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Original article

Effects of cardiac rehabilitation on heart rate recovery of patients undergoing a cardiac rehabilitation programme after acute coronary syndrome

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ABSTRACT

Background: An efficient cardiac rehabilitation programme (CRP) can improve the functional ability of patients after acute coronary syndrome (ACS).
Objective: To examine the effect of a CRP on parasympathetic reactivation and heart rate recovery (HRR) measured after a 6-min walk test (6MWT), and correlation with 6MWT distance and well-being after ACS.
Methods: Eleven normoweight patients after ACS (BMI $< 25\ kg/m^2$; 10 males; mean [SD] age 61 [9] years) underwent an 8-week CRP. Before (pre-) and at weeks 4 (W4) and 8 (W8) during the CRP, they performed a 6MWT on a treadmill, followed by 10-min of seated passive recovery, with HRR and HR variability (HRV) recordings. HRR was measured at 1, 3, 5 and 10 min after the 6MWT (HRR1, HRR3, HRR5, HRR10), then modelized by a mono-exponential function. Time-domain (square root of the mean of the sum of the squares of differences between adjacent normal R-R intervals [RMSSD]) and frequency-domain (with high- and low-frequency band powers) were used to analyse HRV. Participants completed a mental and physical well-being questionnaire at pre- and W8. Exhaustion after tests was assessed by the Borg scale. Pearson correlation was used to assess correlations.
Results: HRR3, HRR5 and HRR10 increased by 37%, 36% and 28%, respectively, between pre- and W8 ($P < 0.05$), and were positively correlated with change in 6MWT distance ($r = 0.58$, 0.66 and 0.76; $P < 0.05$). Percentage change in HRR3 was positively correlated with change in well-being ($r = 0.70$; $P = 0.01$). Parasympathic reactivation (RMSSD) was improved only during the first 30 sec of recovery ($P = 0.04$).
Conclusion: Among patients undergoing a CRP after ACS, increased HRR after a 6MWT, especially at 3 min, was positively correlated with 6MWT distance and improved well-being. HRR raw data seem more sensitive than post-exercise HRV analysis for monitoring functional and autonomic improvement after ACS.

1. Introduction

Cardiovascular diseases remain the most common cause of death among Europe and accounted for 45% of all deaths in 2015 [1]. Alteration of the autonomic nervous system has a key pathophysiological role in the development of most cardiovascular risk factors such as hypertension and metabolic syndrome as well as in the onset of acute coronary syndrome (ACS) and the development of chronic heart failure [2]. Indeed, poor vital prognosis related to an exaggerated sympathetic tone is well demonstrated in these patients and triggers threatening cardiac arrhythmias and sudden death [3].

The R-R variability is a strong predictor of the autonomic nervous modulation of the heart and is extensively used for monitoring patients after ACS or predicting cardiac events [4–6]. Moreover, when assessing exercise capacity, heart rate recovery (HRR) 1 min into recovery provides insight into the speed of parasympathetic reactivation. An abnormally low HRR

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(< 12 bpm after 1 min) can be a marker of poor prognosis and greater disease severity [7]. Conversely, an increased parasympathetic tone has been associated with reduced mortality after ACS [8]. This increased parasympathetic activity is one of the protective mechanisms of exercise training implemented during cardiac rehabilitation, in addition to pharmacological treatment and invasive non-pharmacological interventions [9]. Indeed, cardiac rehabilitation was shown to positively modulate autonomic balance in post-ACS patients [10–12], leading to increased HRR after a maximal symptom-limited exercise test [8].

However, the high costs, required medical supervision, and safety concerns with evaluating maximal exercise capacity is sometimes impossible, especially among patients with chronic heart failure. Thus, several submaximal walking protocols have been developed to estimate cardiorespiratory fitness (CRF). The 6-min walk test (6MWT) is a common method used to estimate CRF in clinical settings lacking cardiovascular exercise testing ability. Indeed, studies have reported poor performance on the 6MWT being associated with poor prognosis. Additionally, the 6MWT may be able to detect differences attributable to therapy, especially in cardiac rehabilitation programmes (CRPs). Finally, even if the 6MWT does not provide an accurate estimation of CRF, it provided a clinically meaningful estimate of CRF and was similar to treadmill exercise testing in predicting cardiovascular events over a median follow-up of 8.0 years among outpatients with stable coronary heart disease [13]. In addition, the 6MWT appears to better reflect daily activity than a laboratory maximal exercise test [14].

An efficient CRP can improve the functional ability of patients after ACS, with a reported increase from 12% and 40% in walking distance on the 6MWT [15,16]. Conversely, the effect of such a programme on modulating the autonomic nervous system of the heart is debated, and some studies reported conflicting results [17,18]. Moreover, to our knowledge, no study has clarified a possible relation between HRR or heart rate variability (HRV) changes during a CRP and functional improvement during a submaximal exercise test such as the 6MWT.

The aim of the present study was to investigate the effect of a CRP on parasympathetic modulation, then the relation between HRV and HRR and any improvement in functional walking performance by the 6MWT and well-being in patients after ACS.

2. Materials and methods

2.1. Participants

We consecutively enrolled 11 normoweight patients (BMI < 25 kg/m^2; 10 males; mean [SD] age 61 [9] years). Inclusion criteria were an acute cardiac event within the previous 2 months and undergoing cardiac surgery and agreeing to participate in an 8-week rehabilitation programme including three training sessions per week. Exclusion criteria were significant cognitive disorders that hampered participation in the tests (Mini Mental State Examination score ≤ 24), acute or chronic respiratory failure, any associated disease that substantially limited walking capacity, acute or chronic heart failure (left-ventricular ejection fraction < 45% by the echocardiographic Simpson method), residual myocardial ischemia, absence of supraventricular premature ectopy able to alter HRV analysis, and modification of drug therapy affecting adaptation to effort (diuretics, angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, beta-blockers, anti-aldosterones, ivabradine) within the 15 days preceding the tests. However, the drug class, even those affecting HR (e.g., beta-blockers), was not an exclusion criterion. Participants were asked to maintain their usual medication throughout the study. They signed a written informed consent before data collection. The experiment was approved by a medical ethics committee (Commission cantonale d'éthique sur la recherche humaine du Canton-de-Vaud, CCER-VD, Lausanne, Switzerland; Agreement 165/14) and was performed in accordance with the Declaration of Helsinki.

3. Experimental protocol

3.1. Rehabilitation programme

Patients followed an 8-week rehabilitation programme with three sessions/week. Each session included a 1-hr aerobic exercise training on a treadmill or cycle ergometer followed by a 1-hr session of gymnastics or water aerobic exercises in the swimming pool when scars were healed. They also had 1-hr relaxation sessions once a week and attended education sessions on cardiovascular risk-factor control (2 hr) and healthy nutrition advice (2 hr).

4. Measurements

4.1. 6MWT

The tests were performed on the first day (pre-), half way (W4) and at the end (W8) of the CRP on a treadmill (HP Cosmos® running machine series mercury, Nussdorf, Germany) with a 0% incline. The speed was self-selected by the participant and could be changed at any time. Before the test, blood pressure was measured by use of an armband (Welch Allyn®, Bronze Series DS44 Integrated Aneroids, New York, USA) and a stethoscope. With abdormal blood pressure or HR before the training session, the doctor was informed and the test was postponed if needed. The participant was equipped with an HR monitor (T6d, Suunto, Vantaa, Finland) and HR belt. After a familiarization period, the participant walked on the treadmill, self-selecting the walking speed, in order to achieve the greatest distance during 6 min.

The modified Borg scale (CR10) was used to quantify the rate of perceived exhaustion after each test [19]. At pre- and W8, participants also completed the in-house–developed well-being questionnaire that is used routinely for clinical purposes at the hospital for investigating physical and emotional changes. Scores for "mental well-being" and "physical well-being" were obtained.

5. Post-exercise HRV

At the end of exercise, the participant immediately sat on a chair placed adjacent to the treadmill. The time between the end of exercise and sitting was < 3 sec. The patient was asked not to move or talk while on the chair. All HRR and HRV analyses have been described in detail elsewhere [20,21]. Briefly, all R-R series recorded by the Suunto® T6d were exported in an Excel compatible file and data for the 10-min recovery period after the 6MWT were extracted. Occasional ectopic beats were visually identified and manually replaced with interpolated adjacent R–R interval values.

6. Post-exercise HRR

HRR was defined as the difference (exercise–recovery) after 1, 2, 3, 5 or 10 min of exercise cessation (i.e., when HRR increases, the recovery is improved) and was calculated from the end of the 6MWT to the end of 1, 3, 5 and 10 min after the test: HRR1, HRR3, HRR5, and HRR10, respectively. The results are obtained in beat per minutes (bpm). We also gathered the time constant (HRR_τ) of the

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