Acta Medica et Biologica
Vol. 46, No.4, 139-146, 1998

Effects of Physical Training on Heart Rate Variability and Blood Cell Counts in Healthy Adults

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Received July 31 1998; accepted December 4 1998

Summary. **The effects of eight weeks of endurance training on autonomic nerve function was assessed by measuring spectral changes in heart rate variability and blood cell counts in 12 healthy subjects. After the 8 week training program, heart rates significantly decreased after training at pre-load resting, during loading, and post-load resting. Low frequency component (LF) power slightly increased from the pre-load resting to the loading phase before the training, but slightly decreased from the pre-load resting to the loading phase after the training. These were not significant, but the difference between the slight increase and the slight decrease was significant ($p<0.05$). The other parameters including high frequency vagal component (HF) power and LF/HF were not significantly changed from the pre-load resting to the loading phase both before and after the training. These results show that sympathetic nerve activity from pre-load resting to loading decreased after training, while parasympathetic nerve activity was not changed. Mean corpuscular volume increased significantly, while lymphocyte count (LYP) decreased significantly ($p<0.05$) from before to after training ($p<0.05$), respectively. Changes in LF power at pre-load resting were positively correlated with changes in LYP from before to after training ($p<0.05$). Changes in HF power at pre-load resting were negatively correlated with changes in LYP from before to after training ($p<0.05$). In conclusion, eight weeks of endurance training caused an adaptation in the sympathetic nerve function, but not in the parasympathetic nerve function.**

Key words—physical training, heart rate variability, autonomic nervous activity, spectral analysis, blood cell count.

INTRODUCTION

Physical training is well known to influence heart rate variability and blood constituents. Many studies have examined the effects of endurance training on the cardiovascular function by measuring changes in maximum oxygen consumption ($\dot{V}O_2max$).[1-5] Dixon et al. reported that the resting high frequency vagal component (HF) of heart rate variability was significantly higher in athletes than non-athletic adults, while the low frequency component (LF) was lower in athletes.[6] In contrast, Puig et al. found that both HF and LF power at supine rest were higher in athletes than in control subjects.[7] Therefore, the effect of endurance exercise on the HF and LF components is controversial. Several studies have analyzed blood constituents during training and demonstrated that endurance training increases hemoglobin concentration (HGB)[8] and monocyte count.[9]

None of the published studies that have investigated the effects of training on the spectrum have analyzed these parameters during exercise loading. In addition, no data has yet been published on the changes in autonomic nervous activity from before to after endurance training on the same subjects.

The purpose of the present study was to assess the effects of eight weeks of endurance training on the autonomic nervous system by measuring spectral changes in the heart rate variability and blood cell counts of healthy subjects.

METHODS

Subjects

Twelve healthy subjects (four males and eight

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Table 1. Characteristics of subjects

N	12
Age (years)	37.5±8.8
Height (cm)	159.8±6.6
Weight (kg)	51.4±8.4
BMI (kg/m²)	20.0±2.5

Data express mean±SD.

females) provided written informed consent to participate in endurance exercise training. Characteristics of the subjects are shown in Table 1. There was no significant change in their weight after the training. None of the subjects had performed any exercise training for at least one year.

Exercise protocol

All subjects were instructed to exercise two days per week for eight weeks. Training was conducted on a 140 square meters floor in a gymnasium, and consisted of 16 sessions. Each exercise session lasted from 22 through 34 min and consisted of warming up, walking, running, and cooling down. During the eight weeks, the duration of running in total was increased as adaptation occurred (Fig. 1). On the first day, we instructed the subjects to run in place and count their own heart rates.[3] This day also allowed the subjects to become accustomed to the initial stress of running.

We recorded time spent on running, walking, warming up, and cooling down for each subject. We also recorded their heart rates immediately after each running session. The heart rate and running time were totaled for each subject and then converted into calories (Kcal) of energy expenditure (EE) per session as follows:

$$EE = METS \times W \times T/60,$$
$$METS = \%\dot{V}O_2max/3.5,$$
$$\%\dot{V}O_2max = \dot{V}O_2max \times (1.375 \times \%HRmax - 40.75)/100,$$

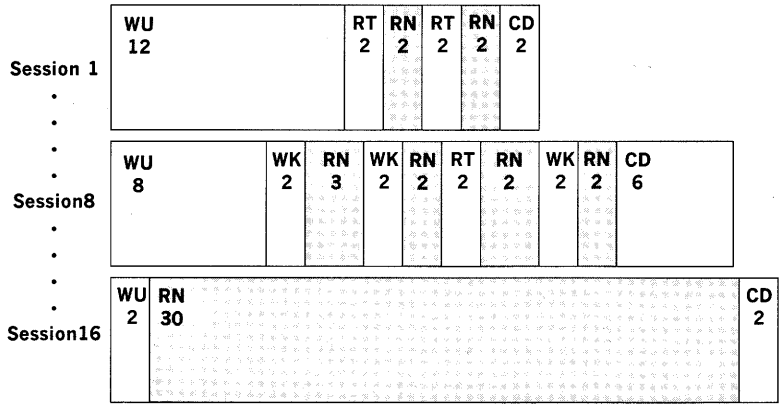

Fig. 1. Training protocol. WU, WK, RN, RT, CD indicates warming up, walking, running, resting and cooling down, respectively. Units are minutes.

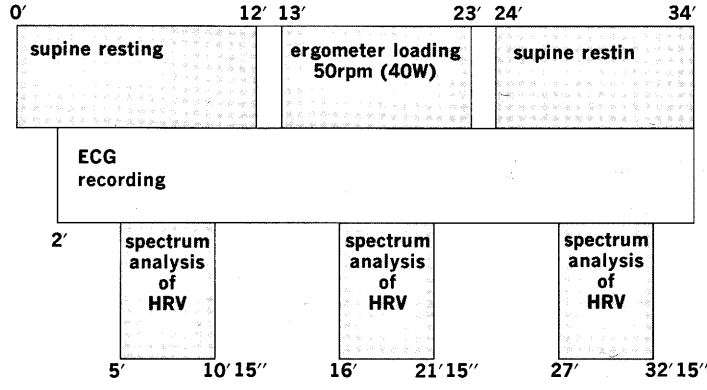

Fig. 2. Recording protocol. (′: min, ″: sec)

$\dot{V}O_2max = 49.93 - 0.278 \times A$,
$\%HRmax = HR/HRmax \times 100$,
$HRmax = 220 - A$,

where METS is the metabolic equivalents, A is age (years) of subject, HR is actual heart rate (beats/min) after running, W is body weight (kg), and T is total running time (minutes) per session.[10,11]

Room temperature before and after training was training was 26.4±2.4℃ and 22.4±1.8℃, respectively, and humidity was 50.4±10.3% and 53.8±4.0%, respectively.

Heart rate variability

We used a bicycle equipped with a mechanically braked ergometer (TUNTURI W1, Canon, Tokyo) for exercise loading. Heart rate was recorded using a heart-rate monitoring system (VANTAGE XL, Canon).

Fig. 2 shows the protocol for exercise and electrocardiogram (ECG) recording.[12] The total time for executing the protocol was 34 min. After 12 min of supine resting, all subjects were instructed to exercise on the bicycle for 10 min. Steady state exercise was to continue during the exercise at 50 rpm (40W) loading.

Such steady state exercise is essential because the heart rate series must be stable in order to obtain its power spectrum. The mean, standard deviation, and coefficient of variation were obtained from the data, and the regression coefficient (RC) of the 10 min recorded was calculated for each subject (Fig. 3). The

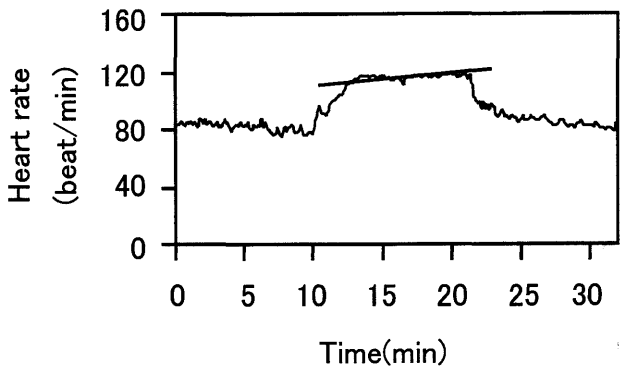

Fig. 3. A heart rate graph obtained from a healthy female aged 43 years before training. The regression line during loading is $y = 0.1x + 113.1$.

power spectrum of heart rate variability was computed using the fast Fourier transform (FFT). We defined the low frequency (LF) band as 0.06 to 0.13 Hz, containing both sympathetic and parasympathetic nervous system components; the high frequency one (HF) was 0.16 to 0.50 Hz, containing mostly parasympathetic nervous system components.[13-18] LF/HF, which is an index of predominance of sympathetic nerve activity, was also calculated. All data were recorded before and after the eight weeks of training.

Blood analyses

Blood samples were obtained from eight subjects (two males and six females) before breakfast immedi-

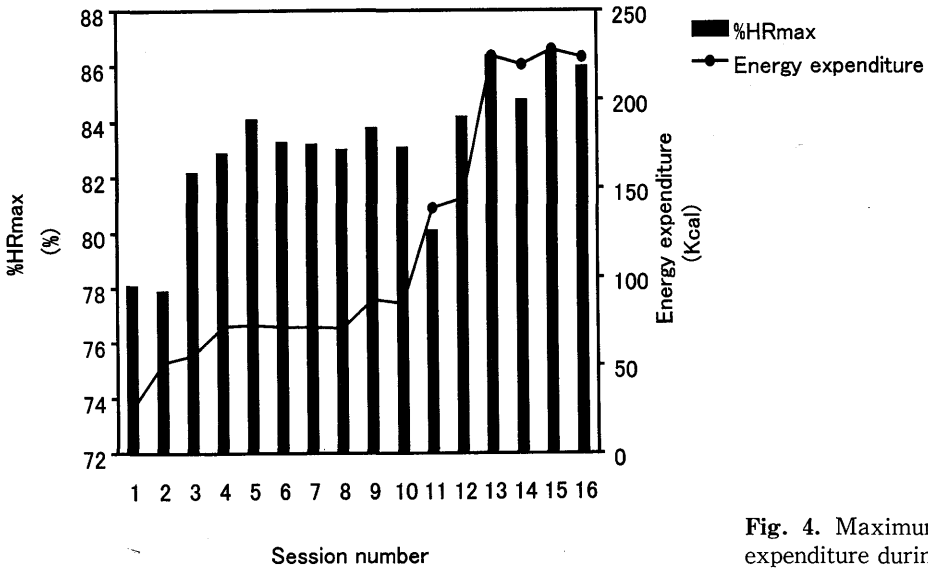

Fig. 4. Maximum heart rate (%) and energy expenditure during the endurance training.

Table 2. Heart rate variability data

Parameter	Before training*[1]	After training*[2]
Heart rate (beat/min)		
Pre-load resting	69.9±10.1	62.5±10.5*
Loading	112.7±13.1	102.9±14.0*
Post-load resting	73.9±11.3	65.4±11.7*
CV		
Pre-load resting	2.7±0.8	3.1±0.9
Loading	2.1±0.8	1.8±0.6
Post-load resting	3.3±1.4	3.3±1.2
RC at loading	0.1±0.0	0.1±0.0
LF power		
Pre-load resting	0.5±0.2	0.6±0.2
Loading	0.6±0.2	0.5±0.2
Post-load resting	0.6±0.2	0.6±0.2
HF power		
Pre-load resting	0.4±0.2	0.3±0.2
Loading	0.4±0.1	0.4±0.1
Post-load resting	0.3±0.1	0.4±0.2
LF/HF		
Pre-load resting	1.5±1.1	2.3±1.7
Loading	2.2±2.1	1.5±1.1
Post-load resting	2.2±1.6	2.4±2.4
Change in LF power		
(LF power during loading)-(LF power at pre-load resting)	0.1±0.2	-0.1±0.2*
(LF power at post-load resting)-(LF power during loading)	0.0±0.2	0.1±0.2
(LF power at post-load resting)-(LF power at pre-load resting)	0.1±0.2	0.0±0.2
Change in HF power		
(HF power during loading)-(HF power at pre-load resting)	-0.1±0.2	0.1±0.2
(HF power at post-load resting)-(HF power during loading)	0.0±0.2	0.0±0.2
(HF power at post-load resting)-(HF power at pre-load resting)	-0.1±0.2	0.0±0.2
Change in LF/HF		
(LF/HF during loading)-(LF/HF at pre-load resting)	0.7±2.3	-0.8±2.0
(LF/HF at post-load resting)-(LF/HF during loading)	0.0±2.5	0.9±1.9
(LF/HF at post-load resting)-(LF/HF at pre-load resting)	0.7±1.9	0.1±2.7
Systolic blood pressure (mmHg)	122.5±18.7	119.8±11.4
Diastolic blood pressure (mmHg)	76.5±11.2	77.3±8.3

Data express mean±SD.
*[1]before the 8 week endurance training'; *[2]after the 8 week endurance training; *statistically significant ($p<0.05$).

ately before and after the training. Four subjects were excluded at the time of the blood examination. Blood cell counts were obtained as white blood cell count (WBC), red blood cell count (RBC), hemoglobin concentration (HGB), hematocrit concentration (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), platelet counts (PLT) and lymphocyte (LYP). All analyses were completed within 6 hours after blood taking.

Statistical analysis

The data were analyzed using a paired Student's *t*-test. Results are expressed as mean±SD. Pearson's correlation coefficients were computed between

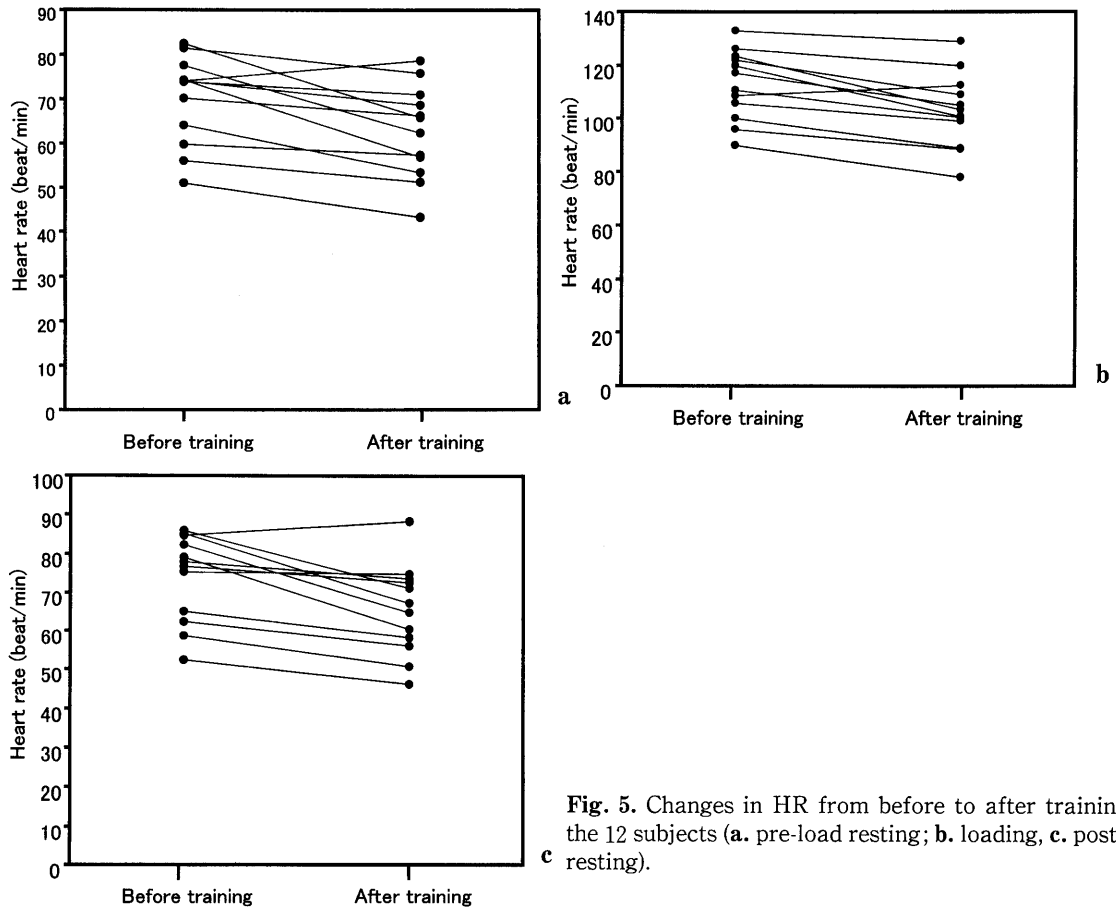

Fig. 5. Changes in HR from before to after training for the 12 subjects (**a.** pre-load resting; **b.** loading, **c.** post-load resting).

changes in power spectra and blood cell counts. Statistical significance was established at the $p<0.05$ level.

RESULTS

Running in endurance training

Fig 4 shows the mean of the intensity of running (% HRmax) and energy expenditure for the 12 subjects for each session. The total running time was 250 min for every subject, and the average energy expenditure for each subject for the eight weeks was 1839.6 Kcal.

Heart rate variability

After the training, we found the following significant changes: Heart rates significantly decreased after training at pre-load resting, during loading, and post-load resting (Table 2 and Fig. 5). LF power slightly

Table 3. Results of blood analyses

Parameter	Before training*1	After training*2
N*3	8	8
WBC ($\times 10^2/\mu L$)	48.5±4.4	49.3±4.4
RBC ($\times 10^2/\mu L$)	430.9±35.9	421.4±35.6
HGB (g/dL)	12.8±0.9	12.8±1.0
HCT (%)	38.6±2.3	38.3±2.8
MCV (fL)	89.7±4.9	91.2±4.2*
MCH (pg)	29.8±1.9	30.4±1.4
MCHC (g/dL)	33.2±0.8	33.4±0.5
PLT ($\times 10^4/\mu L$)	20.3±2.9	20.4±3.4
LYP($\times 10^2/\mu L$)	16.9±1.7	15.4±1.7*

Data express mean±SD.
*1before the 8 week endurance training; *2after the 8 week endurance training; *3Four of 12 subjects were excluded at the time of the blood examination; *statistically significant ($p<0.05$).

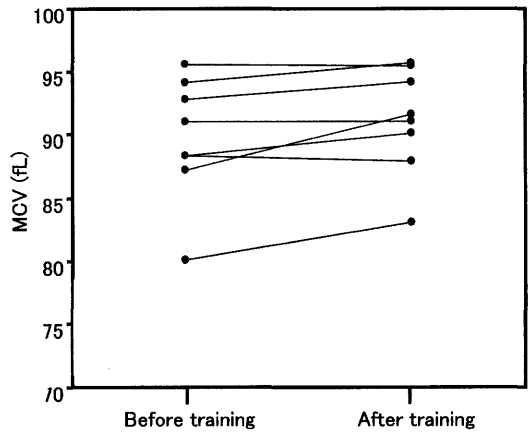

Fig. 6. Changes in MCV from before to after training for eight subjects.

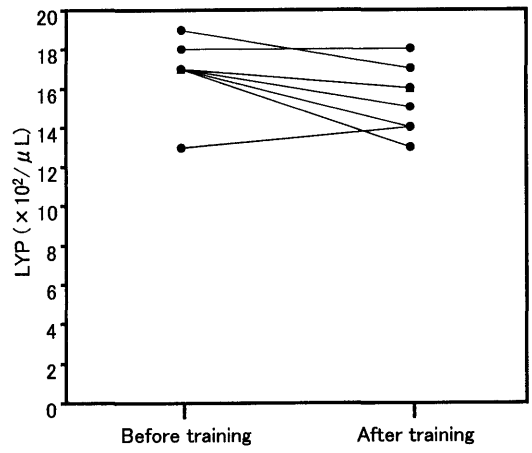

Fig. 7. Changes in LYP from before to after training for eight subjects.

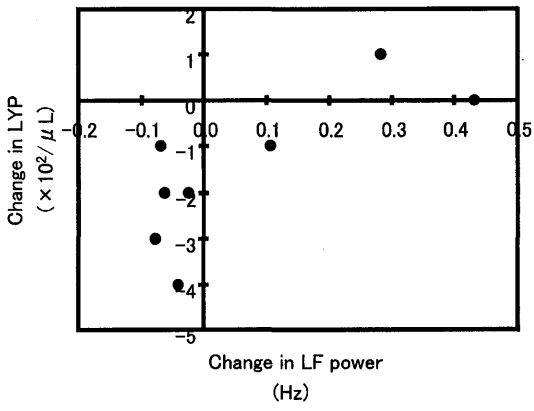

Fig. 8. Correlation between changes in LF power and in LYP after training for eight subjects. Correlation coefficient is 0.76 ($p<0.05$).

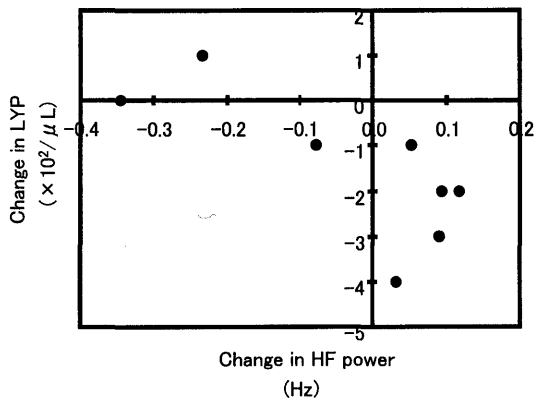

Fig. 9. Correlation between changes in HF power and in LYP after training for eight subjects. Correlation coefficient is -0.75 ($p<0.05$).

increased from the pre-load resting to the loading phase before the training, but slightly decreased from the pre-load resting to the loading phase after the training. These were not significant, but the difference between the slight increase and the slight decrease was significant. The other parameters including HF power and LF/HF were not significantly changed from the pre-load resting to loading phase both before and after the training.

Blood analyses

Table 3 shows the results of blood analysis. After the training, MCV increased significantly, and LYP decreased significantly (Table 3, Figs. 6 and 7).

Correlation between changes in power spectrum and blood analyses

We analyzed the correlation between changes in power spectrum and changes in LYP from before to after training. Changes in LF power at pre-load resting were positively correlated with changes in LYP from before to after training ($p<0.05$) (Fig. 8). Changes in HF power at pre-load resting were negatively correlated with changes in LYP from before to after training ($p<0.05$) (Fig. 9).

DISCUSSION

Autonomic nerve activity contributes to the incidence of various kinds of diseases such as coronary heart disease.[19-21] Computation of the power spec-

trum from heart rate variability is a simple noninvasive method to assess the cardiac neuroregulatory response and disorders[13-17], and the HF and LF bands have been shown to reflect parasympathetic and a mix of sympathetic and parasympathetic nerve activity, respectively. LF/HF is also an index of predominance in sympathetic nerve activity.

An important prerequisite for obtaining the power spectrum is that the heart rate should not change drastically during recording. In the present study, both before and after the training, the regression coefficient of the regression line at loading was nearly zero (Fig. 3); thus, the experimental protocol in this study is applicable to FFT.

In our study, LF power slightly increased from the pre-load resting to the loading phase before the training, but slightly decreased from the pre-load resting to the loading phase after the training. These were not significant, but the difference between the slight increase and the slight decrease was significant. In contrast, the other parameter of HF power was not significantly changed from the pre-load resting to the loading phase either before or after the training. These results show that sympathetic nerve activity from pre-load resting to loading decreased after training, while parasymathetic nerve activity was not changed. Therefore, it is suggested that endurance training causes an adaptation of the autonomic nerve system to exercising.

The cardiovascular centers in the brain alter the intrinsic discharge rate of the sinus node not only via sympathetic and parasympathetic fibres but also hormones.[22] Dixon et al. found that the HF power at pre-load resting is signifcantly higher in athletes compared with controls, and that the LF power is lower.[6] We have already reported that HF power is significantly higher even during loading in athletes compared with controls, and that LF power is lower.[12] In the present study, HR at pre-load resting, loading, and post-load resting significantly decreased after traning, but neither an increase in HF power nor a decrease in LF/HF power at any phases was observed after training. These results suggest that hormones may be involved in the decrement of HR after training.

Ferretti et al. showed that HGB significantly increased after six weeks of endurance training.[8] In another study, no significant changes in WBC were observed in well-trained swimmers after 16 weeks of training.[23] Mitchell et al. reported that 11 college-aged males performing 30 min of cycling for 12 weeks showed no difference in LYP levels between experimental and control groups.[24] In our study, MCV increased significantly after eight weeks of training. This result indicates that exercise may play a role in the regulation of the hematological response to exercise. In addition, we found a significant decrease in LYP after training. This decrease in LYP positively correlated with LF power and negatively correlated with HF power. The relationships between the autonomic nerve function and LYP must be clarified in the future.

In conclusion, eight weeks of endurance training caused an adaptation in the sympathetic nerve function, but not in the parasympathetic nerve function.

Acknowledgments. This work was supported by a Grant-in-Aid for Science Research from the Ministry of Education, Science and Culture of Japan (No. 08922045; 1996).

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