Correlation of training volume in MET-min/week with the percentage of estimated VO_{2p} gain in patients with chronic heart failure with reduced ejection fraction, undergoing a cardiac rehabilitation program

Correlación del volumen de entrenamiento en MET-min/semana con el porcentaje de ganancia de VO_{2p} -carga en pacientes con insuficiencia cardiaca con fracción de expulsión reducida, sometidos a un programa de rehabilitación cardiaca

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Abstract

Objective: Heart failure is a clinical syndrome characterized by a decrease in functional capacity. Cardiac rehabilitation and secondary prevention (CR&SP) programs have been shown to improve quality of life and exercise tolerance in this group of patients, but their effects depends on training volume. Our objective is to evaluate the level of correlation of the training volume measured in metabolic equivalents (MET)-min/week with the percentage of peak oxygen consumption (VO_{2p}) gain (estimated MET) after a CR&SP in patients with chronic heart failure. **Method:** Quasi-experimental study that evaluated the gain of VO_{2p} (estimated MET) in 31 patients after a CR&SP, prior and post-exercise test, which consisted of 30 min of dynamic training at 70% heart rate reserve (HRR) for 6 weeks, with strength training and interdisciplinary intervention. The training volume of each patient was calculated in MET-min/week (Kaminsky's method). Spearman's Rho correlation index was measured and stochastic significance was considered with a value of $p < 0.05$. **Results:** 70.6% were male, average age 61.5 ± 8.9 , with left ventricular ejection fraction average of $38 \pm 4.6\%$; 96.8% of the heart failure had an ischemic origin; 55.9, 29.4 and 5.9% in New York Heart Association functional class I, II and III, respectively. With an average training volume of 504.34 ± 164 MET-min/week. The best correlation was obtained in high-risk population with Rho: 0.486 ($p = 0.008$) measured by estimated VO_{2p} . **Conclusions:** Although there is a substantial gain in exercise tolerance measured by estimated VO_{2p} , we did not obtain a sufficient level of correlation between the volume of training applied and the gain obtained.

Key words: Cardiac rehabilitation. Chronic heart failure. Training volume. Peak oxygen consumption. VO_{2p} .

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Resumen

Objetivo: La insuficiencia cardíaca (IC) es un síndrome clínico caracterizado por disminución en la capacidad funcional. Los programas de rehabilitación cardíaca y prevención secundaria (PRHCyPS) han mostrado mejorar la calidad de vida y tolerancia al esfuerzo en este grupo de pacientes, pero sus efectos son dependientes del volumen. Nuestro objetivo es evaluar el grado de correlación del volumen de entrenamiento medido en equivalentes metabólicos (MET)-min/semana con el porcentaje de ganancia de consumo pico de oxígeno (VO₂p) (MET-carga) posterior a un PRHCyPS en pacientes con IC. **Método:** Estudio cuasiexperimental que evaluó la ganancia de VO₂p (MET-carga) en 31 pacientes posterior a un PRHCyPS, antes y después de una prueba de ejercicio convencional, que consistió en 30 min de entrenamiento dinámico al 70% frecuencia cardíaca de reserva (FCR) durante seis semanas, así como entrenamiento de kinesioterapia e intervención interdisciplinaria. Se calculó el volumen de entrenamiento de cada paciente en MET-min/semana (método de Kaminsky). Se midió el índice de correlación con Rho de Spearman y se consideró significancia estocástica con valor de $p < 0.05$. **Resultados:** El 70.6% fueron de sexo masculino, promedio de edad 61.5 ± 8.9 años, con fracción de expulsión del ventrículo izquierdo promedio de $38 \pm 4.6\%$; el 96.8% de la IC fue de origen isquémico; un 55.9, un 29.4 y un 5.9% en clase funcional según la New York Heart Association I, II y III, respectivamente. Con un volumen de entrenamiento promedio de 504.34 ± 164 MET-min/semana. La mayor correlación se obtuvo en las poblaciones de alto riesgo, con una Rho: 0.486 ($p = 0.008$) por VO₂p-carga. **Conclusiones:** Si bien existe una ganancia sustancial en tolerancia al esfuerzo medido por VO₂p-carga, no obtuvimos suficiente grado de correlación entre el volumen de entrenamiento aplicado y la ganancia obtenida.

Palabras clave: Rehabilitación cardíaca. Insuficiencia cardíaca. Volumen de entrenamiento. Consumo pico de oxígeno. VO₂p.

Introduction

Heart failure (HF) is a clinical syndrome caused by structural or functional abnormality, the main characteristic of which is a reduction in the capacity to perform aerobic exercise, which is the result of insufficient blood flow to the muscles involved in physical activity and that is due to decreased cardiac output and increased intracardiac pressures at rest or under stress^{1,2}. It can be classified according to left ventricular ejection fraction (LVEF) as preserved, mid-range or reduced. Its main complications are disability, recurrent hospitalizations and death¹. Decreased exercise tolerance in patients with impaired ventricular function is a complex phenomenon that involves central modifications (decreased cardiac output and pulmonary venocapillary hypertension), musculoskeletal fiber metabolism (peripheral abnormalities such as endothelial dysfunction, vasoconstriction, ergoreflex activation) and neurohumoral system alterations (catecholamines, antidiuretic hormone, renin-angiotensin-aldosterone system, B-type natriuretic peptide, ANP)³. In patients with HF, concurrent exercise generates significant gains not only with regard to these benefits, but in peak oxygen consumption (VO₂p)⁴, which are related to the training dose (volume). The benefits of physical training in this population have been described from the study by Belardinelli et al. to the ExtraMATCH meta-analysis^{5,6}. Meta-analyses such as HF-ACTION demonstrated a reduction of 39% in relative risk (RR), of 11% in all-cause hospitalization adjusted risk, and a

reduction of 15% in cardiovascular mortality adjusted risk, with a post hoc analysis establishing the volume of training used^{7,8}. However, as cardiac rehabilitation programs have become increasingly heterogeneous (hospital-based, home-based, hybrid) on an also diverse population that requires individualized prescription, variation in training volume has been considerable; for this reason, in studies such as ExtraMATCH II it is difficult for conclusions on hard outcomes to be drawn in this population (particularly with regard to mortality)⁹. The latter evidence contrasts with studies that demonstrate the impact on survival with VO₂p gains ranging from 10 to 25% with continuous moderate training^{10,11}. Total training volume is an important benchmark for improving not only symptomatology, but also other outcomes. Prescription based on energy cost of activity using metabolic equivalents (MET) is the most affordable approach, since it allows volume cutoff point to be transformed into caloric expenditure using Kaminsky's formula for the generation of cardiovascular benefits higher than 1,000 kcal/week or 500-1,000 MET-min/week^{11,12}. However, we do not know the correlation between the training volume expressed in standardized metrics such as MET-min/week calculated with Kaminsky's method¹³ and the favorable impact expressed by the percentage of VO₂p gain measured per workload. Our hypothesis is that if VO₂ gains are training volume-dependent, then there could be a high correlation between training volume (MET-min/week, Kaminsky) and the percentage of VO₂p gain.

Objective

To correlate the volume of aerobic training quantified with Kaminsky's method with the percentage of VO_{2p} gain measured in MET-min/week, after a CR and SP program in patients with HF and reduced ejection fraction (EF).

Methodology

A quasi-experimental study was designed, where VO_{2p} , measured as exercise workload in a conventional stress test, was evaluated (for evaluation, prescription and cardiovascular risk stratification purposes) prior to and after undergoing a supervised concurrent training program consisting of five 30-min sessions per week of dynamic training for 4-6 weeks at 70% of heart rate reserve (HRR), as well as kinesiotherapy sessions (with work on strength resistance and other biomotor qualities) and interdisciplinary intervention. Each patient's aerobic training volume was calculated in MET-min/week using Kaminsky's¹² method, including:

- MET-min. (METs estimated by exercise workload) (duration/session in minutes) (number of sessions/week) = MET-min/week
- Kilocalories. (METs estimated by exercise workload) (patient weight in kg) (training duration in hour fractions) = Kcal/session (number of sessions/week) = Kcal/week

Strength training was provided but not quantified, given that Kaminsky's method was designed for aerobic training. A total of 31 patients with HF and reduced EF were recruited.

Statistical analysis

Spearman's Rho correlation index was measured and was considered with minimal correlation when it was < 0.2 , low correlation when it was $> 0.2 < 0.4$, moderate correlation when it was $> 0.4 < 0.6$, good correlation when it was $> 0.6 < 0.8$ and very good correlation when it was > 0.8 . Stochastic significance was considered when p-value was < 0.05 .

Results

Among the study population, 70.6% were males, average age was 61.5 ± 8.9 years, average LVEF was $38 \pm 4.6\%$, 96.8% of HF cases were of ischemic origin, and the distribution according to New York Heart Association functional class was 55.9, 29.4 and 58.9% in functional class I, II and III, as shown in [table 1](#). When

Table 1. Population demographic characteristics

Clinical characteristics	Total patients (n = 31)
Gender, n (%)	
Males	24 (70.6)
Age (years)	61.5 ± 8.9
BMI (kg/m^2)	28.65 ± 4.6
ICD, n (%)	1 (2.9)
Ejection fraction (%)	38 ± 4.6
NYHA FC, n (%)	
I	19 (55.9)
II	10 (29.4)
III	2 (5.9)
Ischemic heart disease, n (%)	30 (96.8)
Ischemic threshold, n (%)	9 (26.5)
Diabetes mellitus, n (%)	14 (41.2)
High blood pressure, n (%)	25 (73.5)
Dyslipidemia, n (%)	20 (58.8)
Peripheral artery disease, n (%)	2 (5.9)
Obesity, n (%)	18 (52.9)
Smoking, n (%)	17 (50)

BMI: body mass index; ICD: implantable cardioverter-defibrillator; NYHA FC: New York Heart Association functional class.

patients were stratified in risk groups according to the maximum exercise tolerance obtained by the VO_{2p} achieved on initial exercise test, a VO_{2p} -load of 5.9 ± 2.1 METs was obtained, with 74.4% of the population corresponding to groups C and D, which are those who obtained < 7 METs on initial exercise test, as shown in [table 2](#). Similarly, when average training provided volume was calculated, 504.3 ± 164.7 MET-min/week were obtained, as shown in [table 2](#). With this training volume, a $\text{Rho} = 0.486$ ($p = 0.008$) was obtained in the study population, which is considered of high risk for its characteristics, and where a gain of $48.35 \pm 30.64\%$ was obtained when measured by VO_{2p} -load, as shown in [table 3](#). Although we were unable to demonstrate a statistically significant correlation, the VO_{2p} gain in all patients included in the study is evident with the training volume that was provided, as shown in [figure 1](#).

Discussion

Cardiac rehabilitation and secondary prevention programs are designed with concurrent training as the guiding principle and interdisciplinary intervention,

Figure 1. MET gain after a cardiac rehabilitation and secondary prevention program in 31 patients with heart failure with reduced EF. In this figure, the red columns show the gain in tolerance to initial and comparative exercise expressed in METs after a CR&SP program.

MET: metabolic equivalent; CR&SP: cardiac rehabilitation and secondary prevention; EF: ejection fraction.

Table 2. Cardiovascular variables. The groups were made up of patients according to maximum exercise tolerance based on the VO_{2p} achieved on initial exercise test, with groups A and B showing the best exercise tolerance and groups C and D having the worst performance on initial assessment

Cardiovascular variables	Units
Initial VO _{2p} (METs)	5.9 ± 2.1
Cardiovascular risk by VO _{2p} , n (%)	
Group A (> 10 METs)	2 (6.5)
Group B (> 7 < 10 METs)	6 (19.4)
Group C (> 5 < 7 METs)	11 (35.5)
Group D (< 5 MET)	12 (38.7)
Theoretical MET %	75 ± 25
Ejection fraction (%)	38 ± 4.6
Training volume (MET-min/week)	504.3 ± 164.7

VO_{2p}: peak oxygen consumption; MET: metabolic equivalent.

which together contribute to improve quality of life, reintegration into social and work-related life, in addition to a positive impact on exercise tolerance gain measured in VO_{2p} and on hard outcomes such as overall and cardiovascular mortality in the population with HF, as reported in the studies by Belardinelli et al., as well as in meta-analyses such as HF-ACTION and ExtraMATCH I-II^{5,6,7,14}. However, the benefits of concurrent training are dose-dependent, and prescription based on activity-associated energy expenditure expressed in METs is the most widely recommended and standardized approach described by the American College of Sport Medicine and by Kaminsky et al.¹³. This becomes relevant because, for each MET gained, survival increases by 12%¹². The training volume reported in the population with HF is in a wide range, because supervised, hybrid and

Table 3. Correlation matrix of training volume vs. VO_{2p} gain percentage vs. cardiovascular risk group by VO_{2p} obtained on initial exercise test

	VO _{2p} gain (%)	Risk group according to VO _{2p}	Training volume
VO _{2p} gain (%)	1	0.486*	0.052
Risk group according to VO _{2p}	0.486*	1	0.124
Training volume	0.052	0.124	1

* p < 0.01.

Spearman's Rho correlation index (without correlation: 0.0; minimum correlation: 0.0-0.2; low correlation: 0.2-0.4; moderate correlation: 0.4-0.6; good correlation: 0.6-0.8; very good correlation: 0.8-1.0).

VO_{2p}: peak oxygen consumption.

home-based programs, program duration and training intensity were included, as well as weekly frequency, which makes it difficult for the intervention to be standardized and, therefore, for correlations to be established with VO₂ gains, as well as with outcomes such as mortality and hospitalization^{5,6,7,9,14}. In this study, we included a population with HF with reduced ejection fraction (rEF), and all patients obtained VO₂ gains of at least 17.86% (average of 48.35%) with respect to VO_{2p} measured at initial exercise test with the training volume provided, and although a percentage of patients received less than 500 MET-min/week, they were still within the range reported by Kateyian et al.⁸, where cardiovascular benefits were described with at least 3 MET-hour/week, a training volume that was reached by the entire population included in this study. However, the degree of correlation was intermediate, between training volume and the VO_{2p} gain percentage obtained in the population, despite its stochastic significance (p = 0.008). This can be explained because the population was reduced in our

rehabilitation center and some patients did not achieve the training sessions attendance of 80% recommended in exercise prescription guidelines. Another factor that possibly influenced the results was the impossibility for strength training to be quantified; i.e. patients were prescribed concurrent training (aerobic and strength), but Kaminsky's method only contemplates the conversion of aerobic training into MET-min/week or kcal/week, and thus it is not possible for kinesiotherapy sessions energy expenditure to be measured, which explains why, despite the low amounts of training declared (504 ± 164.7 MET-min/week), the percentage of VO_{2p} gain was considerable (given that both components that usually have a favorable impact for VO_{2p} gain were worked on), but quantifying the metabolic cost of strength training for the entire population included in the study was not possible (with Kaminsky's methodology). There is no doubt that cardiac rehabilitation has a positive effect both peripherally and centrally, with all the benefits at the endothelial, neuro-humoral, and endocrine levels, and with a positive impact on hard outcomes such as all-cause death, cardiovascular mortality, quality of life and hospital readmissions, as demonstrated in the studies by Belardinelli et al.,^{5,6} and that training prescription is individual and personalized, but with training volume measurement in a standardized way, it is possible to evaluate whether the goals and results of CR and SP programs are achieved and correlated with prescribed training. Among our limitations, we found that dynamic training volume could not be quantified due to low attendance in a group of patients. Another limitation is the inherent nature of HF with regard to its outcomes. Regarding risk stratification, there were 25.9% of the population that obtained > 7 MET of VO_{2p} on initial exercise test, and VO_{2p} gains are more noticeable in the population with myocardial reserve clear deterioration (Tables 2 and 3).

Conclusions

Although there is a substantial gain in tolerance to exercise measured by VO_{2p} -load, we did not obtain sufficient degree of correlation between the training volume that was applied and the gain obtained. However, all patients obtained VO_{2p} gains, and those in the highest risk groups (C and D), which make up 74.4% of the study population, obtained the highest VO_{2p} gain, with a stochastically significant degree of correlation with the declared training volume.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this research.

Confidentiality of data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

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