

## HEART RATE VARIABILITY IN PATIENTS WITH HEART FAILURE: EFFECT OF EXERCISE TRAINING

JANČÍK J.<sup>1</sup>, SIEGELOVÁ J.<sup>1</sup>, DOBŠÁK P.<sup>1</sup>, SVAČINOVÁ H.<sup>1</sup>, PLACHETA Z.<sup>1</sup>, FIŠER B.<sup>2</sup>, DUŠEK J.<sup>1</sup>, PANOVSÝ R.<sup>3</sup>, ŠPINAROVÁ L.<sup>3</sup>, EICHER J.C.<sup>4</sup>

<sup>1</sup> Department of Functional Diagnostics and Rehabilitation, Faculty of Medicine, Masaryk University, Brno, Czech Republic

<sup>2</sup> Institute of Physiology, Faculty of Medicine, Masaryk University, Brno, Czech Republic

<sup>3</sup> First Department of Cardioangiology, Faculty of Medicine, Masaryk University, Brno, Czech Republic

<sup>4</sup> Department of Cardiology, Hôpital du Bocage and University of Burgundy, Dijon, France

*Received after revision November 2004*

### Abstract

The present study was designed to evaluate whether a specific program of exercise training at anaerobic threshold level may be sufficient to improve heart rate variability (HRV) in patients with chronic heart failure (CHF). We examined 10 patients with CHF (men, mean body weight  $85 \pm 12$  kg; mean age  $61 \pm 13$  years; NYHA class II-III,) after echocardiography, coronarography and under stable therapy. The patients underwent standard bicycle spiroergometry test before and after the training in order to determine basic functional parameters (maximal workload -  $W_{\max}$ , symptom-limited oxygen uptake -  $\dot{V}O_{2SL}$ , oxygen uptake at anaerobic threshold -  $\dot{V}O_{2AT}$ , and metabolic equivalents - METs). The patients underwent 8-week long intensive aerobic training (at anaerobic threshold level, 3 times a week) combined with resistance training at the level of 60% of one repetition maximum (1-RM). Heart rate variability parameters (HRV) were determined by spectral analysis of pulse interval (PI) using the beat-to-beat non-invasive monitoring of ECG, spontaneous and metronome-controlled breathing at 0.3 Hz before and after the training (system Varia-Pulse TF-3). The results showed a significant increase in values of total power after the end of rehabilitation (from  $891 \pm 1011$  ms<sup>2</sup> to  $2829 \pm 3000$  ms<sup>2</sup>; \* $P < 0.05$ , Wilcoxon paired). It is concluded that 8 weeks lasting exercise training at anaerobic threshold level can increase the total power value (TP) of heart rate variability in patients with chronic heart failure.

### Key words

Chronic heart failure, Exercise training, Aerobic training, Resistance training, Cardiopulmonary function testing, Heart rate variability

### Abbreviations used

CHF, chronic heart failure; HF, high-frequency component;  $HR_{\max}$ , maximal heart rate; HRV, heart rate variability; NYHA, New York Heart Association; LF, low-frequency component; PI, pulse interval; LF/HF, LF to HF ratio;  $\dot{V}O_{2SL}$ , symptom-limited oxygen uptake;  $\dot{V}O_{2AT}$ , oxygen uptake at anaerobic threshold; TP, total power;  $W_{\max}$ , maximal workload.

## INTRODUCTION

Low heart rate variability (HRV) is an indicator of increased risk of sudden cardiac death after myocardial infarction and in patients with chronic heart failure (CHF) (1, 2). It is supposed that a regular physical activity could modify this risk factor; however, most of the training methods including the rehabilitation protocols used also in our previously published studies are based on aerobic exercise (3, 4), and until now there is a lack of valid information from actual bibliography concerning the effects of resistance or combined long-term lasting training on the heart rate variability parameters (HRV). Classical methodology for evaluating the benefits of physical training is based on cardiopulmonary exercise testing. This examination is time-consuming and could be potentially life-threatening. The examination of HRV is comfortable for the patient and without any risk. The aim of this study was to investigate if HRV testing can be useful for determination of the influence of 8-week combined exercise training on the heart rate variability expressed in frequency domain parameters in the group of patients with CHF.

## PATIENTS AND METHODS

Ten patients (mean body weight  $85 \pm 12$  kg; mean age  $61 \pm 13$  years) with chronic heart failure were selected according to the inclusion criteria listed below. The treatment regimen of all selected patients was optimised to ensure that the patients were symptomatically stable. Standardised pharmacological treatment at the beginning and in the end of the 8-week period included administration of angiotensine converting enzyme inhibitors (ACEI),  $\beta$ -blockers, diuretics and digitalis in varying combinations. Inclusion criteria were as follows: age over 18 years, symptomatic chronic congestive heart failure NYHA class II-III determined for at least 3 months, and stable for at least 6 weeks; left ventricular ejection fraction  $< 40\%$  (assessed by 2D-echocardiography); symptom limited spiroergometry showed symptom-limited oxygen consumption ( $\dot{V}O_{2SL}$ )  $< 20$  ml.kg.min<sup>-1</sup>. Before the inclusion to the study all the subjects signed the Informed Patient's Consent; the study was approved by the local Ethical Committee and conforms to the principles outlined in the Declaration of Helsinki and to GCP guidelines of European Community.

Heart rate variability was registered by the system Varia-Pulse TF-3. A short-time evaluation of the heart rate variability was done using the beat-to-beat non-invasive monitoring of ECG, spontaneous and metronome-controlled breathing at 0.33Hz before and after the training period of 8 weeks. HRV frequency-domain parameters were determined by spectral analysis of pulse interval (PI).

Combined exercise training was realized at the Department of Functional Diagnostics and Rehabilitation 3 times a week. Resistance training elements were included into the exercise protocol only after 2 weeks of aerobic training. One exercise session lasted 60 min and included: warm-up period (10 min), period of aerobic exercise on bicycle ergometer with load intensity at the level of anaerobic threshold (20 min), period of fitness (or resistance) training performed on combined training machine (20 min), and relaxation period (10 min). In the period of fitness (resistance) training all the subjects started to exercise at 30% level of 1-RM (one repetition maximum), and after 2 weeks they continued at 60% level of 1-RM. The rehabilitation programme was performed by the patients for eight weeks.

Standard exercise spiroergometry (Blood Gas Analyser, MedGraphics, USA) up to the maximum limited by symptoms was carried out before and after 8 weeks of training to assess symptom-limited oxygen consumption ( $\dot{V}O_{2SL}$ ), maximal workload ( $W_{max}$ ), metabolic equivalents (METs) and maximal heart rate ( $HR_{max}$ ). The first spiroergometry test was applied also to determine the anaerobic threshold (ANP) in order to decide the individual training intensity.

Statistical analysis of functional data was performed using the Wilcoxon paired test, the Chi-2 test, the Friedmann test, and analysis of variance ANOVA. The  $P$  value  $< 0.05$  was considered as significant.

## RESULTS

Spiroergometry testing after the 8 weeks of training showed significant increase of  $W_{\max}$  ( $110 \pm 20$  W;  $*P < 0.05$ ), and also a significant increase of  $\dot{V}O_{2SL}$  values ( $1551 \pm 261$  mlO<sub>2</sub>.min<sup>-1</sup>;  $*P < 0.05$ ); the increase of both values was approximately +20 % compared to the initial values (Fig. 1 and 2). Table 1 summarizes the results of all evaluated functional parameters.

Spectral analysis of HRV parameters was evaluated and is presented in Table 2. They are pulse intervals (PI; ms), total power – TP; ms<sup>2</sup>, the power of low frequency component (LF; 0.04–0.14 Hz/ms<sup>2</sup>), the power of high frequency component (HF; 0.15–0.4 Hz/ms<sup>2</sup>) and ratio of LF power to HF power (LF/HF). Spectral analysis revealed a significant increase of the total power (TP) of HRV after 8 weeks of combined exercise training ( $2829 \pm 3000$  ms<sup>2</sup>;  $*P < 0.05$ ) in comparison with the TP initial values (Fig. 3). An increase of other HRV parameters was also observed, but it is without statistical significance.

The results of HRV spectral analysis and the results of functional performance testing indicate that HRV parameters could be useful for the evaluation of the effectiveness of physical training.

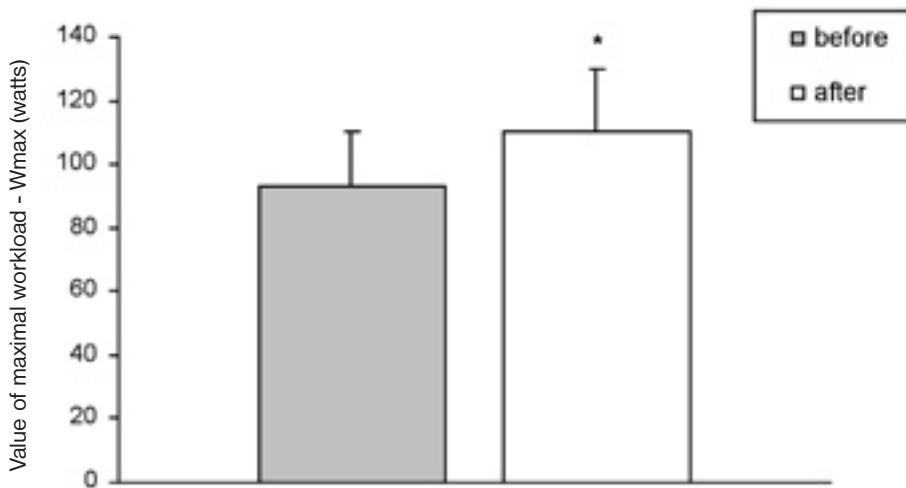
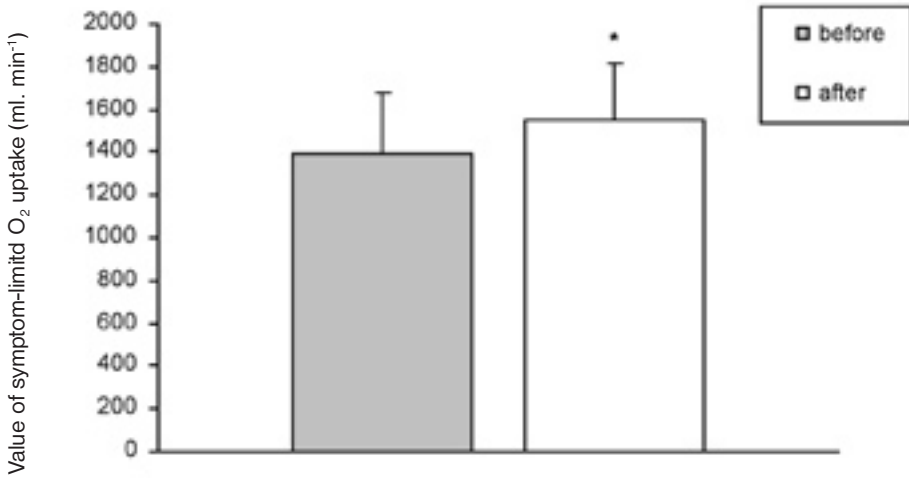


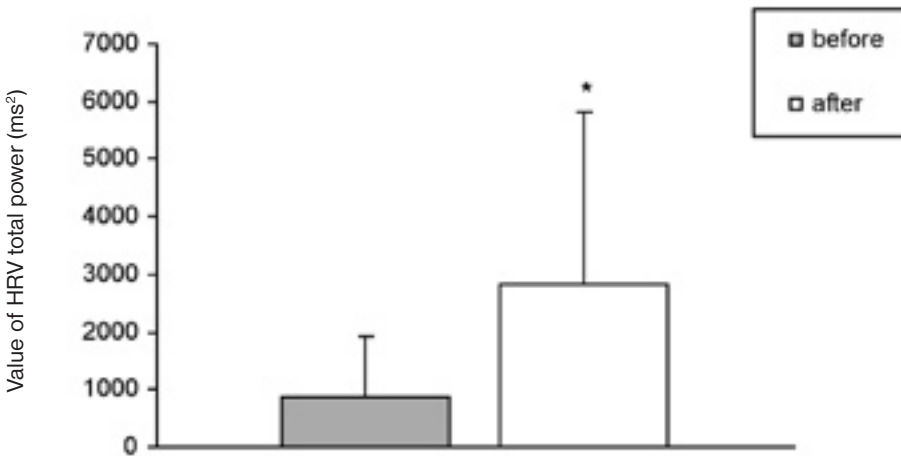
Fig. 1

Comparison of the values of maximal workload ( $W_{\max}$ ) before and after 8 weeks of combined exercise training. Results are expressed as mean  $\pm$  SD ( $*P < 0.05$ ; Wilcoxon paired test).



*Fig 2*

Comparison of the values of symptom-limited oxygen uptake ( $\dot{V}O_{2SL}$ ) before and after 8 weeks of combined exercise training. Results are expressed as mean  $\pm$  SD (\*  $P < 0.05$ ; Wilcoxon paired test).



*Fig 3*

Comparison of the values of spectral analysis of HRV - Total Power (ms<sup>2</sup>) before and after 8 weeks of combined exercise training. Values are expressed as mean  $\pm$  SD (\*  $P < 0.05$ ; Wilcoxon paired test).

Table 1

Results of registered functional parameters assessed by bicycle spiroergometry testing before and after 8 weeks of combined exercise training. Results are expressed as mean  $\pm$  SD; Wilcoxon paired test

Functional parameters	$W_{\max}$ (watts)	$W_{\max} \cdot \text{kg}^{-1}$ (watts. $\text{min}^{-1}$ )	$\dot{V}O_{2SL}$ ( $\text{mlO}_2 \cdot \text{min}^{-1}$ )	$\dot{V}O_{2SL} \cdot \text{kg}^{-1}$ ( $\text{mlO}_2 \cdot \text{min} \cdot \text{kg}^{-1}$ )	METs
Before	93 ( $\pm 17$ )	1.0 ( $\pm 0.2$ )	1399 ( $\pm 284$ )	15.2 ( $\pm 3.4$ )	4.3 ( $\pm 1.0$ )
After	* 110 ( $\pm 20$ )	* 1.2 ( $\pm 0.2$ )	* 1551 ( $\pm 261$ )	* 16.9 ( $\pm 2.8$ )	* 4.7 ( $\pm 0.9$ )

$W_{\max}$ , maximal workload;  $W_{\max} \cdot \text{kg}^{-1}$ , maximal workload per kg;  $\dot{V}O_{2SL}$ , symptom-limited oxygen uptake;  $\dot{V}O_{2SL} \cdot \text{kg}^{-1}$ , symptom-limited oxygen uptake per kg; METs, metabolic equivalents; \*  $p < 0.05$ .

Table 2

Results of the spectral analysis of registered HRV frequency-domain parameters before and after 8 weeks of combined exercise training. Results are expressed as mean  $\pm$  SD; Wilcoxon paired test

Functional parameters	PI (ms)	TP ( $\text{ms}^2$ )	LF ( $\text{Hz}/\text{ms}^2$ )	HF ( $\text{Hz}/\text{ms}^2$ )	LF/HF
before	1016 ( $\pm 137$ )	891 ( $\pm 1011$ )	191 ( $\pm 178$ )	665 ( $\pm 820$ )	1.01 ( $\pm 1.11$ )
after	1046 ( $\pm 124$ )	* 2829 ( $\pm 3000$ )	256 ( $\pm 214$ )	2573 ( $\pm 2875$ )	0.80 ( $\pm 1.12$ )

PI, pulse interval; TP, total power; LF, low-frequency component, HF, high-frequency component; LF/HF, LF to HF ratio; \*  $p < 0.05$ .

## DISCUSSION

In the last 20 years the decreased heart rate variability has been shown to be a significant sign of sudden death risk in patients after myocardial infarction (5), and the predictive value of decreased heart rate variability is comparable to the ejection fraction volume in the risk stratification of patients after myocardial infarction (6).

The autonomic nervous system is permanently influenced by a variety of stimuli of the inner or outer origin. Age and health status belong to the inner stimuli, whereas climatic conditions, day (night) period, actual psychic and physical workload, or changes of the body position are the stimuli of the outer origin (7). For an easier interpretation of the results of HRV examination a test (supine – standing – supine position) was introduced in which the vagal activity increases in supine position, whereas the sympathetic tone is increased in standing position. Moreover, after repeated supine position an overshoot of the spectral power of the high frequency component of the heart rate spectral analysis appears. Thus, in order to analyze the data of vagal activity with maximal precision, an analysis of spectral parameters after repeated supine position is recommended (8).

Regarding to the fact that the amplitude of respiration arrhythmia is predominantly dependent on the frequency and depth of breathing (without breathing frequency control), the variability at high frequency can be submitted to non-predictable changes. A deep and slowed respiration to 6 breath cycles per minute shifts the top of respiratory spectra in the area of 0.1Hz and so can imitate an increase of sympathetic tone modulation of cardiac rhythm (9). In our present study we evaluated 5min intervals of HRV using metronome-controlled breathing at 0.33Hz.

The adaptation of cardiovascular system on resistance exercise training is different from the adaptation on dynamic exercise training. Heart muscle in resistance training shows signs of concentric hypertrophy, whereas the heart muscle adaptation in dynamic training is characterized by increase of heart cavities and only a limited heart wall thickening. In that case the hypertrophy is considered as eccentric (10). In contrast to the resistance exercise the aerobic (or dynamic) training is more efficient on the decrease of heart rate and systolic blood pressure at rest, and also on the increase of stroke volume at rest and during exercise (11). Thus, it is possible to suppose that various types of exercise influence the HRV in a different manner. The results of our study showed statistically significant differences in TP.

Up to the present the influence of combined training on the patients' performance and the autonomic nervous system has not been fully explained. Our results have shown that 8 weeks of combined training led to the increase of functional capacity in patients with chronic heart failure and to the increase of total spectral power. This study contributes to the knowledge about rehabilitation training importance in patients with chronic heart failure.

## Acknowledgement

This study was supported by the grant of Czech Ministry of Health IGA MZČR, No. NR 7983-3, 2004.

*Jančík J., Siegelová J., Dobšák P., Svačinová H., Placheta Z., Fišer B.,  
Dušek J., Panovský R., Špínarová L., Eicher J.C.*

## VARIABILITA SRDEČNÍ FREKVENCE U PACIENTŮ S CHRONICKÝM SRDEČNÍM SELHÁNÍM: ÚČINEK REHABILITACE

### Souhrn

Cílem této studie bylo zhodnotit, zda speciální trénink na úrovni anaerobního prahu zvyšuje variabilitu srdeční frekvence (HRV) u pacientů s chronickým srdečním selháním (CHF). Bylo vyšetřeno 10 pacientů s CHF (mužů, průměrné tělesné hmotnosti  $85 \pm 12$  kg, průměrného věku  $61 \pm 13$  let, NYHA II-III, byla provedena echokardiografie a koronarografie) se stabilizovaným terapeutickým režimem. U všech pacientů bylo provedeno vstupní a výstupní spiroergometrické vyšetření do symptomu limitovaného maxima pro stanovení základních funkčních parametrů (maximální výkon -  $W_{max}$ , symptomy-limitovaná spotřeba kyslíku -  $\dot{V}O_{2SL}$ , spotřeba kyslíku při anaerobním prahu -  $\dot{V}O_{2AT}$ , a metabolické ekvivalenty - METs). Pacienti absolvovali 8-týdenní intenzivní aerobní trénink (na úrovni anaerobního prahu, 3x týdně) kombinovaný s odporovým tréninkem na úrovni 60% tzv.jedenkrát opakovaného maxima (1-RM). Parametry variability srdeční frekvence (HRV) byly určeny pomocí spektrální analýzy tepových intervalů (PI) s využitím monitorování EKG metodou tep po tepu, při spontánním a metronomem kontrolovaném dýchání při frekvenci 0.3Hz před ukončením tréninkového procesu a po něm (přístrojový systém Varia-Pulse TF-3). Výsledky ukázaly signifikantní zvýšení hodnot celkového spektrálního výkonu na konci rehabilitace (ze vstupní hodnoty  $891 \pm 1011$  ms<sup>2</sup> na výstupní hodnotu  $2829 \pm 3000$  ms<sup>2</sup>; \* $P < 0.05$ , Wilcoxonův test). 8-týdenní kombinovaný trénink na úrovni anaerobního prahu může zvýšit hodnotu celkového spektrálního výkonu u pacientů s chronickým srdečním selháním.

### REFERENCES

1. *La Rovere MT, Bigger JT, Marcus FI, Mortara A, Schwartz PJ.* Baroreflex sensitivity and heart-rate variability in prediction of total cardiac mortality after myocardial infarction. *Lancet* 1998; 351: 478-484.
2. *Galiner M, Pathak A, Fourcade J. et al.* Depressed low frequency power of heart rate variability as an independent predictor of sudden death in chronic heart failure. *Eur Heart J* 2000; 21: 475-482.
3. *Jančík J, Várnayová L, Siegelová J. et al.* Heart rate variability in patients with chronic ischemic heart disease: effect of 8-week exercise training. *Proceedings of Symposium: The Importance of Chronobiology in Diagnosing and Therapy of Internal Diseases.* F.Halberg, T.Kenner, B.Fišer (eds.). IDVPZ Brno 2002: 179-184.
4. *Jančík J., Siegelová J., Dobšák P. et al.* Baroreflex sensitivity and heart rate variability in patients with chronic ischemic heart disease and systolic dysfunction: effect of exercise training. *Clin Auton Res* 2003; 13(1): 57.
5. *Hohnloser SH, Klingenberg T, Zabel M.* Identification of patients after myocardial infarction at risk of life-threatening arrhythmias. *Eur Heart J* 1999; Suppl.1: 11-20.
6. *Haláček J, Kára T, Jurák P. et al.* Variability of phase shift between blood pressure and heart rate fluctuations - A marker of short-term circulation control. *Circulation* 2003; 108(3): 292-297.
7. *Semrád B, Fišer J, Honzíkova N.* Aging and cardiac autonomic status. In: *Clinical Guide to cardiac autonomic test.* M. Malik (ed.). London, Kluwer Academic Publishers 1998: 285-300.
8. *Opavský J.* Metody vyšetřování autonomního nervového systému a spektrální analýza variability srdeční frekvence v klinické praxi. In: *J.Salinger: Variabilita srdeční frekvence a její hodnocení*

v biomedicínských oborech - od teorie ke klinické praxi. Sborník článků a abstrakt. Univerzita Palackého v Olomouci. Olomouc, 2004. ISBN 80-244-0805-8.

9. *Kautzner J, Malik M.* Variabilita srdečního rytmu a její klinická použitelnost. *Cor Vasa*, 1998; 40(5): 244-251.
10. *Máček M, Máčková J.* Fyziologie tělesných cvičení. Sdružení pro rozvoj zdravotní a tělesné výchovy ve spolupráci s nakladatelstvím ONYX Praha, 1995. ISBN 80-85228-20-3.
11. *Pollock ML, Franklin BA, Balady GJ et al.* Resistance exercise in individuals with and without cardiovascular disease. Benefits, rationale, safety, and prescription. An advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association. *Circulation* 2000; 101: 828-833.