 when compared to the initial test. By contrast, the HIIT group presented improvement in the tolerance to the exercise, represented by the higher speed and slope for LV2, as well as in the time to reach the VO_2 peak, when compared to the beginning of the physical training. It is possible to observe in Figure 1 that the HIIT group presented a set of greater benefits when compared to the CAT.



Details of the cardiopulmonary test are presented in Table 1. No significant difference was observed in the records of the recovery kinetics of HR and VO₂. The patient presented no difference in the parameters of body composition and physical fitness.

Discussion

The main finding in this study was that Class II and III (NYHA) CHF patients, who took part in a 10-week program of CAT or HIIT, increased their tolerance to physical exercise, when compared to the pre-training moment. Moreover, the HIIT improved a greater number of evaluated parameters when compared to the CAT, illustrating its superiority to conventional training, thus confirming our hypothesis. The parameters of the cardiopulmonary exercise test proved to be useful in the long-term diagnosis and prognosis of CHF and in the intolerance to physical exercise. The VO₂peak has been used for decades as a universal marker, capable of reflecting the severity of the disease,¹⁷ and has been considered the “gold-standard” measurement to identify patients with a worse prognosis,¹⁹ in addition to being a parameter for the prescription of physical training involving this population.^{20,21} In this sense, our study's results present a clinical importance, as they present an improvement in the VO₂peak, which is greater than 1 ml.kg⁻¹.min⁻¹, considered relevant for autonomy and performance of many daily life activities (DLAs).²² Likewise, the VO₂peak data observed in our study are slightly greater than the 0.6 ml.kg⁻¹.min⁻¹

found in the HF-ACTION trial⁸ and corroborate with the meta-analysis findings from Cornelis.²³

The present study demonstrates a wide range of parameters of gas exchanges verified in the submaximal cardiopulmonary exercise test. Woods et al.,²⁴ found strong predictors of adverse heart outcomes and survival in CHF patients through submaximal parameters of gas exchange, especially the VE/VCO₂, VE/VCO₂ slope, and OUES, found with “R=0.9”, formulating prognoses similar to the VO₂peak.²⁴ Other authors have suggested that changes in these prognostic markers for CHF seem to be more important predictors of the capacity of exercise tolerance than the results from the VO₂peak.²⁵

As a result, ventilatory efficiency for the elimination of CO₂ (VE/VCO₂ or VE/VCO₂ slope) in response to submaximal exercise was investigated to determine the prognostic values for CHF patients.²⁵ However, this study found values of lower than 34 and 45, indicating a prognosis of a 50% probability of mortality in two years, regardless of the VO₂peak result. In a study from Chua et al.,²⁶ it was verified that CHF patients, evaluated by the cardiopulmonary exercise test, with a VE/VCO₂ slope >34, presented a greater risk of hospitalization caused by hemodynamic decompensation, as well as death. Ferreira et al.,²⁷ found the cut-off point for the VE/VCO₂ slope ≥43 to be the ideal to determine the recommendation for a heart transplant. The time to obtain the lowest value of VE/VCO₂ (>5:45 minutes) also represents a poor prognosis for this population.²⁸ In this indicator, our

Table 1 – Responses from the cardiopulmonary test before and after 10 weeks of physical training

	CON		CAT		HIIT	
	Before	After	Before	After	Before	After
VO ₂ peak (ml.kg ⁻¹ .min ⁻¹)	19.3±4,5	19.5±4,8	16.2±5,9	17.3±5,9	18.6±2,7	19.8±3,2
Maximal HR (bpm)	121±18	127±24	116±31	113±24	119±11	129±16
Maximal VE/VCO ₂	29.6±5,2	29.1±5,3	28.4±5,4	28.6±5,2	25.4±2,7	25.7±3,7
Minimum VE/VCO ₂	27.5±4,6	26.7±4,1	26.7±4,9	27.3±5,3	23.4±3,0	23.6±3,8
Time to reach VE/VCO ₂ (min)	04:04±01:36	03:53±02:03	02:57±01:37	03:47±01:37	03:34±01:07	05:22±02:56
VE/VCO ₂ slope	30.1±10,0	30.5±16,0	26.6±9,0	23.1±4,5	22.0±3,2	21.7±5,3
VE/VCO ₂ slope % of prediction	113±33	110±52	95±34	82±19*	98±15	79±24*
OUES	2148±1192	1887±841	1559±536	1800±390	2464±807	1926±700
OUES % of prediction	107±105	94±45	83±34	95±21	120±28	90±41
LV1 (ml.kg ⁻¹ .min ⁻¹)	12.5±3,8	15.6±4,2	11.2±4,2	11.2±3,9	13.3±2,3	14.2±2,2
HR LV1 (bpm)	99±13	103±20	95±22	98±21	98 ± 16	94 ± 14
LV2 (ml.kg ⁻¹ .min ⁻¹)	16.7±4,8	18.0±4,5	14.5±6,1	15.0±5,0	15.9 ± 2,3	17.1 ± 2,5
HR LV2 (bpm)	107±16	113±22	106±20	108±22	108 ± 15	112 ± 16

VO₂peak: submaximal oxygen uptake; HR: heart rate; CET: Cardiovascular exercise test; LV1: oxygen uptake at the first ventilator threshold; LV2: oxygen uptake in the second ventilator threshold; VE/VCO₂: ratio between the instantaneous respiratory rate and the release of CO₂; OUES: oxygen uptake efficiency slope. Two-way ANOVA followed by Fisher's post-hoc test. * Significant intragroup difference in relation to pre-training; p<0.001.

patients showed a lesser reach in a shorter period than that which the literature characterized as an indication of poor prognosis.¹⁶ The fact that no changes in the OUES were observed after the physical training may well be related to the characteristics of our sample, which presents an earlier beginning of lactic acidosis during the hyperventilation test, observed by the ventilatory threshold, determined by the central and peripheral incapacity during physical exercise.²⁸

Other important records analyzed in this study concern the prognostic implications of the VO₂ and HR recovery values after ending the cardiopulmonary exercise test. No changes in these indicators were observed, which is in accordance with findings from Myers et al.,²⁹ However, Myers did observe an increase in the VO₂peak in response to eight weeks of aerobic training (walking and cycling) in CHF patients. It is impossible to determine a specific cause for these results. Nevertheless, it can be speculated that the delay in VO₂ recovery is related to the difficulty to recover energy stored in the main muscles used in the cardiopulmonary exercise test.³⁰

The HR recovery kinetics, as a prognostic marker, is well-established and is used as an independent factor of mortality, even in CHF patients that take β-blockers.^{31,32} Therefore, the results of this study showed that the reduction was greater than 12 bpm, in the first minute after ending the exercise. This value was used as a cut-off point to define the mortality in patients with left ventricular dysfunction,³³ whose cut-off point was ≤16 bpm, in an active recovery protocol. Only in the CON group was a reduction of ≤16 bpm observed at the end of the study. The fall in HR immediately after physical exercise occurs in response to the autonomous control, more precisely, the activation of the parasympathetic nerve system due to the sympathetic nerve activity. This adjustment is also an important prognostic marker and is associated with a reduction in the risk of death.¹⁴

In the evaluation of other variables of the cardiopulmonary exercise test, the time to reach the VO₂peak also reflects the capacity to predict mortality in patients with CHF and a reduced LVEF.³⁴ This study showed that the time of duration in the HIIT group was

greater for the VO_2 peak, LV1, and LV2, which is directly related to the positive adaptations of the training. In another study, the authors present results that run in line with those from our study.³⁵

Our results demonstrate consistent improvements in the parameters related to one's tolerance to physical exercise, which is a key characteristic in CHF patients. Appropriately, our study presents important clinical implications for the state of health concerning the autonomy and performance of one's DLAs. On the other hand, our study presents a series of limitations that should be observed, one of which refers to the VO_2 evaluation protocol of CHF patients. The reach of VO_2 peak does not translate into the maximum capacity of exercise and gas exchanges referent to the evaluation and prescription of adequate intensities for physical training. Thus, the VO_{2max} would be more accurate, but with greater risk and discomfort for the participants. Another limitation is the relatively small sample. This makes it impossible to stratify the results, such as severity of CHF, time of diagnosis, and inclusion in the rehabilitation program, among others.

Conclusions

This retrospective study showed that both the conventional protocol (CAT) and a high-intensity interval training (HIIT), carried out over a 10-week period, promoted positive adaptations in the capacity of physical exercise, with an increase in time, speed, and treadmill slopes to achieve important CHF prognostic markers. However, the HIIT group showed improvement in a greater number of variables. Based on these results, we support the concept of the need to measure submaximal variables that reflect a better integration between the mechanisms related to changes in the cardiovascular, pulmonary, and musculoskeletal system of these patients, in attempt to reintegrate CHF patients into social life within society.

Author Contributions

Conception and design of the research: Busin D, Lehnen AM, Tairova OS, Lago PD, Nunes RB. Acquisition of data: Busin D, Tairova OS, Comparsi EP, Carneiro D, Potter M. Analysis and interpretation of the data: Busin D, Lehnen AM, Tairova OS, Comparsi EP, Carneiro D, Potter M, Deresz LF, Lago PD, Nunes RB. Statistical analysis: Busin D, Lehnen AM, Tairova OS, Comparsi EP, Carneiro D, Potter M, Deresz LF, Lago PD, Nunes RB. Obtaining financing: Tairova OS. Writing of the manuscript: Busin D, Lehnen AM, Tairova OS, Comparsi EP, Deresz LF, Lago PD, Nunes RB. Critical revision of the manuscript for intellectual content: Busin D, Lehnen AM, Tairova OS, Comparsi EP, Carneiro D, Potter M, Deresz LF, Lago PD, Nunes RB.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the *Universidade Federal de Ciências da Saúde de Porto Alegre* under the protocol number 3.055.126. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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