Variable Effects of Physical Training of Heart Rate Variability, Heart Rate Recovery, and Heart Rate Turbulence in Chronic Heart Failure

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Background: *Heart rate variability (HRV), heart rate turbulence (HRT), and heart rate recovery (HRR), indices that reflect autonomic nervous system (ANS) activity, are outcome predictors in patients with chronic heart failure (CHF). It is not clear, however, whether they reflect the same components of ANS activity. No study has examined the effects of physical training (PT) training on HRV, HRT, and HRR in CHF.*

Study Objective: *To examine the responses of HRV, HRT, and HRR to a PT program in patients presenting with CHF.*

Methods: *In 41 patients (mean age = 58.7 ± 10.2 years) in New York Heart Association CHF functional classes II or III, and with a left ventricular ejection fraction <40%, HRV, HRT, and HRR were measured before and after 8 weeks of PT.*

Results: *The training was clinically effective in all patients. Before versus after PT, standard deviation of all normal RR intervals increased from 107 ± 30 to 114 ± 32 ms (P = 0.047), high frequency increased from 210 ± 227 to 414 ± 586 ms^2/Hz (P = 0.02), and the low/high frequency ratio decreased from 1.8 ± 1.55 to 1.1 ± 1.2 (P = 0.002). HRT and HRR did not change significantly after PT.*

Conclusions: *In patients with CHF, the positive effects of PT were limited to HRV indices, which reflect parasympathetic activity, without significantly changing HRR and HRT. These observations indicate that different mechanisms modulate HRV, HRR, and HRT, which provide complementary information regarding ANS activity. The 8-week PT program failed to completely normalize ANS function. (PACE 2009; 32:S113–S115)*

heart rate variability, heart rate turbulence, heart rate recovery, autonomic nervous system, heart failure, physical training

Introduction

Disturbances in the activity of the autonomic nervous system (ANS) significantly influence the clinical presentation and prognosis of patients suffering from chronic heart failure (CHF). The noninvasive assessment of indices reflecting ANS activity on the surface electrocardiogram (ECG) can help evaluate the efficacy of therapies. Since physical training (PT) improves the prognosis of patients presenting with CHF, we hypothesized that it also improves the indices that reflect ANS activity.[1,2] Heart rate variability (HRV), heart rate turbulence (HRT), and heart rate recovery (HRR) have a significant prognostic value in CHF.[2–8] However, it is unclear whether they reflect the same components of ANS activity, or whether they respond differently to PT. Therefore, we designed this study to measure the responses of HRV, HRT, and HRR to PT in patients suffering from CHF.

Methods

Patient Population

The study population consisted of 41 patients (mean age = 58.7 ± 10.2 years; 39 men) in New York Heart Association (NYHA) CHF functional class II or III, who underwent an 8-week PT program and consented to participate in the study. The study exclusion criteria were (a) CHF secondary to uncorrected valvular disease; (b) myocardial infarction (MI) or percutaneous coronary intervention (PCI) within the previous 4 weeks, and coronary artery bypass grafting (CABG) within the previous 8 weeks; (c) presence of atrial fibrillation; (d) concomitant neoplastic disease; and (e) patient's refusal to participate in the study. The study was approved by the Institutional Ethics Committee. All patients granted their written informed consent.

Physical Training

After 3 weeks of stable clinical status and optimal medical treatment, the patients underwent

The authors have no potential conflict of interest to disclose.

The study was supported by statute funds from the National Institute of Cardiology, Warsaw, Poland (Study No. 2.9/I/06).

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an 8-week physical-endurance training, with exercise levels ranging from 40% to 60% of peak oxygen consumption (peak VO_2, mL/kg/min) during cardiopulmonary testing. The effectiveness of PT was ascertained by the exercise test duration, peak VO_2, metabolic equivalent (MET), and distance covered during a 6-minute walk test (6-MWT).

Indices of ANS Activity

HRV, HRT, and HRR were measured before and after a cardiac rehabilitation cycle using a 24-hour ECG, recorded with a Spacelabs Lifecard system (Spacelabs, Del Mar Reynolds, Hertford, UK). HRV indices were calculated after prospective interactive ECG analysis, using the Impresario Space software (Del Mar Reynolds). The measurements of HRV included time domain—standard deviation of all normal RR intervals (SDNN) and frequency domain indices. The frequency domain indices were calculated after fast Fourier transformation of five 10-minute ECG segments, recorded between 2 a.m. and 6 a.m. The highest and lowest values were excluded, and the three remaining values were averaged. The power spectrum density of low frequency (LF) 0.04 – 0.15 Hz, high frequency (HF) 0.15 – 0.4 Hz, and the low frequency to high frequency ratio (LF/HF) was calculated.

The measurements of HRT included turbulence onset (TO) and turbulence slope (TS) according to the algorithm described by Schmid et al.[9] HRR was calculated as the difference between the heart rate at peak exercise and 1 minute after the end of the exercise test.

Statistical Analysis

Paired *t*-test was used for continuous variables with normal distributions. The normality of distribution was verified with the Shapiro-Wilk test. The signed-rank test (changes over time) and the Wilcoxon test (to compare groups) were used for variables that were not normally distributed. The χ^2 or Fisher's exact tests were used for qualitative variables. The level of statistical significance was set at $P < 0.05$.

Results

Clinical Characteristics of the Study Population

The study population consisted of 41 patients (39 men and three women; mean age = 58.7 ± 10.2 years) in NYHA CHF functional class II (n = 20), or III (n = 21) due to ischemic (n = 38; 93%) or nonischemic (n = 3; 7%) heart disease, with a left ventricular ejection fraction <40% (mean = 31 ± 6%). Among these 41 patients, 35 (85%) had suffered a prior MI, 25 (61%) had undergone PCI, 14 (34%) CABG, and 12 (29%) had suffered a stroke. A body mass index >30 kg/m^2 was present in 12 (29%) patients, metabolic syndrome in 10 (24%), diabetes in 15 (37%), and hypertension in 12 (29%) patients. The medications used included β-adrenergic blockers in 100%, angiotensin-converting enzyme inhibitors in 95%, angiotensin receptor blocker in 5%, aspirin in 93%, diuretics in 90%, and statins in 95% of patients.

Effectiveness of Physical Training

All measurements which reflected the clinical effectiveness of cardiac rehabilitation improved significantly after the PT. Respective values before and after PT were: (a) exercise test duration 427 ± 118 versus 507 ± 129 seconds (P = 0.002); (b) peak VO_2 17.1 ± 4.6 versus 18.8 ± 5.1 mL/kg/min (P < 0.001); (c) MET 5.1 ± 1.1 versus 6.7 ± 1.6 (P = 0.005); and (d) distance covered in 6 MWT 416 ± 92 versus 462 ± 89 m (P = 0.001).

Indices of ANS Activity

The mean changes in SDNN, HF, LF/HF between before and after PT were, respectively, 107 ± 30 versus 114 ± 32 ms (P = 0.047), 210 ± 227 versus 414 ± 586 ms^2/Hz (P = 0.020), and 1.8 ± 1.55 versus 1.1 ± 1.2 (P = 0.002). LF, TS, TO, and HRR did not change significantly (Table I).

Discussion

The ANS regulation of the heart is impaired in CHF. In our study, the values of HRV, HRR, and HRT were abnormal before the beginning of rehabilitation training, an observation concordant with prior studies.[2–6] In this study, the magnitude of changes in the indices of ANS function after PT was variable (Table I). The changes in SDNN, HF, LF/HF were statistically significant, indicating that PT had beneficial effects on the balance of the ANS components. These observations are concordant with studies reported previously.[2–4,10] Although PT improved the patients' overall physical performance, HRR and HRT did not change significantly. Few studies of patients suffering from CHF have reported improvements in HRR after PT. Streuber et al.[7] observed improvements limited to patients with an HRR response <12 bpm, and Dimopoulos et al.[6] found improvements in HRR by continuous, but not by intermittent, exercise training, suggesting that, despite effective training of patients presenting with CHF, HRR may not improve. Our study is the first to examine the effect of PT on HRT, and first to analyze simultaneously the effects of exercise training on HRV, HRT, and HRR. The limitation of significant changes to HRV indices after a cycle of effective rehabilitation remains unexplained. The ANS indices analyzed

Table I.

Effects of Physical Training (PT) on ANS Indices

	Before PT	After PT	P
Standard deviation of all normal RR intervals (ms)	107 ± 30	114 ± 32	0.047
Low frequency (ms^2Hz)	276 ± 322	356 ± 582	NS
High frequency (ms^2Hz)	210 ± 227	414 ± 586	0.02
Low-to-high frequency ratio	1.8 ± 1.55	1.1 ± 1.2	0.002
Turbulence onset (%)	−1.16 ± 1.59	−1.14 ± 2.2	NS
Turbulence slope (ms/RR interval)	4.25 ± 4.7	4.9 ± 6.2	NS
Heart rate recovery (bpm)	12.0 ± 7.3	12.6 ± 6.7	NS

NS = not statistically significant.

in this study reflect different components of the ANS. HRV reflects its spontaneous activity, HRT reflects the spontaneous response of baroreflex receptor activity to stress, while HRR reflects the recovery of parasympathetic activity after maximal exercise. One might hypothesize that 8-week exercise training has an effect on overall sympathovagal activity, whereas baroreflex sensitivity and parasympathetic recovery remain impaired after this period of cardiac rehabilitation. We observed a trend toward improvement in TS, suggesting that a longer period of PT is needed to achieve significant improvements in HRT indices. Our findings indicate that a full evaluation of the effects of therapies on the ANS, including clinically effective PT, must be based on multiple components of its activity, reflecting sympath-ovagal tone, baroreflex sensitivity, and parasympathetic recovery. Further studies are needed to develop more effective methods of cardiac rehabilitation, to improve in all three components, in patients suffering from CHF. The type of physical exercise, its duration, and the length of the rehabilitation program might induce different responses among these components of the ANS.

Study Limitations

The 92% prevalence of ischemic heart disease in our patient population does not allow an application of our results to patients with nonischemic heart disease. We did not exclude patients who had undergone CABG, in whom both afferent and efferent cardiac innervations might have been impaired.

Conclusions

In patients with heart failure, clinically effective PT significantly improved the HRV indices, which reflect parasympathetic activity, without significantly changing HRR and HRT. Since the response of HRV, HRT, and HRR to PT was dissimilar, these indices seem to represent different aspects of ANS activity. The 8-week training program used in this study, although clinically effective, failed to completely normalize ANS function in patients suffering from CHF.

References

1. Piepoli MF, Davos C, Francis DP, Coats AJS, Belardinelli R, Purcaro A, Dubach P, et al. ExTraMATCH Collaborative. Exercise training meta-analysis of trials in patients with chronic heart failure (Ex TraMATCH). BMJ 2004; 328:189–192.
2. Malfatto G, Branzi G, Riva B, Sala L, Leonetti G, Facchini M. Recovery of cardiac autonomic responsiveness with low-intensity physical training in patients with chronic heart failure. Eur J Heart Fail 2002; 4:159–166.
3. Kiilavuori K, Toivonen L, Naveri H, Leinonen H. Reversal of autonomic derangements by physical training in chronic heart failure assessed by heart rate variability. Eur Heart J 1995; 16:490–495.
4. Larsen AI, Gjesdal K, Hall Ch, Aukrust P, Aarsland T, Dickstein K. Effect of exercise training in patients with heart failure: A pilot study on autonomic balance assessed by heart rate variability. Eur J Cardiovasc Prev Rehabil 2004; 11:162–167.
5. Myers J, Hadley D, Oswald U, Bruner K, Kottman W, Hsu L, Dubach P. Effects of exercise training on heart rate recovery in patients with chronic heart failure. Am Heart J 2007; 153:1056–1063.
6. Dimopoulos S, Anastasiou-Nana M, Sakellariou D, Drakos S, Kapsimalakou S, Maroulidis G, Roditis P, et al. Effects of exercise rehabilitation program on heart rate recovery in patients with chronic heart failure. Eur J Cardiovasc Prev Rehabil 2006; 13:67–73.
7. Streuber SD, Amsterdam EA, Stebbins CL. Heart rate recovery in heart failure patients after a 12-week cardiac rehabilitation program. Am J Cardiol 2006; 97:694–698.
8. Koyama J, Watanabe J, Yamada A, Koseki Y, Konno Y, Toda S, Shinozaki T, et al. Evaluation of heart-rate turbulence as a new prognostic marker in patients with chronic heart failure. Circ J 2002; 66:902–907.
9. Schmidt G, Malik M, Barthel P, Schneider R, Ulm K, Rolnitzky L, Camm AJ, et al. Heart-rate turbulence after ventricular premature beats as a predictor of mortality after acute myocardial infarction. Lancet 1999; 353:1390–1396.
10. Selig SE, Carey MF, Menzies DG, Patterson J, Geerling RH, Williams AD, Bamroongsuk V. Moderate-intensity resistance exercise training in patients with chronic heart failure improves strength, endurance, heart rate variability, and forearm blood flow. J Card Fail 2004; 10:21–30.