THE EFFECT OF ANAEROBIC AND AEROBIC TESTS ON AUTONOMIC NERVOUS SYSTEM ACTIVITY IN HEALTHY YOUNG ATHLETES

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ABSTRACT: In the evaluation of physical efficiency in professional athletes two tests are used: Wingate test (WT) and incremental test for maximal oxygen uptake (IT). In the former anaerobic power is evaluated and in the latter aerobic power. The influence of these tests on autonomic nervous system (ANS) activity is not fully examined. The aim of the study was to assess the influence of anaerobic and aerobic tests performed on the consecutive days, on the ANS activity in young healthy athletes. Ten athletes aged 17±1 were included in the study. The ANS parameters (baroreflex sensitivity – BRS_WBA, heart rate variability–HRV) were analysed on the basis of 10-minute systolic arterial pressure and heart period (HP) records during controlled breathing (0.23 Hz). BRS_WBA, HRV indices and mean HP were analysed before (examination 1) and 1 hour after WT (examination 2), 1 hour after IT (examination 3), and on the day after the tests (examination 4). The borderline statistically significant decrease in BRS_WBA in examination 2 in comparison to 1 was found (16.4 ± 10.5 vs 9.4 ± 3.9 ms/mmHg, p=0.059). In examination 3 in comparison to 1 the significant decrease in BRS_WBA was found (8.8 ± 6.2 ms/mmHg, p<0.05). SDNN, PNN50, RMSSD and HF were significantly lower in examination 2 comparing to 1 (p<0.05); the changes of HFnu were borderline statistically significant (p=0.059). These lower values were also noticed after examination 3 and returned to the initial values in examination 4. The mean HP showed similar changes. LF/HF increased significantly in examination 2 in comparison to 1 (p<0.05). The changes in LFnu were borderline statistically significant. Anaerobic and aerobic exercise tests lead to the decrease in ANS parasympathetic activity and to the increase in sympathetic one in young healthy athletes. These changes persist for at least one hour after exertion. The return to the initial values is observed the following day after the tests.

KEY WORDS: autonomic nervous system, physical exertion

INTRODUCTION

Wingate test and incremental test for maximal oxygen uptake are used to evaluate the level of athletes' preparation for competition. Anaerobic power is evaluated in the former and aerobic power in the latter. The influence of this complex exertion on autonomic nervous system (ANS) activity is not fully examined. However, investigating this issue seems to be important from the practical point of view.

The influence of exertion on cardiovascular system depends on its intensity, type of exercise and its duration. On the one hand, moderate single exertion in sedentary people during recreation activity may lead to increased parasympathetic activity of ANS [11]. Physical activity lasting several months in this group of examinees, as well as long-lasting intensive training in group of athletes preparing for competitions lead to beneficial changes in sympathetic-parasympathetic balance [5,12].

On the other hand, extreme exertion leads to adverse permanent shift of ANS activity from parasympathetic domination to sympathetic one. Iellamo et al. demonstrated this in examination of Italian rowing champions [7]. Persistent sympathetic activation resulting from short-term exertion such as marathon race or strength-testing competition was also described [2,3,4].

There is not enough data in the literature concerning the influence of combination of Wingate test and incremental test for maximal oxygen uptake on ANS activity. Due to the differentiated effect of physical exercise on ANS, it is impossible to predict the sympathetic-parasympathetic balance changes as a result of these two tests. As the exertion in the tests is very intensive, the impact on ANS function may be important.

It should be noted that ANS activity is influenced by spontaneous breathing in an examinee. For example, breathing at the rate of 15/min. is equal to 0.25 Hz. However, reduction of breath rate to 6/min. (0.1 Hz) may influence ANS indices in low frequency band (0.04-0.15 Hz). In a group of professional athletes it is particularly important, because they breathe at a lower rate than sedentary people.

The aim of the study was to evaluate the influence of Wingate test and incremental test for maximal oxygen uptake on the ANS function in professional athletes.

MATERIALS AND METHODS

Ten young healthy athletes (5 men and 5 female) aged 17 ± 1 (16-19 year). The subjects undergoing the tests had been training medium- and long-distance running professionally for three years. The tests were performed during the period of preparation for competition (trainings for 10 to 13 hours per week). Criteria:

1. absence of any disease, particularly cardiovascular diseases
2. no drugs and alcohol intake, no cigarette smoking
3. sinus rhythm in ECG
4. consent to participate in the study

Each person was examined in the morning, four times, according to the study protocol: 1) before Wingate test, 2) one hour after Wingate test, 3) on the second day, one hour after the incremental test for maximal oxygen uptake and 4) on the day after the tests. Examinees did not eat for at least four hours and did not smoke cigarettes or drink coffee for twelve hours before the tests.

A ten-minute recording of systolic arterial pressure (SAP) and heart period (HP) were performed in every examinees. Tests were carried out in compliance with detailed protocol, in a quiet laboratory room, in supine position, with head lifted by 30°, while athletes were relaxed. The stabilisation of SAP and HP took place within the first 15 minutes of the tests. Then the SAP and HP records were performed during paced breathing (RC) at a rate of 0.23 Hz.

On the basis of obtained SAP and HP records, baroreflex sensitivity (BRS), heart rate variability (HRV) and mean heart period (mean HP) were analysed.

Tests of physical efficiency. Tests of physical efficiency were performed in the laboratory of Academy of Physical Education and Sport in Gdańsk. The athletes' anaerobic efficiency was assessed in 30-second version of Wingate test. A 5-minute warm-up was carried out using the cycloergometer. The maximum intensity of exertion was defined by heart rate of 140-150/min. After a 5-minute rest the athletes aimed at achieving maximum rate of pedalling in the shortest possible time and maintaining this rate as long as they could. In this study cycloergometer 'Monark' 824-E was used with mechanically adjusted resistance of the flywheel. The parameters assessing the anaerobic efficiency (the maximum power, time needed for achieving and maintaining it and the amount of work done) were calculated using MCE V2.0 computer software.

The incremental test for maximum oxygen uptake, using the cycloergometer, was performed to assess the aerobic efficiency in the athletes. The examinees performed the test with gradually increased load, until the maximum oxygen uptake was obtained. After a 2-minute rest, the athletes were pedalling without the load for 3 minutes, maintaining the pedalling rate of 50/min. For the next 5 minutes, the examinees were pedalling with load of 100 W, maintaining the rate of 50/min. From the 10th minute of the test the load was increased by 25W every minute. The exertion was continued until the test was stopped or when the pedalling rate decreased below 10% of the required value of 50/min.

The telemetric exhaled gases analyser (made by Cosmed) was used to analyse aerobic power indices: VO2 max – maximum oxygen uptake, AT – aerobic-anaerobic threshold. Oxygen uptake (VO2), carbon dioxide exhaling (VCO2) and minute ventilation (VE) were monitored continuously. Heart rate was measured using the Polar sport tester, synchronised with the exhaled gases analyser. The AT was calculated using the indirect method, on the basis of VE analysis (during the rapid occurrence of non-linear VE recording in the test). Respiratory quotient (RQ) was also used to assess AT. AT threshold was achieved when RQ was ≥ 1.

Assessment of ANS activity. Signal of SAP was obtained with non-invasive method (FINAPRES, Ohmeda). HP recording was performed using one- lead ECG (MINGOGRAF 720C). Self-adjustment FINAPRES function was switched off directly before the actual recording and it was switched on again after each recording.

The recorded analog SAP and HP signals were synchronised and processed by analog to digital converter with sampling frequency of 250 Hz and transfered to computer with POLYAN software [8]. Then BRS and HRV indices were calculated. HP signal resolution equal to 1 ms was obtained using linear interpolation algorithm.

Before the assessment of BRS indices, the ectopic beats and trends were removed from the recordings. Next, a fragment of stable SAP and HP recording, not shorter than 240 seconds, was selected for the analysis. BRS was evaluated automatically, which decreased the subjectivity of the analysis. Bivariate spectral analysis between SAP and HP time series was performed using Blackman-Tukey algorithm with a 0.03 Hz bandwidth Parzen window. Value of BRS_WBA was obtained by averaging the estimated gain function

TABLE I. HRV INDICES ± SD AND MEAN HP ± SD BEFORE (1) AND WITHIN 1 HOUR AFTER WINGATE TEST (2), WITHIN 1 HOUR AFTER INCREMENTAL TEST FOR MAXIMAL OXYGEN UPTAKE (3), AND ON THE DAY AFTER THE TESTS (4).

	1	2	3	4
TP ms2	6592± 7003◊	4186± 2875	4709± 6471	6565± 5870
LF ms2	1220± 750	1347± 1169	1095± 1127	1241± 855
LFnu	24± 14	36± 14	34± 14	27± 13
HF ms2	6481± 7369*◊	2248± 1828	3417±5101	4661± 5140
HFnu	76± 14	64± 14	66± 14	73± 13
LF/ HF	0.36± 0.28*	0.62± 0.34	0.58± 0.34	0.41± 0.25
Mean HP msek	964± 104*	873± 78••	911± 103•••	1050± 172

* 1 vs 2 p<0.05; ◊ 1 vs 3 p<0.05; • 1 vs 4 p<0.05; ◊◊ 2 vs 3 p<0.05; •• 2 vs 4 p<0.05; ••• 3 vs 4 p<0.05

in the 0.04-0.15 Hz range, using all points of SAP and HP function regardless of coherence value and variability [9]. Values of BRS_WBA were measured in ms/mmHg.

The following parameters of short-term HRV were used:

SDNN (ms) – standard deviation of RR intervals over the selected time interval

pNN50 (%) – percentage of intervals differing by > 50 ms from the preceding interval

RMSSD (ms) – square root of the mean of sum of the squares of differences between adjacent RR intervals

TP (ms2) – the variance of RR intervals over the selected time interval

LF (ms2) – power of low frequency component (0.04-0.15 Hz)

HP (ms2) – power of high frequency component (0.15-0.4 Hz)

LFnu – LF power in normalised units

HFnu – HF power in normalised units

LF/HF – ratio of LF power to HF power

The tests were integral part of a large program for assessment of physical exercise influence on ANS function. Independent Bioethical Committee for Scientific Research in Medical University of Gdańsk agreed to performed this program (NKEBN/10/2003).

Statistical analysis. Statistica 6.0 computer software was used for statistical analysis. The values of continuous variables were expressed as mean ± standard deviation (SD). The significance of differences between indices in the subsequent recordings with reference to basal values was assessed using the matched-pair Wilcoxon test, as the distribution of variables was not normal. The value of $p \leq 0.05$ was statistically significant.

RESULTS

Maximum oxygen uptake (VO2max) in the examined athletes was equal to 52.3 ± 5.5 ml/kg/min. Values of ANS parameters were diagnostic in all examinees.

BRS_WBA after Wingate test decreased comparing to the initial value: from 16.4 ± 10.5 to 9.4 ± 3.9 ms/mmHg (p= 0.059). After incremental test for maximum oxygen uptake, the value of BRS_WBA also decreased comparing to the first test (8.8 ± 6.2 ms/mmHg, p= 0.028). In the last examination, performed on the following day, the increase of BRS_WBA to 12.5 ± 6.7 ms/mmHg comparing to the former recording was observed, however it was statistically insignificant (p= 0.1). These results are illustrated in Fig. 1.

Table 1 and Figs. 2a and 2b present data concerning HRV parameters and mean HP obtained in the performed tests. It is important to note that all time-domain measures of HRV decreased significantly after Wingate test in comparison to the initial values. The decreased values of SDNN and pNN50 persisted after the incremental test for maximum oxygen uptake, returning to the initial values on the following day. Mean HP had similar changes. However, the increase of RMSSD value just after incremental test for maximum oxygen uptake was observed but it was statistically insignificant comparing to the former recording.

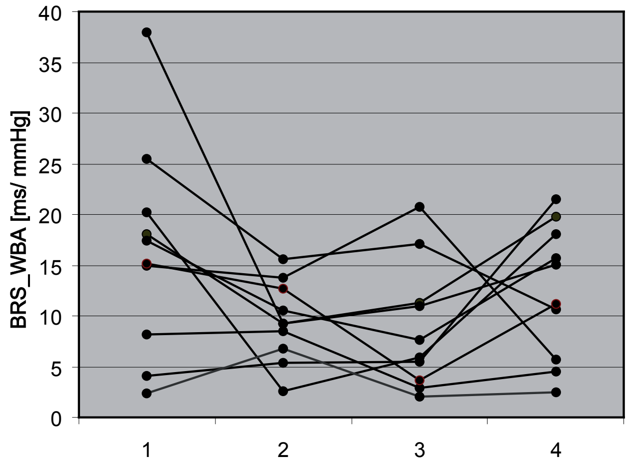

FIG. 1. BRS_WBA BEFORE (1) AND 1 HOUR AFTER WINGATE TEST (2), 1 HOUR AFTER INCREMENTAL TEST FOR MAXIMAL OXYGEN UPTAKE (3), AND ON THE DAY AFTER THE TESTS (4).
BRS_WBA (1) vs BRA_WBA (2)- p=0.059
BRS_WBA (1) vs BRS_WBA (3)- p=0.028

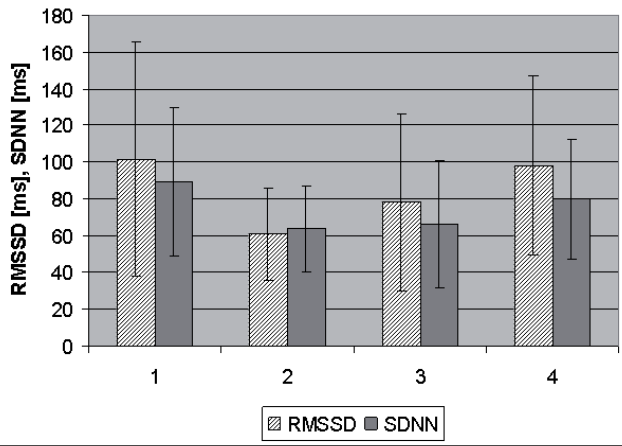

FIG. 2a. RMSSD AND SDNN BEFORE (1) AND 1 HOUR AFTER WINGATE TEST (2), 1 HOUR AFTER INCREMENTAL TEST FOR MAXIMAL OXYGEN UPTAKE (3), AND ON THE DAY AFTER THE TESTS (4).
RMSSD (1) vs RMSSD (2)- p=0.013; SDNN (1) vs SDNN (2)- p=0.022
RMSSD (1) vs RMSSD (3)- p=0.059; SDNN (1) vs SDNN (3)- p=0.017

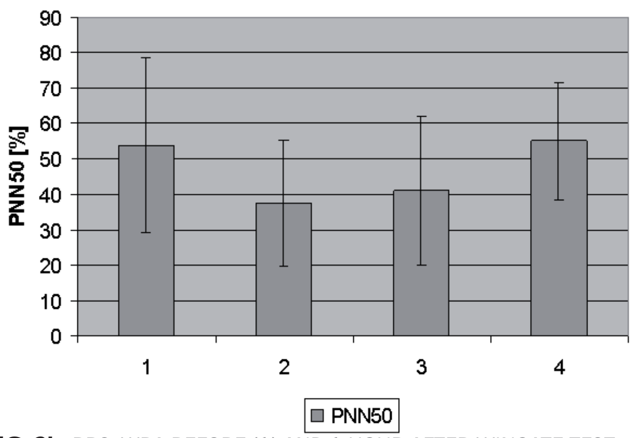

FIG. 2b. BRS_WBA BEFORE (1) AND 1 HOUR AFTER WINGATE TEST (2), 1 HOUR AFTER INCREMENTAL TEST FOR MAXIMAL OXYGEN UPTAKE (3), AND ON THE DAY AFTER THE TESTS (4).
BRS_WBA (1) vs BRA_WBA (2)- p=0.059
BRS_WBA (1) vs BRS_WBA (3)- p=0.028

The changes of TP, HF and HFnu were similar to the changes observed in time-domain HRV parameters: in the second recording these values decreased. The decrease of HF was statistically significant. The decrease of TP was insignificant and the decrease of HFnu was borderline statistically significant ($p = 0.059$). The lower values of TP and HFnu also noticed in the third recording. However, after the incremental test for maximum oxygen uptake, the increase of HF value in comparison to the second recording was found, but it was statistically insignificant. The return to the basal values was observed on the day after the tests. LF/HF value increased significantly in the second recording ($p = 0.047$). LFnu value also increased, but with borderline statistical significance ($p = 0.059$). LF value did not change significantly during the tests.

DISCUSSION

The main observation of this study is the decrease of parasympathetic activity and increase of sympathetic activity of ANS due to the anaerobic and aerobic exercise in athletes. The changes persisted for at least 60 minutes after the tests. Return of the parasympathetic-sympathetic balance to the initial state is observed on the day after the tests. The sequence of tests chosen for the study is the standard of assessment of aerobic-anaerobic power in professional athletes. Both tests are intensive. However, the incremental test for maximal oxygen uptake is definitely more exhausting and the convalescence period after this test sometimes requires even several days, while after the Wingate test, which is considerably shorter, the return of the general efficiency to the initial state is observed on the following day at the latest.

The group of athletes assessed in the study was sparse (10 persons). However, it should be stressed that similarly to most of the studies involving athletes, the study group consisted of selected professional athletes, training the same sport. The study group was very homogeneous, considering the period of professional training, intensity of the training and the level of obtained results. All the athletes represented the same region of Republic of Poland.

The data in the literature, suggesting the increase of parasympathetic activity after a single exercise, concern a medium intensity. For example, Pober et al. observed in a group of young sedentary volunteers the increase of HF and pNN50 and decrease of LF and LF/HF after 60-minute cycling with intensity needed to achieve 65% of maximum oxygen uptake [10]. The previous reports published by the authors showed a significant increase of SDNN and TF- BRS values due to a 30-minute running on a treadmill performed until heart rate was equal to 130/min. in similar group of young people [11]. However, the exertion applied in the mentioned studies was less intensive than during anaerobic and aerobic tests in this study.

Other authors found similar results indicating adverse reduction of ANS parasympathetic activity and increase of sympathetic one after the extreme exertion [2,3,4,6]. For example, Bernardi et al., evaluating the influence of a 46-kilometer mountain marathon, have shown the decrease of SDNN and HF and the increase of LF/HF [2]. In recent studies published by the authors the decrease of BRS- WBA and increase LF/HF value after a 42-kilometer marathon were reported [3].

Increased sympathetic activity in response to anaerobic and aerobic exercise shown in this study is of special importance due to the elimination of spontaneous breathing. This may influence the parameters measured in low frequency band (0.04-0.15 Hz) when assessed in athletes.

In this study the changes of ANS function towards sympathetic domination in response to anaerobic- aerobic exertion persisted for at least one hour after the exercise. These changes returned to the initial values the next day. In the previous studies by the authors, similar changes of ANS indices after 42-kilometer marathon persisted longer, up to two days after the competition. However, in the study by Gratze et al. assessing athletes taking part in strength-testing competition, the decrease of parasympathetic activity and increase of sympathetic activity were observed even up to three days after the exercise [4]. The differences between this study and other mentioned studies may be explained by the fact that the intensity of exertion during anaerobic and aerobic tests is maximal and leads to persistent sympathetic domination, its duration is shorter than during a marathon or strength-testing competition.

The problem assessed in the study (influence of very intensive anaerobic and aerobic effort on the activity of autonomic nervous system) is of clinical importance. It is the first reported study that assesses the influence of two tests (anaerobic and aerobic) on both HRV parameters and baroreflex sensitivity. However, it is not possible to refer directly the results of the study to another groups, for example the one consisting of sedentary persons. It is known that influence of physical effort in these groups is not identical and varies according to the level of training of assessed persons. There is no data in the available published reports on assessment of the influence of two tests (Wingate test and incremental test for maximal oxygen uptake) on the activity of ANS in persons not training professionally. This problem is interesting from the practical point of view and encourages further studies on this topic.

CONCLUSIONS

Short-term complex exertion during anaerobic and aerobic tests in professional athletes performed in order to evaluate their level of preparation for competition, leads to the decrease in ANS parasympathetic activity and to the increase in sympathetic one. These changes persist for at least one hour after exertion. The return to the initial values is observed the following day after the tests. Thus, it may be assumed that ANS function changes as a result of the anaerobic and aerobic tests does not have a significant and potentially adverse effect in the assessed group of professional athletes.

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