World Journal of Medical Sciences 10 (4): 475-477, 2014
ISSN 1817-3055

DOI: 10.5829/idosi.wjms.2014.10.4.83252

Dynamics of Vegetative Support of Cardiac Function in Young Swimmers During the Training Process

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Abstract: Vegetative support of cardiac function in young swimmers during the training process was a subject of our scientific research. High level of functioning of physiological systems providing hemodynamics in young athletes was revealed. It was established that the level of humoral-metabolic effects on the formation of the heart rate does not exceed 50%, which is a favorable prognostic sign. Higher heart rate (HR) values during the recovery period if compared with those before the exercise indicate the need for corrective measures aimed at improving the efficiency and optimizing the performance of the major energy systems during sports activities.

Key words: Autonomic Nervous System・Heart Rate Variability・Orthostatic Test・Adaptation.

INTRODUCTION

Functionality of the circulatory system is a sensitive indicator of adaptive reactions of the whole organism. Numerous regulatory mechanisms maintain the work of the circulatory system and also determine the adaptive capacity of the system as a whole unit as well as its individual components [1].

Currently heart rate variability (HRV) is an important indicator in medicine [2-8] and in sports physiology [3, 9], which allows to define "physiological price of particular activity". Thus, the reduction of the total power spectrum, excessive growth of sympathetic-adrenal activity, lack of reactivity of the parasympathetic division of the autonomic nervous system may indicate an increasing fatigue or overtraining [2].

Evaluation of HRV values helps to assess the current functional state of the body and to identify the manifestation of disadaptation or overtraining. It also promotes scientific prediction of the physical capabilities of athletes involved in various sports in order to optimize the training process, which is now the key challenge of a mass sport and high performance sport.

Purpose of the Study: To study the dynamics of vegetative support of the heart activity in young swimmers during the training process.

MATERIALS AND METHODS

29 young swimmers in the average age of 14.36 ± 1.56 years were assessed using the computer electrocardiograph "Poly-Spectrum 8E" (LLC "Neurosoft") in the period of the training process: before training and 1 hour after training.

Background record of the electrocardiogram (ECG) was performed in accordance with the international standards for 5 minutes [10].

Active orthostatic test. ECG was performed for 6 minutes of the orthostasis. When analyzing the first minute of rhythmogram recording, orthostasis was excluded.

ECG was recorded in three standard limb leads and three augmented limb leads to detect sinus rhythm and exclude possible artefacts and ectopic beats from the analysis. Sinus rhythm is characterized by a positive P wave in leads I, II and aVF. P-wave is positive in lead III, but there may be biphasic P (+/-) wave in aVL lead-negative or having +/- type. Premature beat itself and the cardiocycle following it were excluded from the analysis in the presence of ectopic beats.

Spectral analysis of a five-minute recordwas carried out in three frequency bands: HF, LF, VLF [10], using the software "Poly-Spectrum-Rhythm" (LLC "Neurosoft"). At the same time total power (TP) of the spectrum and

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additive contribution of each frequency component in total power of the spectrum as a percentage, as well as interaction vagosympathetic index LF/HF were determined.

The maximum (R-Rmax), the minimum (R-Rmin) and the average normal RR intervals-RRNN were determined. In order to assess the severity of sinus arrhythmia indicators of HRV time analysis-pNN50% (percentage of consecutive pairs of RR intervals differing by more than 50 ms) as well as the coefficient of variation-CV% were used.

30:15 coefficient was determined during the transition period while performing active orthostatic test (AOT). The examined patient placed in the orthostasis after 15 minutes of being in a horizontal position. At the same time a control electrocardiography was performed. We recorded the minimum and the maximum RR intervals in the range of the first 40 cardiocycles on the resulting rhythmogram. Then the ratio of the longest RR interval to the shortest was calculated.

Statistical analysis was performed using the software STATISTICA V. 6.0. Given that the resulted data had an abnormal distribution of samples, it was decided to use nonparametric methods (Wilcoxon signed-rank test for dependent samples) to compare the data. The median value and interquartile range at the level of the 25^{th} (C25) and 75^{th} (C75) percentiles were used to assess the data.

Main Part: When conducting background ECG recording prior to the exercise, it was revealed that all the athletes had irregular sinus rhythm, which can be regarded as a sign of normal heart rate variability. The average value of HR in this case was equal to 56.4 ± 1.1 beats per minute. Along with the high values of pNN50% and CV% this fact should be regarded as a manifestation of high vagal activity. Given the fact that the high activity of parasympathetic nerve provides a trophic effect on the heart, this can be regarded as a result of adaptive compensatory processes aimed at creating energy and resource reserves required for an adequate response to urgent or increasing physical activity.

When placing in orthostatic position there is an acute change of hemodynamics accompanied by involving adaptive body reserves aimed at its modulation in accordance with the new conditions. The first minute of orthostasis on the ECG was not analyzed as it was considered as a transition period where emergency adaptation mechanisms induce hemodynamic changes involving the rate of venous return.

Subsequent analysis of a five-minute ECG recordrevealed time changes of HRV. There was a reduction of RRNN values, which manifested itself in an increase in heart rate by 35.6% ($p < 0.001$), which was equal to 76.5 ± 1.9 beats per minute. At the same time the percentage of consecutive RR intervals differing by more than 50% (pNN50%) was significantly decreased-by 79.1% ($p < 0.001$). However, pNN50% values were much higher than such values for healthy children registered during the orthostatic test. CV% values were decreased by 13.4% ($p < 0.001$). The received orthostatic changes of HRV time analysis may indicate high adaptation reserves in the athletes being surveyed.

The spectral analysis of background HRV recording prior to the exercise revealed a high incidence of the total power spectrum: this was typical for the young athletes. At the same time high-frequency oscillations-HF, reflecting the activity of the vagus nerve, make a great contribution to the spectral power. Low values of the vagosympathetic balance-LF/HF also indicate a high vagal activity in the formation of the heart rhythm.

During an orthostasis there is a decrease in the total power spectrum by 44.1% ($p < 0.001$) associated with an increase in contribution of the sympathetic effects (% LF) by 25.8% ($p < 0.001$) and humoral-metabolic effects (% VLF) of stimulant circuit of cardiac activity by 64.5% ($p < 0.001$). Against this background, there is a decrease in activity of the brake circuit regulation (% HF) by 62.6% ($p < 0.001$). This results in an acute increase in vagosympathetic balance.

In the transition period of orthostasis after taking the vertical position within the first 30-40 cardiocycles there is initially a considerable increase in the heart rate. Usually this occurs on the 15th cardiac cycle and then declines to the 30-40th cardiocycle. Ratio of the longest RR interval to the shortest one in the described range indicates the reactivity of the parasympathetic division of the autonomic nervous system and is called as 30:15 coefficient-$K_{30/15.}$ The average values of $K_{30/15}$ coefficient before training was 1.84 (C25-1.77; C75-2.03), which is considerably higher than the lower limit of normal, which is equal to 1.25 and characterizes high reactivity of the vagus for this type of physical load.

An hour after the workout background ECG record didn't show any HR trend on rhythmogram, which allowed to analyze stationary process. After a workout, the average background heart rate was 78.1 ± 1.7 beats per minute. This value is higher by 35.6% ($p < 0.001$) than that before physical training. The values of pNN50% decreased by 76.2% ($p < 0.001$), while the CV% value decreased by 19.7% ($p < 0.001$).

The spectral analysis of HRV after a workout on the background of ECG recording revealed a reduction in the total power spectrum as compared with the background ECG recording before the workout by 61.2% ($p < 0.001$) associated with the change in additive contribution of each spectral component. At the same time there was a decrease in vagal activity by 47.4% ($p < 0.001$), an increase in sympathetic influences by 21.8% ($p < 0.001$) and a considerable increase in humoral-metabolic effects on the formation of the heart rate-by 61.5% ($p < 0.001$). At the same time an increase in vago-simpatic balance was equal to 50.6% ($p < 0.001$).

An average heart rate recorded during the orthostatic test after training was equal to 93.7 ± 1.9 beats per minute. There was an increase in the heart rate by 20.0% ($p < 0,001$) compared with the background HR value.

The proportion of normal RR intervals differing by more than 50 ms (pNN50,%) decreased by 80.4%, while the CV% reduction was by 5.1% ($p < 0.005$).

If compared with the orthostatic tests conducted before the training, the heart rate increased by 22.5% ($p < 0.001$). PNN50% values decreased by 72.3% ($p < 0.001$) and the values of CV% decreased by 11.1% ($p < 0.001$).

During the orthostatic test in the spectral analysis of HRV after physical exercise there was a reduction in the total power spectrum by 30.2% as compared with the background value ($p < 0.001$). Vagal activity decreased by 52.4% ($p < 0.001$). Sympathetic influences in the overall power spectrum has not changed, while the increase in humoral-metabolic effects on the formation of the heart rate was 24.4% ($p < 0.001$). The vagosimpatic balance has been sharply increased-by 65.3% ($p < 0.001$).

If compared with orthostatic data obtained before training, the total power spectrum decreased by 49.1% ($p < 0.001$). Activity of the parasympathetic division of the ANS was decreased by 35.5% ($p < 0.001$), while the activity of sympathetic division of the ANS-by 7.6% ($p < 0.05$). Humoral and metabolic effect increased by 16.3% ($p < 0.05$).

Reactivity of the parasympathetic division of the ANS was determined by $K_{30/15}$ coefficient. This parameter decreased in transitional period of orthostasis by 31.1% ($p < 0.001$).

CONCLUSIONS

- Young swimmers have a high level of functioning of physiological systems providing hemodynamics. After a workout, there is a decrease in overall power spectrum values, but its absolute values remain high.
- The level of humoral-metabolic effects on formation of the heart rate does not exceed 50%, which is a good prognostic sign, as the high level of catecholamines is an inducer of peroxidation.
- The elevated heart rate values during the recovery period indicate the need for corrective measures for improving the efficiency and optimizing the performance of the major energy systems during sports activities.

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