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CHANGES IN THE ANAEROBIC THRESHOLD IN AN ANNUAL CYCLE OF SPORT TRAINING OF YOUNG SOCCER PLAYERS

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ABSTRACT: The aim of the study was to assess changes in the anaerobic threshold of young soccer players in an annual training cycle. A group of highly trained 15-18 year old players of KKS Lech Poznań were tested. The tests included an annual training macrocycle, and its individual stages resulted from the time structure of the sports training. In order to assess the level of exercise capacities of the players, a field exercise test of increasing intensity was carried out on a soccer pitch. The test made it possible to determine the 4 millimolar lactate threshold (T LA 4 mmol $\cdot$ l^{-1}) on the basis of the lactate concentration in blood [LA], to establish the threshold running speed and the threshold heart rate [HR]. The threshold running speed at the level of the 4 millimolar lactate threshold was established using the two-point form of the equation of a straight line. The obtained indicators of the threshold running speed allowed for precise establishment of effort intensity used in individual training in developing aerobic endurance. In order to test the significance of differences in mean values between four dates of tests, a non-parametric Friedman ANOVA test was used. The significance of differences between consecutive dates of tests was determined using a post-hoc Friedman ANOVA test. The tests showed significant differences in values of selected indicators determined at the anaerobic threshold in various stages of an annual training cycle of young soccer players. The most beneficial changes in terms of the threshold running speed were noted on the fourth date of tests, when the participants had the highest values of 4.01 $m \cdot s^{-1}$ for older juniors, and 3.80 $m \cdot s^{-1}$ for younger juniors. This may be indicative of effective application of an individualized programme of training loads and of good preparation of teams for competition in terms of players' aerobic endurance.

KEY WORDS: soccer, lactate threshold, threshold speed, threshold heart rate

INTRODUCTION

Soccer is one of the most popular sports in the world and may be taken up by men, women and children with varied levels of abilities. Preparation of a soccer player is complex and determined by technical, tactical, biomechanical and mental factors as well as physical fitness [5,34,36]. One of the reasons for the popularity of soccer worldwide is the fact that it requires above-average ability levels in many aspects of training. Recently more and more attention has been devoted to selection of soccer players with an appropriate anthropometric and fitness profile offering the possibility of systematic training in order to achieve the highest level of performance. Mastering the preparation of a soccer player often focuses on the improvement of technical or tactical abilities at the expense of physical preparation, which frequently affects the final score of a championship match [5].

A high level of endurance, power and speed allows players to reach deeper to access soccer abilities during the game. Therefore, game analysis from a metabolic and motor activities' point of view should be the first step on the way to rational management and programming of soccer players' fitness training [7]. On the basis of this information, an appropriate selection of physical loads with regard to their character, volume and intensity may be applied. It leads to improvement of specific motor abilities corresponding to the requirements of soccer.

Due to the duration of a soccer game, the covered distance of 10-12 km and the intensity of a player's exertion during a game (approx 75% $\dot{V}O_2max$), a good level of aerobic endurance allows the player to use his or her aerobic energy supplies during the game to a greater extent [6]. The study of Bangsbo revealed [4] that more than 90% of the energy used by a soccer player during a game is covered by aerobic metabolic processes supplying the necessary energy to move with a low and moderate running speed. Due to the high (above anaerobic threshold – AT) and very high intensity exercise (sprints), a player's tolerance to increasing fatigue process is improved. A high level of endurance allows a player to develop a higher speed of play that can be maintained for the whole duration of the game.

A player should be optimally prepared for such great sport exertion. Observation of exercise capacities in individual stages of players' development, and in training cycles they are subject to in the training process, provides an opportunity to optimize the sports training.

Maximal oxygen consumption (VO_2max) and anaerobic threshold are the main parameters used to describe aerobic performance capacity and basic aerobic endurance, respectively [3,23-25]. According to several studies [9,5,12,21,26,27,29] the best indicators regulating a soccer player's individual loads during aerobic endurance training are running speed with exercise intensity corresponding to the anaerobic threshold – the so-called "threshold speed" (VAT) – and a corresponding heart rate (HR_{AT}). The VAT and HR_{AT} obtained during exercise tests allow for the precise determination of exercise intensity in individual training.

Taking the above into consideration, the aim of this study was to assess the effect of used training loads on changes in the anaerobic threshold of young soccer players at various stages of an annual training cycle.

MATERIALS AND METHODS

The participants were a group of highly trained 15-18-year-old male soccer players of KKS Lech Poznań S.A. in two age groups: older juniors (Group A – 19 players) and younger juniors (Group B – 14 players) in the annual training cycle of the 2009/2010 season. The dates of the tests were determined by the following macrocycle time framework:

- 1st test – (March 2009) after the completion of the basic preparatory period (T1),
- 2nd test – (July 2009) before the commencement of the shortened preparatory period (T2),
- 3rd test – (January 2010) before the commencement of the basic preparatory period (T3),
- 4th test – (March 2010) after the completion of the basic preparatory period (T4).

Before the first test the players performed the so-called zero test.

Before doing this study, the researchers obtained approval from the local ethical committee of Piasecki University of Physical Education in Poznań. All participants were informed about the study procedure and all measurements were taken in the same measuring conditions.

The participants' anthropometric characteristics and training experience are presented in Table 1.

In order to determine the level of players' anaerobic threshold, an outdoor exercise test of increasing intensity was carried out on a soccer field. The test made it possible to establish the threshold values of heart rate and the threshold running speed using an invasive method. For the assessment of anaerobic threshold, the measurement of heart rate [HR] and the level of lactate concentration in capillary blood [LA] of players carrying out the endurance exercise test were applied. For this purpose [27], an ellipse with a circumference of 250 m was marked on the pitch. A player covered a fixed 250 m distance and increased every few repetitions the running speed, which was reflected in increased heart rate and the level of lactate concentration in the blood. Heart rate [HR] during the exercise was established using a Polar Sport Tester telemeter. The blood lactate level was calculated by an enzymatic assay using an Epoll-20 spectrophotometer. A player started the exercise test from a run at the speed of $2.8\ m \cdot s^{-1}$, which increased by $0.4\ m \cdot s^{-1}$ with each load. After completing each load, blood was collected from a finger tip to measure lactate concentration in capillary blood and heart rate was measured. If a player did not sustain the running speed with the current load, the exercise test was stopped. Heart rate during the tested physical activity was measured with a Polar Sport Tester telemeter. The blood lactate level was calculated by an enzymatic assay based on the method of Gutmann and Wahlenfeld [16] in

TABLE 1. ANTHROPOMETRIC CHARACTERISTICS AND TRAINING EXPERIENCE OF OLDER (A) & YOUNGER (B) JUNIORS OF KKS LECH POZNAŃ

Parameters	Group	Date			
		I	II	III	IV
Age (years)	A	16.9 ± 0.88	17.2 ± 0.88	17.7 ± 0.88	17.9 ± 0.88
	B	15.3 ± 0.36	15.8 ± 0.36	16.1 ± 0.36	16.3 ± 0.36
Body height (cm)	A	175.7 ± 5.98	177.9 ± 5.08	178.9 ± 5.06	180.2 ± 4.55
	B	174.3 ± 4.19	176.5 ± 5.13	177.2 ± 5.25	178.9 ± 4.58
Body mass (kg)	A	69.8 ± 6.41	70.5 ± 5.55	71.8 ± 5.42	72.7 ± 4.07
	B	66.2 ± 6.06	67.4 ± 6.13	68.5 ± 6.04	70.4 ± 6.01
Trening experience (years)	A	7.8 ± 3.35	8.1 ± 3.35	8.6 ± 3.35	8.8 ± 3.35
	B	6.4 ± 2.86	6.9 ± 2.86	7.2 2.86	8.4 ± 2.86

capillary blood for 20 seconds after each load. In order to assess the players' lactate concentration, 50 μl of capillary blood was transferred into a centrifuge tube containing single use perchloric acid. The sample was shaken, centrifuged and stored in the refrigerator until analysis (2-3 hours). Solutions were mixed and incubated for 30 minutes at room temperature. Extinction was measured at a wavelength of λ = 340 nm in relation to the water.

The threshold running speed at the level of 4 mmol $\cdot$ l^{-1} lactate threshold was established using a two-point form of the equation of a straight line. On the basis of the calculated threshold running speed [VAT] using straight line parallelism also the threshold heart rate was established [HR_{AT}]. Indicators obtained in this way allowed for a precise determination of training intensity.

A detailed test protocol and all methodological procedures of the applied test are included in the paper of Jastrzębski et al. [27].

For all tested parameters the arithmetic mean (×) and standard deviation (SD) were calculated. The conformity of distribution was tested with the Shapiro-Wilk test. The level of critical significance was set at $p < 0.05$. As the conditions of normal distribution or uniformity of variance were not met, non-parametric Friedman ANOVA test was used. The significance of differences between the dates of tests was assessed using a post-hoc Friedman ANOVA test. Statistical analysis was carried out using STATISTICA 10.0.

Control of training loads

The subject of analysis was training loads applied at the time of the study. The applied training loads programme aiming to improve the participating players' exercise capacity had a comprehensive character. In the main preparatory period and, first of all, in the sub-period of general preparation, versatile loads prevailed. The most often used means of versatile preparation are general warm-ups, supplementary sports and continuous runs with varied pace. A basic microcycle of this sub-period included eight training units, of which at least two were carried out outside the soccer field. Moreover, three units were devoted to aerobic endurance training, but with task-oriented forms of play as well as task-oriented and school games. The range of intensity during these training units was within individual players' values [HR_{AT}]. From the metabolic point of view, the exercises were directed at maintaining players' aerobic-anaerobic capacity.

In soccer, the basic training cycle in the competitive period is a weekly microcycle defined by the time between matches. Here the selection of appropriate training loads is a significant factor supporting the exercise capacity developed in the preparatory period. A training microcycle from this period contained 6-7 training units of which two were treated as individual practices. On the first day of the week, training loads were directed towards aerobic work and their aim was to enhance recovery from playing a competitive match. The greatest loads were used on the second and third days of the week, during which most exercises were specific in nature, using a wide range of technical and tactical exercises and games. On the fourth and fifth days of the weekly microcycle, apart from elements of general endurance, a plan of special preparation of players for the next match was carried out. It involved technical and tactical exercises taking into consideration the nearest opponent. In order to avoid chronic fatigue, the loads were at an average and low level, and in training sessions anaerobic and non-lactate work prevailed.

Training loads in the junior teams of KKS Lech Poznań were continuously monitored by evaluating players' heart rate and lactate concentration. A player's heart rate was measured using a Polar telemetric sport tester. In the metabolic control of plasma lactate concentration the Lactate Scout was applied after different exercises.

Table 2 shows general characteristics of training loads between individual dates of tests for the tested training groups.

RESULTS

The detailed comparative analysis of heart rate at the level of the 4 milli-molar lactate threshold [HR_{AT}] of an older junior (A), pre-

TABLE 2. MEAN VALUES OF TRAINING LOADS OF OLDER JUNIORS (A) AND YOUNGER JUNIORS (B) IN A WEEKLY MACROCYCLE IN INDIVIDUAL TRAINING PERIODS

	Basic Preparatory Period Jan–Mar		Competitive Period (spring) Mar-Jun		Shortened Preparatory Period Jul-Aug		Competitive Period (autumn) Sep-Nov	
	A	B	A	B	A	B	A	B
Warm up	2.5	2.0	2.25	1.75	2.5	2.0	2.25	1.75
Endurance running	2.5	2.0	0.75	0.5	2	1.5	0.75	0.5
Technical/tactical training	2.5	2.0	3.0	3.5	2.5	2.0	3.5	4.0
Strength training	1.5	1.0	1.0	0.5	1.5	1.0	1.0	0.5
Small sided games	3.0	2.5	2.5	2.0	3.0	2.5	2.5	2.0
Match play	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Total	13.5	11.0	11.0	9.75	13.0	10.5	11.5	10.25

sented in Figure 1, showed significant statistical differences between the 2nd and 3rd dates of tests ($p<0.05$). In the study both the lowest (171.8 ± 10.31 beats·min^{-1}) and the highest (178.9 ± 3.87 beats·min^{-1}) values of the discussed haemodynamic indicator were noted. Mean values noted on the 1st and 4th tests were similar and did not show significant statistical differences between other dates.

On the basis of the analysis it was noted that mean values of threshold heart rate [HR_{AT}] in the group of younger junior players (B) were from 171.2 ± 7.85 beats·min^{-1} to 177.9 ± 4.92 beats·min^{-1}. The results [HR_{AT}] on every subsequent date were not statistically significant (Fig. 2).

The threshold running speed [VAT] is one of the most important indicators regulating a player's individual loads during aerobic endurance training. Figure 3 presents mean values of the parameter in question in older junior players (A). It shows that the highest level of threshold running speed was noted on the 4th date of tests when the mean value was 4.01 ± 0.32 m·s^{-1}.

The comparative analysis of the threshold running speed showed statistical differences between individual dates of tests. A statistically significant difference was noted between 2nd and 4th tests, between 1st and 4th tests and between 2nd and 4th tests ($p \le 0.01$).

Changes in the analysed indicator were similar in the group of younger junior (B). Also on the 4th date of tests young soccer players had the highest values of threshold running speed of 3.80 ± 0.18 m·s^{-1}. A detailed analysis of the indicator in question showed statistically significant differences between the 2nd and 3rd dates and the 2nd and 4th dates ($p \le 0.01$).

DISCUSSION

In rational management of the training process of soccer players, a systematic control of loads at a physiological level is necessary. The main task of this control is to establish the effect of training loads on the conditioning level of a player, in particular, specifying the rate, direction and level of adaptive changes of the body and its individual systems and organs. This is of particular importance in the case of young players.

The analysis of relations between loads and adaptation gives rise to the need to control and assess these physiological indicators which, on the one hand, determine the current state of exercise capacity, and, on the other hand, predict the direction of further adaptive changes. Currently, in the diagnosis of the training process the anaerobic threshold (AT) is used more and more commonly [1,8,29,38]. In order to establish the anaerobic threshold, many invasive and non-invasive methods are used. In soccer, the most commonly used method is based on determining lactate concentration during an exercise test of progressive intensity and using interpolation of the load which corresponds to the level of LA concentration equal to 4 mmol·l^{-1} (called the lactate threshold) [10,12,13,29,32,35].

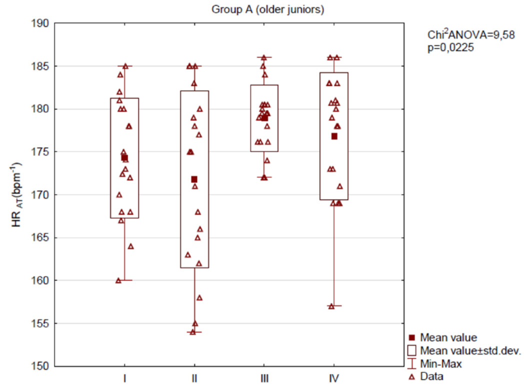

FIG. 1. THRESHOLD HEART RATE IN THE GROUP OF OLDER JUNIORS (A) ON FOUR DATES OF TESTS

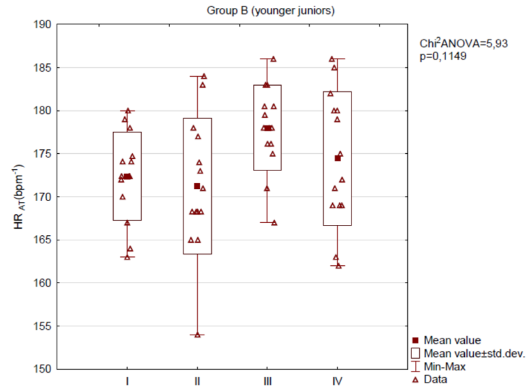

FIG. 2. THRESHOLD HEART RATE IN YOUNGER JUNIOR GROUP (B) ON FOUR DATES OF TESTS

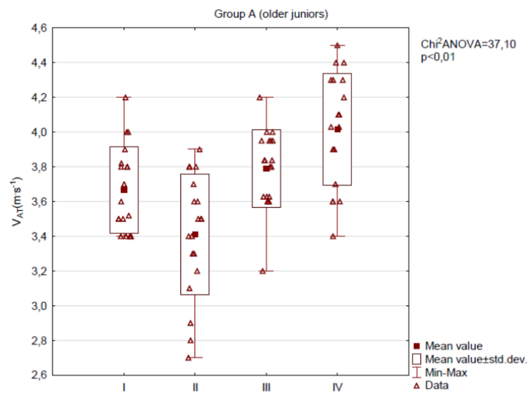

FIG. 3. THRESHOLD RUNNING SPEED IN THE GROUP OF OLDER JUNIOR (A) ON FOUR DATES OF TESTS

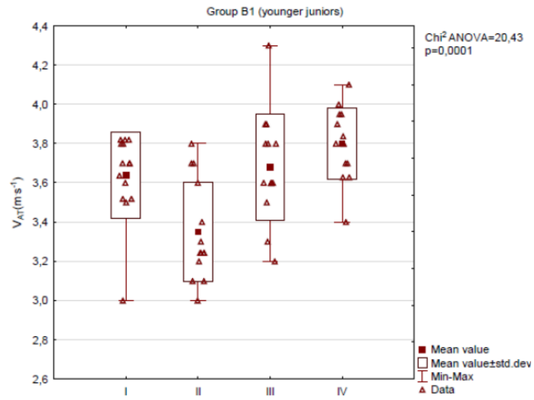

FIG. 4. THRESHOLD RUNNING SPEED IN THE GROUP OF YOUNGER JUNIORS (B) ON FOUR DATES OF TESTS

Recently, non-invasive methods of determining the anaerobic threshold have also been used, one of the most popular being the ventilatory threshold (VT) established on the basis of gasometric indicators [1,17,19]. In the cross-sectional literature of the subject [20], apart from the above methods of establishing the anaerobic threshold, the 25 most important concepts were listed, among which the most important ones are maximal lactate steady state (MLSS), lactate minimum speed (LMS), onset of blood lactate accumulation (OBLA), and individual anaerobic threshold (IAT).

The method of anaerobic threshold establishment applied in this study with modifications is used in many professional soccer clubs. The anaerobic threshold is usually calculated from the lactate performance curve using a field level test, an organizationally, time and financially efficient test for large groups of players. According to many authors [1,32,35], among many indicators, threshold running speed (VAT) has the greatest diagnostic value in the assessment of effectiveness of applied training loads. It provides information about the dynamics of adaptive mechanisms of the body under the influence of applied training loads.

The present study revealed significant differences in threshold running speed between different stages of the training macrocycle. The most favourable changes in terms of exercise adaptation of examined players (Groups A and B) were noted after the basic preparatory period (T4). This trend has also been confirmed by Śliwowski et al. [39], Silva et al. [35] and McMillan et al. [32]. Also other authors [4,9,15,29] demonstrated that the level of VAT in senior players during the competitive period was significantly lower than the one observed after preparatory periods.

The older juniors (A) displayed higher values of threshold running speed (T1 – 3.67 $m \cdot s^{-1}$, T2 – 3.41 $m \cdot s^{-1}$, T3 – 3.79 $m \cdot s^{-1}$, T4 – 4.01 $m \cdot s^{-1}$) as compared with the younger juniors (T1 – 3.64 $m \cdot s^{-1}$, T2 – 3.35 $m \cdot s^{-1}$, T3 – 3.68 $m \cdot s^{-1}$, T4 – 3.80 $m \cdot s^{-1}$). Data similar to the data noted in the current study (older junior A) were also noted in the group of highly trained 17-year-old British players [32]. Mean values of the threshold running speed V/AT in compared periods of the annual training cycle increased from 3.78 $m \cdot s^{-1}$ to 4.05 $m \cdot s^{-1}$ (the start and the end of the season, respectively).

According to Kindermann et al. [30], high class soccer players should be characterised by a level of threshold values expressed as running speed exceeding 4 $m \cdot s^{-1}$. Kalapotharakos et al. [28] in their study of three Greek 1st division teams revealed mean values of VAT at the levels of 3.88 $m \cdot s^{-1}$ in a team at the top of the table, 3.69 $m \cdot s^{-1}$ in a team in the middle of the table and 3.66 $m \cdot s^{-1}$ in a team at the bottom of the table. Significant differences in threshold running speed were noted in 81 Turkish soccer players with regard to their field position [40]. Forwards and defenders featured higher VAT values (3.9 $m \cdot s^{-1}$ and 3.8 $m \cdot s^{-1}$, respectively) as compared with midfielders and goalkeepers (3.7 $m \cdot s^{-1}$ and 3.5 $m \cdot s^{-1}$, respectively). On the other hand, the study of Casajus [12] indicated that the mean threshold running speed for the 1st division Spanish players at the end of the season was 3.6 $m \cdot s^{-1}$. A similar level of threshold running speed (3.8 $m \cdot s^{-1}$) was noted in the 1st division German team [10]. Other studies [35] carried out in a professional team of Brazilian players indicate that the threshold running speed at the turn of the 12-week training cycle was 3.7 $m \cdot s^{-1}$ (1st date), 4.0 $m \cdot s^{-1}$ (2nd date) and 4.1 $m \cdot s^{-1}$ (3rd date of tests).

The VAT level suggested by Kindermann et al. [30] was accepted also by the coaching staff of KKS Lech Poznań as a criterion of positive selective assessment of functional preparation of promising players completing the older junior stage. The indicated level was achieved by older juniors of KKS Lech Poznań in the fourth test (Fig. 3).

A significant indicator from the point of view of training practice is recording heart rate at the anaerobic threshold (HR_{AT}). Such data make it possible to select training loads individually as well as to control exercise intensity in a training unit on an on-going basis. A rough analysis indicates that players' adaptation in terms of threshold heart rate in the present study did not run parallel to the threshold running speed. Unlike in the case of VAT, significant differences in HR_{AT} were found only in the team of older juniors between the 2nd and 3rd tests ($p < 0.05$, Fig. 1). The scope of changeability of HR_{AT} in older juniors ranged from 179 to 172 bpm^{-1}, whereas in younger juniors it was similar and ranged from 180 to 172 bpm^{-1}. HR_{AT} values similar to the ones in the present study (T3) were reported by Hegerud et al. [21] in highly trained 18-year-old Norwegian players. The players subjected to a special 8-week endurance training (including 2 x week 4-minute intervals, with the intensity of 90 95% HR_{MAX}) achieved the level of 178 bpm^{-1}, which corresponded to 87.6% HR_{MAX}. A recent study of Emre et al. [18] found mean threshold HR values in young Turkish players from an elite club at 179.3 bpm^{-1} (U-17), 175.3 bpm^{-1} (U-19) and 177 bpm^{-1} (U-21). The results in this study support the well-documented fact that the level of threshold heart rate in young players is higher than that in senior players [2,11,14,37].

Periodization of sports training and related changes in training loads in individual training periods have therefore a direct impact on the level of players' exercise adaptation. The analysis of tests carried out by players of KKS Lech Poznań revealed significant differences in their aerobic exercise capacity in individual periods of the annual training cycle. The most favourable changes in terms of exercise adaptation of the tested players were noted after the basic preparatory period (T4). In the analysis of character of training in the basic preparatory period a significant dominance of loads of versatile work type in the total load was noted. The above loads and the total volume of work reached here the highest level as compared with other training periods. Considering the share of training means used in the analysed period, the means of versatile preparation, typical for the accumulation stage, i.e. various forms of continuous and varied pace runs and general warm-ups, deserve particular attention. Also simplified and task-oriented games were of high significance, aimed among other things at developing players' general endurance by appropriately chosen technical and tactical aspects of the game. It seems, however, that the most important for the improvement of exercise capacity were, first of all, various individualised (at the level of lactate threshold) forms of continuous and varied pace runs. The above data correspond to the results of Bangsbo [4], Janssena [26], Bunc and Psota [11], who claim that exercises performed with the intensity close to AT are most effective in the development of aerobic abilities. These exercises may be successfully used in the training of young soccer players. Our experience of many years indicates that a 20-minute continuous run at variable intensity corresponding to the anaerobic threshold applied additionally once or twice a week in the competitive periods allows players to maintain high exercise functional fitness of the body for a longer time, and prevents it from falling significantly at the end of the competitive periods. It seems that this type of training loads (of slightly lower volume) should also take place in individual microcycles of the competitive period of young soccer players. We realize, however, that in the competitive periods in young teams, maintaining aerobic exercise capacity should mainly be combined with the development of technical and tactical abilities, mainly with the use of so-called small sided games [22,23,31,33]. To conclude the above, in order to develop aerobic training capacities of young players, combining these two training solutions seems to be optimal.

CONCLUSIONS

The study showed that periodization of sports training and related changes in training loads in individual periods of an annual training cycle of soccer players of KKS Lech Poznań had a direct impact on changes in the aerobic threshold. This was related mainly to threshold running speed where similar trends of changes were noted both in the older junior and younger junior age categories. The most favourable changes in terms of the participants' exercise adaptation were noted in basic preparatory periods. The programme of running training which included a careful selection of games of varied intensity and duration was of main importance here. This indicates the effective use of an individualised programme of training loads and good preparation of groups for the competitive period in terms of aerobic exercise capacity. The test of establishing the 4 $mmol \cdot l^{-1}$ lactate threshold may be a diagnostic tool which on the one hand will allow for monitoring of soccer training of young players, and on the other hand will enable forecasting and individualization of training loads.

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