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APPLICATION OF THE ANAEROBIC THRESHOLD CONCEPT – A KEY FACTOR FOR AN OPTIMAL EFFECT FROM A SPORT TRAINING PROCESS

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ABSTRACT

In this research we studied the effect from the application of the anaerobic threshold, aimed at modeling of the training process and increase of the aerobic functional abilities in active female athletes. We conducted two VO_{2max} exercise tests for assessment of the dynamics in the functional aerobic and work capacity of the athletes as a result of an undergone 45 days training camp. The planned training loads were carried out at dosed intensity based on the individually determined anaerobic threshold. We found statistically a significant increase in the maximal speed achieved on the treadmill (9.1 %; $p^* < 0.05$), in absolute and relative values of the maximal oxygen uptake (8.9 %, 7.5 %; $p^* < 0.05$) and decrease of maximal pulmonary ventilation (-4.8 %; $p^* < 0.05$). These data allowed us to acknowledge a positive effect from the undergone training process on the basic aerobic functional parameters. The results confirm the opinion that the application of the individual anaerobic threshold is an essential factor for optimal effect in aerobically-purposed training activities.

Keywords: *anaerobic threshold, functional work capacity, VO_{2max} exercise test, active athletes.*

INTRODUCTION

The application of the concept of the “aerobic-anaerobic metabolic transition (anaerobic threshold)” for planning and control of training loads in sport is a fundamental scientific approach in conduction of activities aimed at improvement of muscle metabolic processes. An important criterion which determines the ability for continuous exercising is the balance between energy production and its utilization in the working muscles. The reciprocal coordination of these two processes is limited by the individual characteristics of the cardio-vascular system and the muscle metabolism, due to which a “critical threshold” in the intensity of the realized physical effort is observed. Above this “critical threshold” the respiratory, cardio-vascular and cellular-metabolic response of the organism cannot adequately supply the necessary energy for the involved muscles and the functional work capacity is sharply reduced [1]. In the 70ies of the last century Wasserman [2] described this threshold as the “aerobic-anaerobic metabolic transition” and defined the term “anaerobic threshold”. According to him the “anaerobic threshold (AnT)” may be analyzed through the intensity of the realized workload, at which metabolic acidosis in the working muscles, as well as related changes in the respiratory parameters in athletes occur. Several years later McArdle [3] commented on the thesis that the theory of AnT could be effectively applied in planning of training activities. The essence of this method is calculation of “heart rate training zones (HRTZ)” using the anaerobic threshold which allows control of the intensity of training load with a heart rate monitor. The constantly increasing dynamics of modern soccer requires reconsideration of the scientific views on the role of aerobic capacity of athletes for optimal performance. Reilly et al. [4] conducted detailed tests and concluded that during a soccer game the motor activity of the players is characterized to a high percentage with running, therefore high aerobic capacity is of key importance for high sport achievements. The scientific approach in optimizing the aerobic capacity of soccer players includes the application of the AnT concept through determination of individual "heart rate zones". Modeling of the training process based on HRTZ allows a corrective analysis of the volume and intensity of the realized training loads with adequate adaptation to the individual functional characteristics of the players [5].

The aim of the present work is to study the influence of the application of the concept of the individual anaerobic threshold on some key functional parameters (maximal ergometric work capacity (S_{max}); maximal pulmonary ventilation (VE_{max}); maximal oxygen uptake (VO_{2max}) and maximal heart rate (HR_{max})), which characterize the aerobic potential and functional work capacity of the athletes.

EXPERIMENTAL

The subjects of the study were 13 healthy female soccer players (average age 20.62; ±2.47 years) from the representative team of the National Sport Academy and the national team of the Republic of Bulgaria. Before the start of the basic training preparation, following a detailed informed consent from the subjects involved, we conducted a VO_{2max} exercise test of the athletes and determined their work capacity and anaerobic threshold. During the training camp (duration – 45 days) the athletes followed individually planned training load programs, modeling work intensity through HRTZ, based on the predetermined AnT and strictly controlled with heart rate monitors. We applied a model for structuring of the training regimen, commonly used by Bulgarian specialists. It is characterized with 4 HRTZ: aerobic regimen (HR = 65-75% of AnT), mixed aerobic-anaerobic regimen (HR = 75-90% of AnT), mixed anaerobic-aerobic regimen (HR = 90-105% of AnT) and anaerobic regimen (HR > 105% of AnT) [3, 6]. After the completion of the basic training preparation we repeated the VO_{2max} exercise test with precise assessment of the dynamics in the functional aerobic and work capacity.

The workload was performed on a treadmill ergometer - Quasar 4.0 Med (HP Cosmos, Germany). A stepwise exercise test was conducted based on the protocol of Iliev I. [7], which is characterized with initial speed of 6 km h^{-1} and stepwise increase every 90 sec with 1.2 km h^{-1} until objective voluntary exhaustion is achieved. We used the following criteria to verify maximal exertion: a plateau in VO_2 dynamics, maximal respiratory exchange ratio (RER_{max}) > 1.15 and physical inability to continue the test [8]. Continuous gas-exchange measurement by the breath-by-breath method was made using a specialized computerized metabolic system Oxycon (Erich Jaeger GmBH & Co Wuerzburg, Germany). The individual ventilatory AnT was determined through a detailed analysis of the registered by the metabolic system cardio-respiratory parameters. We can classify the studied parameters into two major groups:

1. Anthropometric: height; weight; body mass index (BMI); body fat percentage (% BF, calculated by the skinfold method using the regression equations of Parizkova J. [9]); absolute muscle mass.

2. Functional: maximal ergometric work capacity (expressed as the maximal speed achieved on the treadmill, S_{max}); VE_{max}; VO_{2max}; HR_{max}; AnT; RER_{max} ($RER_{max} = RQ_{max}$, an indirect equivalent to the respiratory quotient) [3].

Relative values were used to ignore the influence of body weight in the comparative analysis of the functional parameters. They were expressed as ratio of absolute values to body weight of the respective athlete. In the mathematical-statistical processing we considered the fact that two related samples were compared – the values of the studied parameters before and after the training camp. This requires the application of the Paired Sample T statistical test for optimum reliability of the results, preceded by a distribution normality test of the respective parameters with the specialized tests of Kolmogorov-Smirnov and Shapiro-Wilk (SPSS14). Student's T criterion was used for evaluation of the statistical results with a standard level of significance ($p<0.05$).

RESULTS AND DISCUSSION

We carried out the statistical processing of the results in two stages with analysis of the reliability of the null hypothesis on the dynamics of the key parameters in both completed exercise tests. The complex analysis of the results from the first test convinced us that the aerobic capacity of the soccer players was not optimal (VO_{2max} kg^{-1} = 48.42; ±3.54), which resulted in relatively low maximal work performance (S_{max} = 13.54; ±1.04) and required the conduction of a purposeful scientifically-

Table 1. Dynamics of the key anthropometric parameters due to a conducted training process ($p<0.05$, * - statistically significant differences).

Parameters	After a training process		Before a training process		Difference	t	p
	$\bar{X}_2$	Sx_2	$\bar{X}_1$	Sx_1	$\bar{X}_2 - \bar{X}_1$		
Body weight (kg)	59.09	6.30	58.62	6.07	0.47	1.23	0.84
Height (m)	1.68	0.06	1.67	0.04	0.01	1.05	0.94
BMI	21.49	1.39	20.75	1.37	0.74	1.32	0.69
Body fats (%)	18.75	4.24	19.06	4.85	- 0.31	1.28	0.74
Muscle mass (%)	28.52	4.86	27.43	4.79	1.09	1.63	0.26

Table 2. Values of the registered maximal functional parameters during exercise tests before and after a conducted training process ($p<0.05$, * - statistically significant differences).

Parameters	After a training process		Before a training process		Difference	t	p
	$\bar{X}_2$	Sx_2	$\bar{X}_1$	Sx_1	$\bar{X}_2 - \bar{X}_1$		
S_{max} (km h^{-1})	14.77	0.85	13.54	1.04	1.23	2.46*	0.048
VE_{max} (l min^{-1})	97.81	12.06	102.75	13.85	- 4.94	2.38*	0.053
VO_{2max} (ml min^{-1})	3075	251.55	2823	196.44	242	3.72*	0.00
VO_{2max} kg^{-1} (ml min^{-1}/kg)	52.04	2.91	48.42	3.54	3.62	2.83*	0.01
HR_{max} (beats min^{-1})	191	6.91	193	7.47	- 2	1.63	0.26
AnT (beats min^{-1})	182	5.24	181	4.82	1.00	1.34	0.76
RER_{max}	1.26	0.03	1.23	0.05	0.03	1.15	0.94

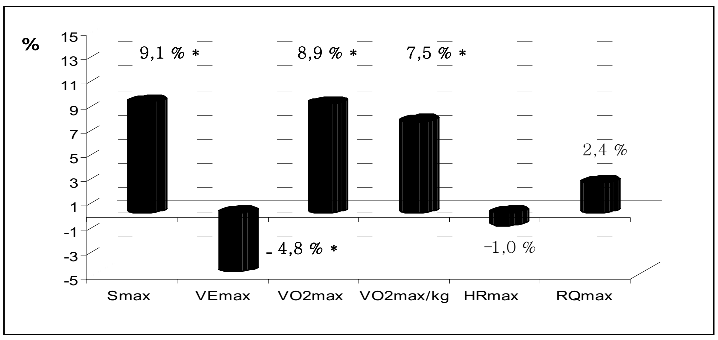

Fig. 1. Dynamics of the key functional parameters due to a conducted training process ($p<0.05$, * - statistically significant difference).

modeled training process. In the second test (following the training camp) we established a minimal increase in body weight, BMI, absolute muscle mass and decrease in body fat percentage of the athletes (Table 1).

The observed changes in all anthropometric parameters have proved to be statistically insignificant ($p>0.05$), therefore we assumed that no significant dynamics in the main body parameters was observed. The statistically insignificant increase of absolute muscle mass (1.09 %; $p>0.05$) and the other somathotype characteristics of the soccer players do not support the thesis for a direct causal relationship between the anthropometric and functional parameters registered during the second test (Table 1). On the ground of this result we can assume that the observed positive dynamics in the functional parameters is most probably not a direct consequence of the determinant influence of the factor "increased absolute muscle mass" (Table 2).

During the completed exercise test following the training camp, we established a significant increase in S_{max}, absolute and relative values of VO_{2max} and decrease of VE_{max}. The changes in HR_{max}, AnT (expressed by the corresponding heart rate) and RER_{max} were statistically insignificant ($p>0.05$) and we considered appropriate not to discuss their dynamics in detail, since it is minimal and does not require a concise scientific analysis. We evaluated the influence of the conducted training process through analysis of the changes in the key parameters, which characterize aerobic power and S_{max}, absolute and relative VO_{2max} values and VE_{max}. The statistically significant increase of the maximal speed achieved on the treadmill (1.23 km h^{-1}; $p^*<0.05$), absolute and relative VO_{2max} values (242 ml min^{-1}; 3.62 ml min^{-1}/kg; $p^*<0.05$) and the decrease of VE_{max} (4.94 l min^{-1}; $p^*<0.05$) allowed us to acknowledge a positive effect on the functional work capacity of the athletes (Fig. 1).

This statement is also confirmed by the registered minimal decrease of HR_{max} (2 beats min^{-1}; $p>0.05$). We established significant dynamics in the absolute and relative VO_{2max} values (8.9 %, 7.5 %; $p^*<0.05$), which is most probably due to increased adaptive aerobic abilities as a result of improved mechanisms of oxygen transport and utilization in exercising muscles. We can interpret the minimal changes in RER_{max} between the two tests (2.4 %; $p>0.05$) as an indirect indicator of the lack of significant difference of the role of the involved anaerobic capacity in the energy supply of the physical effort. This allowed us to assume that the achieved higher S_{max} was not determined by a significantly increased role of the anaerobic energy supply, but rather key factors were the established changes in the aerobic power and its more economic realization.

CONCLUSIONS

It is widely acknowledged that absolute and relative VO_{2max} are the main indirect physiological indications which characterize the oxygen-transporting and oxygen-utilization systems in the organism [10]. On this ground we can interpret the increase in the absolute and relative VO_{2max} values (8.9 %, 7.5 %; $p^* < 0.05$) as a proof of positive influence on the aerobic capacity of the athletes. The important aerobic factors, which contribute to optimal exercise performance during prolonged physical workouts, are the maximal aerobic power and the oxygen cost of movement (economy) [7]. Both components act coordinately with varying interrelation in different athletes, but in all cases their dynamic development leads to an increase of the work capacity [11]. In this context we can formulate the thesis that the registered increase of the maximal work capacity, expressed as S_{max} (9.1 %; $p^* < 0.05$), is an indirect sign of the increased aerobic capacity or more economic realization of the existing aerobic abilities in the energy supply of the motor activity. Although a detailed objective analysis of the relation between these two factors cannot be made, the increased maximal exercise performance is the most substantial confirmation of the positive effect on the functional work capacity of the soccer players due to the conducted training process [3, 7, 10, 11]. This opinion is also supported by the established decrease in VE_{max} (-4.8 %; $p^* < 0.05$), which may be regarded as a logical consequence of the increased efficiency of the cardio-respiratory system with optimal energy loss by respiratory movements [8]. The lack of significant dynamics in RER_{max} between the two conducted tests (2.4 %; $p > 0.05$) allows us to assume that most probably there is no significant transformation in the role of anaerobic capacity in energy supply of the motor activity.

Therefore, as a conclusion of the present research we can summarize that the presented data confirm the opinion of leading specialists of a present positive effect on the aerobic capacity and the exercise performance as a result of the application of the anaerobic threshold concept with determination of individual HRTZ and control of training activities [12, 13, 14, 15]. The modeling of the training load intensity based on the individual AnT proved to be an optimal scientifically-grounded approach during preparation aimed at increase of the aerobic fitness of active athletes.

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