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Validation of rate of perceived exertion-based exercise training in patients with heart failure: Insights from autonomic nervous system adaptations

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ABSTRACT

Background: Exercise prescription in cardiac patients is based on heart rate (HR) response to exercise. How to prescribe long-term exercise training outside medically-supervised settings also considering changes in individual physical capacity over time is unknown. In this study we hypothesized that in patients with chronic heart failure (CHF) the session-rate of perceived exertion (RPE), a subjective-based training methodology, provides autonomic and functional capacity changes superimposable to those observed with HR-based Training Impulses (TRIMPi) method.

Methods: Twenty patients with stable CHF were randomized to either aerobic continuous training (ACT) or aerobic interval training (AIT) for 12 weeks. For each TRIMPi-guided exercise session, the session-RPE was recorded. By this method, internal training load (TL) is quantified by multiplying the RPE of the whole training session, using the Borg CR10-scale, by its duration. Heart rate variability (HRV), and baroreflex sensitivity (BRS) were assessed at baseline and at 3 weeks intervals.

Results: Significant correlations were found between $TRIMP_i$ and individual session-RPE, for both ACT and AIT ($r = 0.63$ to 0.81), ($P < 0.05$). The same occurred when ACT and AIT groups were pooled together ($r = 0.72$; $P < 0.01$). R–R interval, HRV and BRS were significantly and very highly correlated with weekly RPE-session (r^2 ranged from 0.77 to 0.97; $P < 0.001$). A significant relationship between session-RPE and performance at the 6MWT was also found.

Conclusions: Session-RPE is an easy-to-use, inexpensive and valid method for exercise prescription and health maintenance, consistent with objective physiological indices of training, that could be used for long-term physical activity in patients with CHF.

1. Introduction

Exercise training, is currently recommended in combination with pharmacological therapy in patients with chronic heart failure (CHF) at a class 1 level [1,2]. It is well established that to be effective over time, exercise training should be maintained all-life long. This would imply the need of a continuous adaptation of exercise prescription, in terms of volume and intensity, especially in aging individuals. Current guidelines for exercise prescription commonly utilize HR as target tool, namely percentages of maximum heart rate (HRmax), and heart rate reserve (HRR) [3], or little bit more sophisticated measures that take into account also the lactate profile and individual internal training load [4]. These types of exercise prescription are usually done in clinical rehabilitation, centers, where patients are followed as in- or outpatients for a limited period of time. The issue thus exists as to how prescribing long-term exercise training taking into account: 1) the need of practising regular physical activity outside medically-supervised settings and 2) the physiological aging processes with the attendant changes in individual physical capacity over time. Hence, a more practical and user-friendly method of exercise prescription would be mandatory.

A simple method to quantify internal training load has been advanced by Foster et al. [5] and referred to as session-RPE. By this method, internal training load (TL) is quantified by multiplying the whole training session rating of perceived exertion (RPE) using the Borg category ratio scale [6] (CR10-scale) by its duration. This product represents in a single number the magnitude of internal TL in arbitrary units (AU) and has been used and validated in athletes of different sport disciplines [5,7,8]. Borg's CR10 is considered a global indicator of exercise intensity including physiological (oxygen

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uptake, HR, ventilation, beta endorphin, circulating glucose concentration, and glycogen depletion) and psychological factors [9] and as such it could be considered an accurate indicator of global internal TL. The RPE-session method might potentially be used by cardiac patients for long-term, self-selected physical activity management. However, whether this easy-to-use training method would provide similar physiological adaptations as with the more usual HR-targeted training methodologies is patients with cardiac diseases is not known.

We recently reported in patients with chronic heart failure (CHF), that exercise training programs guided by the TRIMPi method [10], a measure of internal TL which integrates in a single term both the volume and intensity of exercise, i.e., the "dose", by utilizing the relationship that exists between increase in HR and lactate production at individual level, induced a dose-dependent curvilinear response in several parameters exploring autonomic nervous system cardiac regulation while simultaneously increasing functional capacity [10].

In the present study we sought to test the hypothesis that in the same patients, the session-RPE method provides similar autonomic adaptations and improvement in functional capacity as those observed with the more complex HR-based TRIMPi method.

2. Methods

2.1. Patients and study design

We enrolled 20 consecutive male patients with post-infarction heart failure referred to our center for a cardiac rehabilitation program. Subject eligibility was determined at the initial screening visit. Patients were included in the study if they had left ventricular ejection fraction (LVEF) < 40% at echocardiographic examination, symptomatic heart failure with functional New York Heart Association (NYHA) class II or III, clinical stability without hospital admission for HF in the previous 3 months, sinus rhythm and were on optimal medical treatment. Patients were excluded if they had unstable angina or recent acute myocardial infarction (less than 6 months), frequent atrial or ventricular premature beats, conduction defects, pacemaker, uncontrolled hypertension, history of severe kidney diseases, significant pulmonary disease, severe lower extremities vascular or other diseases which could prevent a symptom limited exercise test, coexisting valvular disease and insulin-dependent diabetes. Medications were not altered throughout the study. The patients reported in the present study were the same of other investigations having different purposes [4,10].

Patients were randomly assigned on 1:1 basis to a 12-week aerobic continuous training (ACT) or aerobic interval training (AIT), both programmed according to the TRIMPi method [4,10]. For each TRIMPi-guided exercise session, the RPE-session according to Foster [5] was also recorded. To validate the session-RPE method we used the correlation between session-RPE responses with those observed with the TRIMPi method, the latter assumed as criterion validity. Reliability of the session-RPE method was assessed before the beginning of the study as intraclass correlation coefficient and coefficient of variation. The corresponding values were 0.96 and 1%, respectively.

ACT and AIT programs guided by TRIMPi have been reported in detail elsewhere [4,10,11]. Shortly, for all patients, the exercise training program consisted of "uphill" treadmill walking, 2 days a week for the first three weeks, 3 days a week for the second three weeks, 4 days a week for the third three weeks, 5 days a week for the last three weeks. Specifically, patients in the ACT group walked continuously at a moderate training intensity, ~45–60% of HRR for 30–45 min, according to the training periodization. Patients in the AIT group warmed-up for 9 min with calisthenics and stretching exercise, before walking four 4-minute intervals by 2–4 times at ~75–80% of HRR, with active pauses of 3 min of walking at 45–50% of HRR. The treadmill running velocity and inclination were adjusted continuously to ensure that every training session was carried out at the assigned HRR throughout the training period. Heart rates were recorded (5-second sampling rate) using short-range telemetry (Polar Team System, Polar Electro Oy, Kempele, Finland). Heart rates were recorded (5-second sampling rate) using short-range telemetry (Polar Team System, Polar Electro Oy, Kempele, Finland). All training sessions were performed in the morning as it was for the 6 minute walking test (6MWT) and cardiopulmonary exercise test performed before and after training. Data from 42 training sessions were collected for each patient. Each training session was supervised by a physical therapist.

To allow for TRIMPi-guided trainings, at baseline, all patients underwent progressive incremental treadmill test until volitional fatigue with monitoring of gas exchange (Vmax 29 C, SensorMedics) using a modified Bruce protocol for the assessment of individual blood-lactate concentration profile, maximal HR and functional capacity. Capillary blood samples were taken from the earlobe each 3 min and immediately analyzed to assess blood-lactate concentration using an electroenzymatic technique (YSI 1500 Sport, Yellow Springs Instruments, Yellow Springs, OH, USA). The highest HR measured during the maximal incremental test was used as maximum reference value (HR_{max}). Blood lactate concentrations were plotted against running speeds and fractional HR elevation (ΔHR), and individual blood-lactate concentration profiles were identified via exponential interpolation [4,7,8].

2.2. RPE determination

The subjective perception of effort as session-RPE and HR were assessed in each patient, for each training session, during 12 different weekly training periodizations. The session-RPE was determined by multiply the training duration (minutes) by session RPE. Individual RPE was assessed using the Borg 10-point scale modified by Foster [5]. This product represents in a single number the magnitude of internal training load (TL) in arbitrary units (AU).

Patients were educated and familiarized with the use of the Borg 10-point scale before the beginning of the experiment. To ensure that the perceived effort was referred to the whole training session rather than the most recent exercise intensity, each patient was asked to provide a rating of the overall difficulty of the exercise bout, and each individual RPE was recorded about 30 min after completion of each training session. We explained to the patients that we wanted a global rating of the entire training bout using whatever cues they felt to be appropriate. Each patient reported the perception of training session effort by indicating the number on the Borg 10-point scale.

2.3. Autonomic assessment

BRS and Heart rate Variability (HRV) were investigated in each patient at baseline and 3 weeks apart on 4 subsequent occasions, according to the training periodization. BRS was assessed by means of the sequences technique [12] by analyzing simultaneous recordings of non-invasive finger beat-by-beat BP (Finapres, Ohmeda 2350, Englewood, CO, USA) and the electrocardiographic trace from a precordial lead at a sampling rate of 250 Hz (REP 10, Marazza, Italy), as described in details previously [10,11]. HRV considered in the present study was the standard deviation of mean R–R interval, inasmuch as this is the HRV parameter more consistently reported to be impaired in CHF. All assessments were made in the morning. After instrumentation, the subjects lay supine for 15 min before experiments to relax in the room made dark and noiseless; thereafter, blood pressure (BP) was measured twice, 5 min apart by sphygmomanometer, and the measurements were averaged. After BP measurements, continuous data acquisition was performed for 10 min.

After ANS assessment, on the same days, patients also performed a 6MWT, as a measure of functional capacity, according to standardized procedures [13].

All patients gave written informed consent to participate in the study, which was approved by the local Ethics Committee.

3. Statistics

The results are expressed as means ± SD and 95% confidence intervals (95% CI). Before using parametric tests, the assumption of normality was verified using the Shapiro–Wilk W test. Pearson product–moment correlation coefficients with linear regression analysis were calculated to determine whether there was a significant relationship between session-RPE and the HR-based method. Qualitative magnitude of associations was reported according to Hopkins [14] as follow: trivial $r < 0.1$, small $r < 0.1$ to <0.3, moderate r 0.3 to <0.5, large r 0.5 to <0.7, very large r 0.7 to <0.9, nearly perfect $r > 0.9$ and perfect $r = 1$. To express the dose–response relationship between the exercise stimulus and changes in ANS parameters, correlations between the mean weekly session-RPE and ANS parameters at baseline, 3, 6, 9 and 12 weeks were estimated from a second order regression [10,11,15,16]. A multivariate between-within subject analysis of variance was conducted to assess the impact of the two different training programs on mean weekly session-RPE and ANS parameters. The effect size (η^2) was calculated to assess meaningfulness of differences. Effect sizes values of 0.01, 0.06, and 0.14 were considered small, moderate and large, respectively. Statistical significance was set at $P < 0.05$.

4. Results

Out of 20 patients, 16 completed the study: 2 patients in the ACT group and 2 in the AIT group discontinued the study. The reason for discontinuation was in 1 case the development of permanent atrial fibrillation, which prevented HRV and BRS assessment, and in 3 cases the willingness of the patient to discontinue in the study, not related to medical reasons. Baseline characteristics of the patients are reported in Table 1. There were no significant differences between the ACT and