

Cardiovagal Response to Acute Mild Exercise in Young Healthy Subjects

Grzegorz Raczak, PhD, MD; Gian Domenico Pinna, MS*; Maria Teresa La Rovere, MD, FESC*; Roberto Maestri, MS*; Ludmiła Daniłowicz-Szymanowicz, MD; Wojciech Ratkowski, MD**; Monika Figura-Chmielewska, MD; Małgorzata Szwoch, MD; Karolina Ambroch-Dorniak, MD

Background The aim of the present study was to investigate the effect of a single bout of mild exercise on autonomic nervous system activity in healthy subjects.

Methods and Results The study group comprised 18 healthy males, aged between 20 and 24 years, who had not been training regularly for the last 3 months. A supine recording of systolic arterial pressure (SAP) and RR interval and the administration of the phenylephrine test were performed at baseline and repeated after a 60-min recovery period following treadmill exercise training for 30 min at 65% of maximal heart rate. Mean SAP and RR interval, heart rate variability (HRV) indices (the standard deviation of normal-to-normal RR intervals (SDNN), the square root of the mean of squared differences between successive intervals and the percentage of adjacent RR intervals differing more than 50 ms), noninvasive spectral baroreflex sensitivity (Spe-BRS) and phenylephrine baroreflex sensitivity (Phe-BRS) were assessed before and after training. Mean SAP measured after exercise was lower than baseline (120 ± 12 mmHg vs 128 ± 12 mmHg, $p=0.05$). Spe-BRS and Phe-BRS increased significantly after exercise, from 11.8 ± 6.1 ms/mmHg to 16.0 ± 7.8 ms/mmHg ($p=0.034$), and from 16.0 ± 8.8 ms/mmHg to 21.9 ± 9.3 ms/mmHg ($p=0.022$), respectively. A parallel increase was also observed in SDNN (from 81 ± 44 ms to 96 ± 53 ms, $p=0.02$), but the other HRV indices showed no significant differences between pre- and post-exercise.

Conclusions A single session of mild exercise performed by sedentary young men leads to significant autonomic nervous system improvement, which suggests that even mild physical activity is beneficial for neural cardiac regulation and should be recommended to sedentary healthy subjects. (Circ J 2005; 69: 976–980)

Key Words: Baroreflex sensitivity; Heart rate variability; Mild physical exercise

The activity of the human autonomic nervous system plays a substantial role in the physiological adaptation of circulation to changes in activity. In healthy subjects at rest, parasympathetic tone predominates, resulting in relative blood pressure reduction and bradycardia, whereas during physical exercise, there is decreased parasympathetic activity and an accompanying increase in sympathetic activity^{1,2}. Cessation of the effort shifts the balance toward parasympathetic predominance, eventually restoring blood pressure to the values recorded at rest.

Exercise training has been shown to improve vagal control of the heart in healthy subjects³ as well as in patients suffering from both myocardial infarction^{4–6} and different stages of heart failure^{7,8}. The essential role of exercise training in not only improving the autonomic balance but also cardiac output during exercise⁹ as well as in reducing cardiac mortality among post-infarction patients, has been reported recently⁵.

It has been hypothesized that an increase in parasympathetic activity is beneficial to cardiovascular function

because it makes cardiac work more economical by reducing resting heart rate and contractility, leading to a decrease in myocardial oxygen demand. The beneficial influence of vagal overactivity on the electrical stability of myocardium, which prevents malignant ventricular arrhythmias in post-infarction patients, is also widely recognized^{1,10,11}.

Although the data on the effects of physical training on autonomic control in healthy subjects remain controversial, the mortality reduction observed in physically active subjects compared with sedentary persons^{11–13} strongly suggests that exercise is beneficial.

For all these reasons, health policy makers in industrialized countries are emphasizing physical activity among healthy subjects, as well as in patients with different degrees of heart dysfunction. However, the implementation of this healthy behavior is still far from being sufficient. According to a recent epidemiological study performed in Finland, Spain, Germany, Russia, Hungary and Poland, adequate physical activity consistent with European and American cardiological societies' recommendations is carried out by 30.2% of the Finnish general population, with progressively lower proportions in the other countries down to 6.4% in Poland⁴.

Hence, there is still a need to demonstrate to the community and physicians the numerous benefits of regular physical training. Recent studies showed that even a single bout of maximal exercise is able to positively affect the autonomic balance of normal subjects for up to 24 h^{3,15}. Accordingly, the aim of the present study was to assess whether a single bout of mild exercise is capable of inducing a posi-

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Second Cardiological Department, Medical University of Gdańsk, Gdańsk, Poland, *Divisione di Cardiologia e Bioingegneria, Fondazione "Salvatore Maugeri", IRCCS, Istituto Scientifico di Montescano, Montescano (Pavia), Italy and **Academy of Physical Education and Sport in Gdańsk, Gdańsk, Poland

Mailing address: Grzegorz Raczak, PhD, MD, II Department of Cardiology Medical University of Gdansk, Dębinki 7 Str, 80-952 Gdańsk, Poland. E-mail: gracz@amg.gda.pl

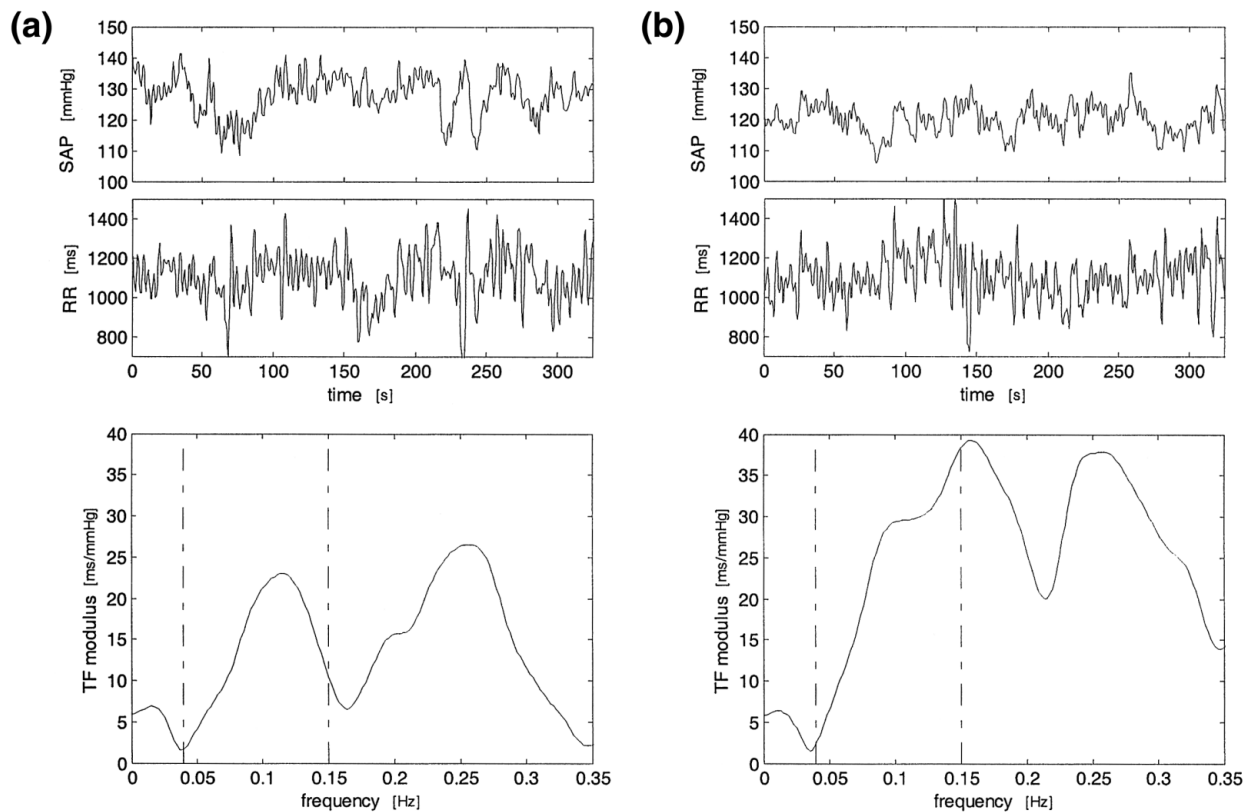


Fig 1. Transfer function based measurements of baroreflex sensitivity before (a) and after (b) exercise. In both conditions, the 2 top panels show the systolic arterial pressure (SAP) and RR time series and the bottom panel shows the transfer function modulus plotted as a function of frequency: its mean value in the 0.04–0.15 Hz frequency band (evidenced by dash-dotted lines) is the estimate of baroreflex gain (Spe-BRS). In this example, Spe-BRS increases from 14.3 ms/mmHg to 23.0 ms/mmHg after exercise.

tive change in the activity of the autonomic nervous system, which would represent a novel and valuable argument in this context.

Methods

Study Subjects

We studied 18 healthy males (mean age, height, weight, body mass index \pm SD: 20 ± 2 years, 182 ± 5 cm, 79 ± 12 kg, 23 ± 3 , respectively) who were students of the Academy of Physical Education and Sport in Gdańsk and did not have a history of smoking. Systolic blood pressure, diastolic blood pressure and R-R interval were respectively: 122 ± 13 mmHg, 79 ± 8 mmHg, 917 ± 146 ms. All subjects were normotensive and had no history of cardiopulmonary disease that could influence the autonomic nervous system. None of them was taking medications nor had performed regular long-term physical training during the 3 months preceding the study.

Subjects were asked to refrain from drinking beverages containing alcohol or caffeine for 12 h before the recording sessions. On the day of the study, normal arterial blood pressure, heart rate and sinus rhythm on electrocardiogram (ECG) were assessed in every subject. Approval was obtained from the Ethical Committee of Medical University of Gdańsk.

Study Protocol

Autonomic evaluation was based on heart rate variability

(HRV) and baroreflex sensitivity (BRS) assessments. The latter was performed noninvasively by the transfer function method and by the phenylephrine test. Subjects were studied in the morning in a fasting state. The experimental protocol comprised 4 consecutive sessions: (1) baseline autonomic evaluation, (2) treadmill exercise, (3) 60 min recovery and (4) post-exercise autonomic evaluation. The baseline session was preceded by 15 min signal stabilization.

Autonomic Evaluation

ECG (Mingograf 720C) and beat-to-beat noninvasive arterial blood pressure (Finapres 2300, Ohmeda) were recorded continuously during a 10-min supine rest. Signals were acquired in a PC workstation and processed through dedicated software.¹⁶ The RR interval (resolution 1 ms) and systolic arterial pressure (SAP) time series were automatically obtained from the raw signals. From the RR data, the following HRV parameters were computed: the standard deviation of normal-to-normal RR intervals (SDNN), the square root of the mean of squared differences between successive intervals (RMSSD), and the percentage of adjacent RR intervals differing more than 50 ms (pNN50). BRS was assessed noninvasively by the transfer function method.¹⁷ RR and SAP time series were resampled at 2 Hz by cubic spline interpolation and visually inspected to select the widest sub-record free from large transients, artefacts or marked changes in the fluctuation pattern of the signals. After linear detrending, bivariate spectral analysis was

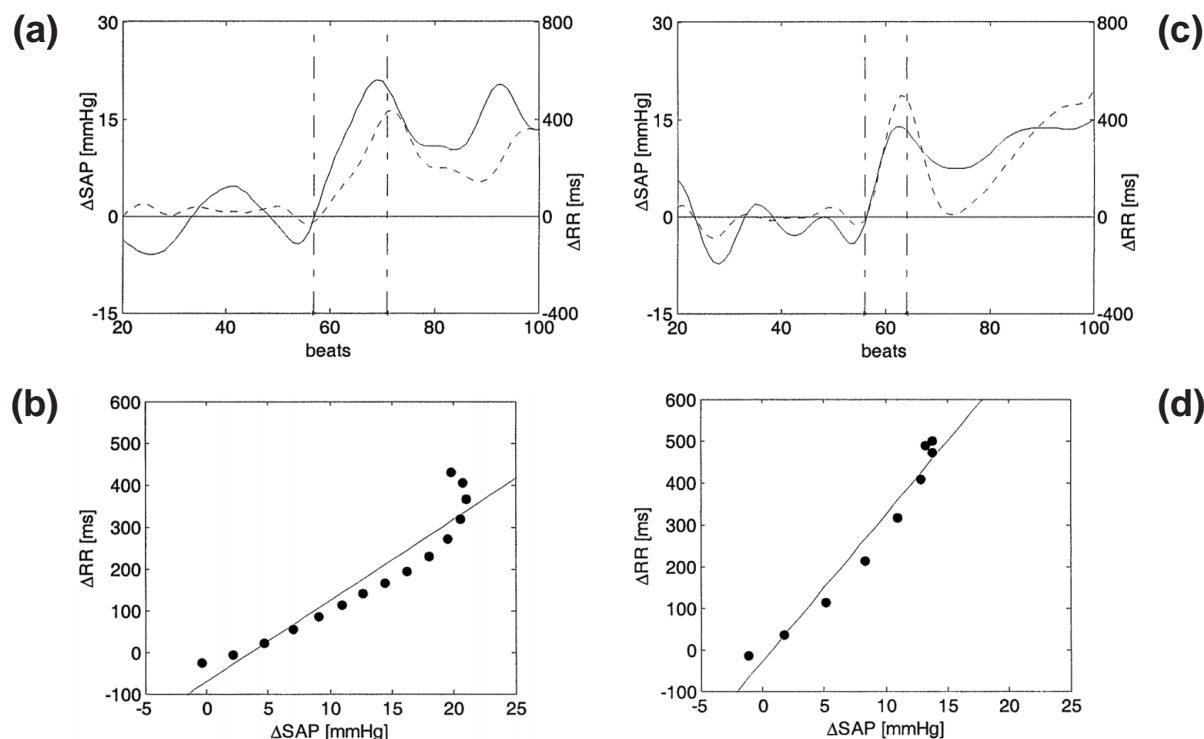


Fig 2. Measurement of baroreflex sensitivity according to the phenylephrine test before (a, b) and after (c, d) exercise. (Top panel) Beat-to-beat changes in systolic blood pressure (solid line) and in RR intervals (dotted line) compared with baseline. Analysis is limited to the points included between vertical dash-dotted lines in panels a and c, corresponding to the pressure increase. These points are used (panels b and d) for calculation of the regression line. In this case, the slope increases from 19.1 ms/mmHg to 30.3 ms/mmHg.

performed using the classical weighted covariance method (also known as Blackman-Tukey spectral estimator) with a 0.03 Hz bandwidth Parzen window. Spectral BRS (Spe-BRS) was obtained by averaging the transfer function modulus over the entire low frequency band (LF, 0.04–0.15 Hz). The reliability of Spe-BRS has been assessed in a previous study from our group¹⁸

This recording session was followed by the phenylephrine test performed according to the well-established method of Smyth et al!⁹ Briefly, phenylephrine was given as an intravenous 30 s bolus of 2 µg/kg to raise the SAP by 15–40 mmHg. If needed, the phenylephrine dose was increased by 50 µg in subsequent injections to reach the target blood pressure increase or to obtain an obvious increase in RR interval when the pressure rise was below this threshold. The test was repeated at 10 min intervals at least twice. In order to assess the BRS, the RR intervals collected during the phenylephrine test were plotted against the preceding SAP value and the slope of the regression line relating RR changes to SAP changes was automatically computed. Only regression lines with a statistically significant slope ($p < 0.05$) were accepted for analysis. BRS (Phe-BRS), expressed as ms/mmHg, was computed as average of test results (typically 3).

Treadmill Exercise

Treadmill exercise was performed starting with 3 min of warm-up followed by incremental 3 min stages, beginning at the speed of 5 km/h (at 120 W) and increasing the speed by 1 km/h (30 W) until 65% of maximal heart rate (220 beats/min – age) was reached. Treadmill speed was then adjusted to maintain the subject's heart rate at the

target level. Exercise at this level was carried out for 30 min.

Statistical Analysis

Measurements were compared by the Wilcoxon matched pairs test. All data are presented as mean ± standard deviation. A p value < 0.05 was considered statistically significant.

Results

Target heart rate increase (65% of maximal frequency) was obtained and maintained for 30 min by all subjects. Mean SAP value, estimated in the whole group at 1 h after exercise cessation appeared to be lower than the initial value with borderline significance (120 ± 12 mmHg vs 128 ± 12 mmHg, $p = 0.05$).

Two patients had to be discarded from analysis because of the presence of a large number of ectopic beats and artefacts in either the recording performed before or after training. The median duration of analyzed recordings was 290 s (range: 180–490 s). The mean values of arterial BRS measured according to the phenylephrine test increased significantly after exercise (16.0 ± 8.8 vs 21.9 ± 9.3 ms/mmHg, $p = 0.022$). A significant increase was also observed in Spe-BRS (11.8 ± 6.1 vs 16.0 ± 7.8 ms/mmHg, $p = 0.034$). Representative examples of spectral and phenylephrine BRS assessment, before and after exercise, are shown in Figs 1 and 2, respectively.

The mean SDNN value was significantly higher in the post-exercise recording compared with baseline evaluation (96 ± 53 ms and 81 ± 44 ms respectively, $p = 0.020$). The other

HRV indices did not show significant differences. All results are summarized in Table 1.

Discussion

Our results from a population of young healthy untrained male subjects indicate that even a single session of mild exercise brings about a change in the autonomic balance towards an increase in parasympathetic activity. Major changes were obtained in baroreceptor sensitivity.

At present it is well established that exercise improves the autonomic nervous system function in different populations.²⁻⁵ Most published studies have focused on the influence of long-term training cycles, usually lasting several weeks^{4,5,20} whereas the effect of a single training session has scarcely been investigated. Somers et al, in a study of hypertensive subjects performing a single training session, found that 10 min after exercise cessation BRS was decreased, the initial value was restored 20 min after exercise, and BRS increased above baseline after 40–60 min.¹⁵ Halliwill et al obtained similar results in a group of healthy sedentary subjects.²¹ Convertino et al demonstrated that the increase of BRS after acute exercise lasted for at least 24 h.³

It is important to note that in all but one of these studies (Halliwill et al²¹) the exercise was carried out at high intensity, resulting in a heart rate increase to at least 79% of its maximal value. Our study not only confirms the beneficial influence of a single training session on the autonomic nervous system activity, but also indicates that more intensive effort is not necessary to exert favorable changes on the autonomic balance, and that even a mild exercise strain, namely at 65% of maximal heart rate, can be sufficient. This observation may be of practical value because it could encourage sedentary subjects to undertake activity of rather low intensity.

An important finding of the present investigation is the significant increase in both the invasive and noninvasive measurement of BRS. Because these 2 techniques explore different physiological conditions, assume a different model of short-term pressure regulation and may be corrupted by different noise sources,²² we interpret their substantial concordance as evidence of the robustness of our findings of an acute increase in sensitivity of the baroreflex after acute dynamic exercise. The mechanisms linking acute exercise to changes in cardiac BRS resulting in increased parasympathetic activity have not been fully elucidated. Plasma catecholamines do not seem to be involved in this process, as norepinephrine concentrations were found to remain above pre-exercise levels at 60 min after moderate exercise in the Halliwill study.²¹ A direct involvement of the central nervous system in the acute changes in baroreceptor discharge can not be excluded.²³

Despite the lack of any change in mean RR interval, all HRV measurements relating to parasympathetic activity, such as SDNN, pNN50 and RMSSD, increased on average, but only SDNN reached statistical significance. This finding may be related to the fact that HRV increases with vagal tone only within a given range. It has been demonstrated that beyond a certain level, increasing parasympathetic activity is not associated with a rise in HRV, but rather leads to the opposite effect.²⁴ This is likely to be the case in our population of young students who exhibited values in HRV greater than usually observed even before exercise, and might be even more likely for pNN50 and RMSSD, which are related to short-term variation.

Table 1 Comparison of Autonomic Nervous System Function Indices in the Study Group Before and After Mild Physical Exercise

n=16	Before exercise	After exercise	p-value
Average SAP (mmHg)	128±12	120±12	0.05
Average RR (ms)	974±157	981±139	0.93
SDNN (ms)	81±44	96±53	0.020
RMSSD (ms)	89±66	109±90	0.16
pNN50 (%)	43±27	48±26	0.47
Spe-BRS (ms/mmHg)	11.8±6.1	16.0±7.8	0.034
Phe-BRS (ms/mmHg)	16.0±8.8	21.9±9.3	0.022

SAP, systolic arterial pressure; SDNN, standard deviation of normal- to-normal RR intervals; RMSSD, square root of the mean of squared differences between adjacent RR intervals; pNN50, percentage of adjacent RR intervals differing more than 50 ms; Spe-BRS, baroreflex sensitivity computed by the spectral method; Phe-BRS, baroreflex sensitivity obtained by the phenylephrine method.

It has been shown that physical training decreases blood pressure, although the magnitude of this change varies among different groups of subjects.²⁵⁻²⁷ The mechanisms responsible for such phenomenon are not clear. Despite showing in the present study that post-exercise blood pressure reduction was accompanied by an increase in BRS, a causal relationship between these changes can not be demonstrated. Moreover, Legramante et al suggest that a decrease in total peripheral resistance related to mechanisms other than the baroreceptor reflex can play an important role.²⁶

Conclusions

A single session of mild exercise performed by young people without previous regular training leads to significant autonomic nervous system improvement, which suggests that even mild physical activity can be beneficial for neural cardiac regulation and should be recommended to sedentary healthy subjects.

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