Medicina Sportiva, Vol. 11 (2): 43-47, 2007
DOI: 10.2478/v10036-007-0008-0

THE INFLUENCE OF SHORT-TERM MAXIMAL ANAEROBIC AND AEROBIC EXERTION ON AUTONOMIC NERVOUS SYSTEM ACTIVITY IN HEALTHY YOUNG ATHLETES

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Abstract

Daniłowicz L, Raczak G, Szwoch M, Ratkowski W, Toruński AB. The influence of short-therm maximal anaerobic and aerobic exertion on autonomic nervous system activity in healthy young athletes. *Med Sport* 2007; 11(2): 43-47.

Introduction: The Wingate test (WT) and incremental test for maximal oxygen uptake (IT) are used in the evaluation of physical efficiency in professional athletes. In the former anaerobic power is evaluated and in the latter aerobic power.

Aim: The aim of the study was to evaluate the effect of the tests on autonomic nervous system activity (ANS) in young healthy athletes.

Material and methods: Eight athletes aged 17± 1 were included in the study. On the first day WT was performed, on the second day the IT. The ANS parameters (baroreflex sensitivity - BRS_WBA and heart rate variability - HRV) were analyzed on the basis of 10-minute systolic arterial pressure (SAP) and heart period (HP) records during controlled breathing (0.23 Hz). ANS indices and mean HP were analyzed before (examination 1) and within 1 hour after WT (examination 2), and within 1 hour after IT (examination 3).

Results: The significant decrease in BRS-WBA in examination 2 in comparison to 1 was found (18.1±10.7 vs. 9.4±3.9 ms/mmHg, p=0.049). In examination 3 in comparison to 1 the significant decrease in BRS_WBA was also found (7.7±5.2 ms/mmHg, p=0.011). SDNN, PNN50, RMSSD, HF and HFnu were significantly lower in examination 2 comparing to 1 (p<0.05). These lower values were noticed also after examination 3. The mean HP showed similar changes. LF/HF and LFnu increased significantly in examination 2 in comparison to 1 (p<0.05). LF did not change significantly during the examinations.

Conclusions: Short-term maximal complex exertion during anaerobic and aerobic tests leads to the decrease in parasympathetic activity and to the increase in sympathetic activity of ANS in young healthy athletes. These changes last at least one hour after exertion.

Key words: *autonomic nervous system, baroreflex sensitivity, physical exercise*

Introduction

Two tests that are commonly used for evaluation of athletes' preparation for competition are the Wingate test and incremental test for maximal oxygen uptake. The former test is used to evaluate anaerobic power while the latter is used to test aerobic power. The influence of the complex exertion in these two tests on autonomic nervous system (ANS) activity is not fully examined. From the practical point of view, it seems important to investigate this issue.

The problem described above is a result of the fact that the influence of exertion on cardiovascular system depends on various factors, including intensity, type and duration of the exercise. Moderate single exertion applied as a recreation activity in sedentary people may lead to increased parasympathetic activity of ANS (1). Physical activity lasting several months in these people, as well as long-lasting intensive training in group of athletes preparing for competitions, lead to beneficial changes in sympathetic-parasympathetic balance (2,3). However, high increase in exertion intensity may result in adverse permanent shift of ANS activity from parasympathetic domination to sympathetic one, as it was demonstrated by Iellamo et al in his study of Italian rowing champions (4). Persistent sympathetic activation was also reported as a result of short-term exertion such as marathon race or strength-testing competition (5-7).

Available reports on the influence of combination of Wingate test and incremental test for maximal oxygen uptake on ANS activity provide ambiguous data. Complex nature of influence of physical exercise on ANS makes it impossible to predict the sympathetic-parasympathetic balance changes caused by these two tests. On the other hand, the exertion applied to professional athletes preparing for competition, undergoing these tests, is very intensive. Therefore, it cannot be assumed that the impact on ANS function is not important.

It is important to note that spontaneous breathing by the examined person has a significant influence on

ANS activity. For example, breathing at the rate of 15 breaths per minute is equal to 0.25 Hz, but reduction of breath rate to 6 breaths per minute (0.1 Hz) may influence ANS indices in low frequency band (0.04-0.15 Hz). This fact is particularly important in a group of professional athletes who tend to breathe at a lower rate than sedentary people.

Aim

The aim of the study was to assess the influence of short-term, extreme exertion during Wingate test and incremental test for maximal oxygen uptake on the ANS function in professional athletes preparing for the competition.

Material and Methods

Eight young healthy athletes aged 17 ± 1 (16-19 year), preparing for the competition, were included in the study. Additional inclusion criteria were: absence of any disease (particularly ones of cardiovascular origin), no drugs and alcohol intake, no cigarette smoking, sinus rhythm in ECG and consent to participate in the study

According to the study protocol, each person was examined three times in the morning: 1) before the Wingate test, 2) within one-hour period after the Wingate test, 3) on the following day, within one-hour period after the incremental test for maximal oxygen uptake. Examinees did not eat for at least four hours and did not smoke cigarettes or drink coffee for twelve hours before the tests. In each examined person, a ten-minute recording of systolic arterial pressure (SAP) and heart period (HP) were performed. Tests were carried out in full compliance with the detailed protocol, in a quiet laboratory room, while the examined persons were relaxed and lying in supine position, with head lifted by 30°. During the first 15 minutes of each test, recordings were not made, because the stabilisation of SAP and HP took place. After that, the SAP and HP were recorded during paced breathing (RC) at a rate of 0.23 Hz, synchronized by voice played back from tape. The obtained SAP and HP recordings were used for analysis of baroreflex sensitivity (BRS), heart rate variability (HRV) and mean heart period (mean HP).

Tests of physical efficiency

Tests of physical efficiency were performed in the laboratory of Academy of Physical Education and Sport in Gdańsk. The Wingate test was performed on the first day and the incremental test for maximum oxygen uptake was performed on the following day.

Wingate test

The anaerobic efficiency was assessed in athletes using the 30-second version of the Wingate test. Each test started with a 5-minute warm-up using the cycloergometer, with maximum intensity of exertion defined by heart rate of 140-150/min. After a 5-minute rest, the main test was started. 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 with mechanically adjusted resistance of the flywheel was used. 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

The incremental test for maximum oxygen uptake, was performed using the cycloergometer in order 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 recording made at 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 one 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: $\dot{V}O_2max$ – maximum oxygen uptake, and AT – aerobic-anaerobic threshold. During the tests, oxygen uptake (VO_2), carbon dioxide exhaling (VCO_2) 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, from VE analysis results (during the rapid occurrence of non-linear VE recording in the test). Respiratory quotient (RQ) was also used to assess AT. It was assumed that AT threshold is achieved when RQ is equal to or above 1.

Assessment of ANS activity

Signal of SAP was obtained using non-invasive beat-to-beat method using FINAPRES (Ohmeda), with sleeve placed on middle phalanx of the third digit of the right hand. HP recording was performed using MINGOGRAF 720C. Self-adjustment FINAPRES function was switched off directly before the actual recording and it was switched on again after each recording in order to recalibrate the device.

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

The assessment of BRS indices was preceded by removal of the ectopic beats and trends 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. Value of BRS_WBA was calculated from spectral analysis of spontaneous SAP and HP variations using Blackman-Tukey algorithm with Parzen window of 0.03 Hz bandwidth, as an averaged module of transfer function 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 expressed in ms/mmHg.

The following parameters were included in analysis of short-term HRV (10):

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

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

RMSSD (ms) – root-mean-square value of differences between adjacent RR intervals

TP (ms^2) – total spectral power (ms^2)

LF (ms^2) – power of low frequency components (0.04-0.15 Hz)

HP (ms^2) – power of high frequency components (0.15-0.4 Hz)

LF_{nu} – normalized LF power

HF_{nu} – normalized HF power

LF/HF – ratio of LF power to HF power

The tests were an integral part of a larger program for assessment of influence of physical exercise on ANS function. A consent to perform the study was received from the Independent Bioethical Committee for Scientific Research in Medical University of Gdańsk (NKEBN/10/2003).

Statistical analysis

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

Results

Maximum oxygen uptake ($\dot{V}O_2max$) in the examined athletes was equal to 53.6 ± 6.0 ml/kg/min. In all examined persons, diagnostic values of ANS parameters were obtained.

Barorefl;ex sensitivity was decreased after the Wingate test comparing to the initial values: from 18.1 ± 10.7 to 9.4 ± 3.9 ms/mmHg (p= 0.049). After incremental test for maximum oxygen uptake, the value of BRS_WBA also decreased comparing to the first test (7.7 ± 5.2 ms/mmHg, p= 0.011). These results are illustrated in Figure 1.

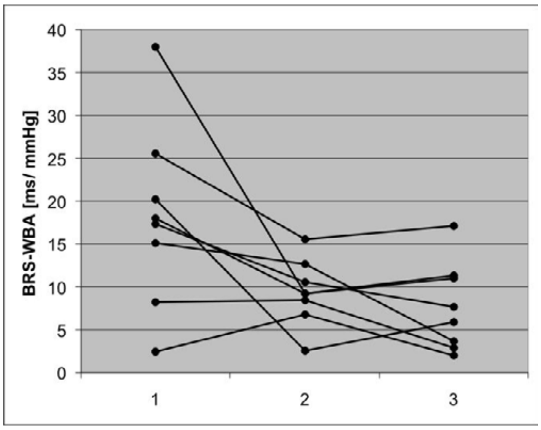

Figure 1. *BRS_WBA before (1) and within 1 hour after Wingate test (2), within 1 hour after incremental test for maximal oxygen uptake (3)*
BRS_WBA (1) vs BRA_WBA (2)- p=0.049
BRS_WBA (1) vs BRS_WBA (3)- p=0.011

Table 1 presents data concerning HRV parameters and mean HP values obtained in the performed tests. It is important to note that all time-domain HRV indices were significantly decreased after the Wingate test, comparing to their initial values. The decreased values of SDNN and pNN50 persisted after the incremental test for maximum oxygen uptake. Similar trends were observed in case of mean HP. The increase of RMSSD value after incremental test for maximum oxygen uptake was observed. However, this change was statistically insignificant comparing to the previous recording.

Table 1. *HRV indices and mean HP before (1) and within 1 hour after Wingate test (2), within 1 hour after incremental test for maximal oxygen uptake (3)*

	1	2	3
SDNN	91 ± 41∗♦	65 ± 26	64 ± 38
PNN50	56 ± 25∗♦	36 ± 20	36 ± 19
RMSSD	108 ± 68∗♦	62 ± 28	75 ± 52
TP	6927 ± 7725♦	4448 ± 3188	4589 ± 7283
LF	1215 ± 813	1421 ± 1307	1098 ± 1277
Fnu	20 ± 13∗♦	35 ± 16	35 ± 14
HF	7312 ± 8038∗♦	2458 ± 1984	3383 ± 5706
HFnu	80 ± 13∗♦	65 ± 16	65 ± 14
LF/ HF	0,29 ± 0,24∗♦	0,61 ± 0,39	0,60 ± 0,36
Mean HP	944 ± 111∗	843 ± 57	893 ± 43

∗ 1 vs 2 p<0.05; ♦ 1 vs 3 p<0.05; ♦♦ 2 vs 3 p<0.05

In spectral analysis, changes of TP, HF and HF_{nu} were similar to those observed in time-domain. In the second recording, statistically significant decrease of HF and HF_{nu} values. The lower values of TP and HF_{nu} were also noticed in the third recording. Increase of HF value in comparison to the second recording was found, but it was statistically insignificant.

In analysis of LF_{nu} and LF/HF parameters, statistically significant increase was observed in the second recording. After the incremental test for maximum oxygen uptake, values of these parameters were also significantly higher comparing to the first recording. LF value did not change significantly during the tests.

Discussion

The main observation in this study is that short-term, complex anaerobic-aerobic maximum exertion in professional athletes results in decrease of parasympathetic component of ANS and increase of sympathetic component of ANS. These changes are observed after the Wingate test and they persist after the incremental test for maximum oxygen uptake.

The data in the literature, suggesting the favourable increase of parasympathetic activity after a single exercise, concern an exertion of moderate 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, as a result of 60-minute cycling with intensity needed to achieve 65% of maximum oxygen uptake (11). The previous reports published by the authors showed a significant increase of SDNN and TF-BRS values after 30-minute running on a treadmill, performed until heart rate was equal to 130/min, in a similar group of young people (1). However, the exertion applied in the mentioned studies was less intensive than during anaerobic and aerobic tests in professional athletes examined in this study.

An adverse, from the clinical point of view, reduction of ANS parasympathetic activity and increase of sympathetic one after the extreme exertion after the one-time, extreme exertion was reported by several researchers (5-7,12). For example, Bernardi et al evaluated the influence of a 46-kilometer mountain marathon and they have shown the decrease of SDNN and HF and the increase of LF/HF (5). In recent studies published by the authors, the decrease of BRS-WBA and increase of LF/HF value after a 42-kilometer marathon were reported (6). Similar changes were observed in the study by Gratze et al, assessing athletes taking part in strength-testing competition (7). In this study, increase of parasympathetic activity was obtained and it persisted for at least 60 minutes after each test, although the exertion was applied for much shorter time, comparing to the studies mentioned above. It should also be noted that increased sympathetic activity as a response to anaerobic-aerobic exertion, found in this study, is of particular importance, because of exclusion of spontaneous breathing that could influence the indices measured in low frequency range (0.04-0.15 Hz) in examined athletes. It was achieved by imposing the paced breathing at a rate of 0.23 Hz.

On the other hand, it should be stressed that although the maximum exertion was applied in athletes examined in anaerobic and aerobic tests, no further adverse increase in sympathetic activity was observed after the incremental test for maximum oxygen uptake, performed on the following day, comparing to results obtained on the first day after the Wingate test, for all parameters assessed in this study. Therefore, it may be assumed that the protocol of anaerobic and aerobic tests used in the study is safe for the examined athletes.

Conclusions

Short-term, complex, maximum exertion in anaerobic and aerobic tests, performed in professional athletes in order to evaluate their level of preparation for competition, results in decreased ANS parasympathetic activity and increased sympathetic one. These changes persist for at least one hour after exertion.

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Received: July 01, 2006
Accepted: May 31, 2007
Published: June 27, 2007

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A – Study Design
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C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection