Original Paper
Biol. Sport 2011;28:55-62

CHANGES IN AEROBIC PERFORMANCE IN YOUNG FOOTBALL PLAYERS IN AN ANNUAL TRAINING CYCLE

Accepted for publication 15.07.2010

AUTHORS: Śliwowski R.[1], Rychlewski T.[2], Laurentowska M.[2], Michalak E.[2], Andrzejewski M.[3], Wieczorek A.[1], Jadczak Ł.[1]

[1] Department of Team Sports Games of the University School of Physical Education in Poznań
[2] Department of Physiology of the University School of Physical Education in Poznań
[3] Department of Theory and the methodology of the recreation, University School of Physical Education Poznań

Reprint request to:
Robert Śliwowski
Department of Team Sports Games of the University School of Physical Education in Poznań
01-001 Poznań, Poland
e-mail: robertsliwowski@wp.pl

ABSTRACT: The aim of this study was to assess and compare the levels of aerobic performance of young football players in various periods of an annual training macrocycle. The study covered a group of fifteen 14-15-year-old football players of KKS Lech Poznań S.A. The study was carried out on five dates in key moments of the time frame of the annual training cycle (the beginning and the end of the basic preparatory period, the end of the spring round of the starting period and the beginning and the end of the autumn round of the starting period). In order to establish the level of aerobic performance the subjects performed an exercise test with increasing intensity on a Woodway treadmill with a 5% elevation. The initial speed of the treadmill belt was 8 $km \cdot h^{-1}$ and was increased every three minutes by 2 $km \cdot h^{-1}$ until exhaustion. During the exercise test the following physiological indicators were recorded on an ongoing basis using the Cardio Pulmonary Exercise computer system (Medical Graphics Corporation, USA): $\dot{V}O_2$, $\dot{V}O_2 \cdot kg^{-1}$, VE, $\dot{V}O_2 \cdot HR^{-1}$, RQ, as well as the running speed (V) and the distance covered. The values of parameters obtained at the level of the ventilatory threshold and with maximum load were analysed. In order to test the significance of differences in mean values between five dates of tests, Friedman's non-parametric analysis of variance (ANOVA) was used. The significance of differences between successive dates of tests was tested using post-hoc Friedman's ANOVA test. The tests showed significant differences in aerobic performance of young footballers in individual periods of the annual training cycle. The most favourable changes in terms of exercise adaptation of the participants were noted after the basic preparatory period. Then statistically significant changes were noted in the majority of the tested physiological parameters both with maximum load (MAX) and at the level of the ventilatory threshold (VT). In starting periods, probably as a result of a shift in training emphasis towards special loads, their gradual regression was noted.

KEY WORDS: physical efficiency, soccer, $\dot{V}O_{2max}$, anaerobic threshold

INTRODUCTION

Football is one of the most complex and demanding disciplines in which high sports achievements depend on many closely related factors. Due to the energetic aspect of the performance of many motor tasks, football is a sport of endurance and speed. It is characterised by a high changeability in speed of the game, as well as extensive and varied physical activity [4].

During a match at a high sports level the players perform approximately 1000 [32], 1300 [3], or 1400 [31] motor activities which are repeated in various order and at various moments of the game. Changes in these activities depend on the speed of moving, the direction in which individual technical elements are performed and on following the movements of the opponent. The most important forms of a player's motor activity are: starting from various positions and changes in direction, accelerating, multiple runs at a distance of several dozen metres (with or without the ball), technical activities with the ball, as well as marching and jogging [18].

Depending on the used method of observation of the play during a match it is assumed that an average distance covered by the players during a football match is from 8 to 12 km [4,32,39,42], whereas the value depends on the position of the player and the adopted tactics and is highly correlated with the level of $\dot{V}O_{2max}$. A review of the literature [36] indicates that the longest distances (approx. 15 km) are covered by the players of the English league. According to Barros et al. [6] the longest distance is covered by fullbacks (10.6 km), followed by central and wide midfielders (10.5 km). Central defenders cover the shortest distance (9 km) during 90 minutes of play.

The overall distance covered by footballers in a match includes on average: 24% marching, 36% jogging, 20% running with submaximal intensity, 11% sprinting and 7% running backwards [32]. Each of the above forms of motor activity is carried out at various distances, with very significant frequency of exertion. Only 2% of the total distance involves activities with the ball.

The analysis of the match heart rate (HR) and lactate concentration indicates that football involves interrupted exertions with varying intensity. The range of HR during a match is usually 155 to 170 beats·min^{-1} [2,39], which corresponds usually to 85% of HR_{max} and corresponds to the energy requirement of 70-75% $\dot{V}O_{2max}$ [32,37]. The heart rate depends not only on the speed of the game, but also on the position of the player in the team. Van Gool et al. [42] showed that mean values of HR are for defenders 155, midfielders 170, and forwards 171 beats·min^{-1}. They also noted that mean value of heart rate after the first half of the match is higher (169 beats·min^{-1}) than after the second half (165 beats·min^{-1}) and depends on the distance covered. The energy expenditure during the game is close to the anaerobic threshold (AT), exceeding it sporadically (but sometimes quite significantly) [3,34,42]. The study of Strøyer et al. [37] indicates that mean values of heart rate in young footballers during a match are higher than values noted in senior footballers: 173-177 beats·min^{-1} in pubertal boys and 173-178 beats·min^{-1} in boys in the final stage of puberty.

In the phases of the game when the players perform high intensity exertions there is a significant increase in the rate of glycolysis, which results in an increase in concentration of lactic acid (LA). The study of Ekblom [20] carried out on footballers of a professional Swedish league showed that the mean concentration of LA after the first half of the match was 9.5 mmol·l^{-1}, and 7.2 mmol·l^{-1} after the end of the match. Rohde and Espersen [35], studying players at half time and after the match of the Danish 1st league, obtained mean values from 3 to 6 mmol·l^{-1}. Also the study of Bangsbo [3], Thatcher and Batterham [39] confirmed that a mean concentration of LA in blood of highly qualified players after the match is at the level of 4-6 mmol·l^{-1}. The study of Capranica et al. [13] indicated on the other hand that the mean concentration of LA in young footballers after a match was 3.1 – 8.1 mmol·l^{-1}.

Taking into account the motor and energetic characteristics of the game, a condition for efficient performance of a footballer is a high level of performance – both aerobic and anaerobic [24,34,36]. Aerobic performance allows for more economical and effective carrying out of pitch activities without visible symptoms of fatigue and significantly contributes to a faster rate of recovery during breaks between more intensive exertions (mainly anaerobic-lactate ones). The studies of Bangsbo [2] prove that as many as 98% of the energy used during a match is covered by aerobic metabolic processes. Maximum stimulation of anaerobic processes during a game of football may only cover approximately 2% of the energy used. It should be remembered that sprints and accelerations during the game, which very often occur in series, activate aerobic processes. Thus, energetic securing of muscle work during a game of football requires the use of almost all metabolic paths: a) aerobic, b) aerobic-anaerobic, c) anaerobic-glycolytic, d) anaerobic-phosphagenic. Specific proportions between the above components are determined mainly by individual functional performance predispositions of a player, as well as tactical position on the pitch and volitional involvement in the game.

The aim of this study is to assess and compare the level of aerobic performance of young footballers in various periods of an annual training macrocycle.

MATERIALS AND METHODS

Participants. The participants of the study were a group of fifteen 14-15-year-old football players of KKS Lech Poznań S.A. All observations which are the basis of the discussion in the article were carried out in the key points of the time frame of an annual training cycle: January – the 1st date of tests before the start of the basic preparatory period, March – the 2nd date of tests at the end of the basic preparatory period and the beginning of the spring starting period, June – the 3rd date of tests at the end of the spring starting period, September – the 4th date of tests at the end of the shortened preparatory period and the beginning of the autumn starting period, November – the 5th date of tests at the end of the autumn starting period. The above division is justified by the physiological diagnosis of the state of trainedness in football.

Methodology of physiological tests. All laboratory tests were carried out in the morning in a specialist Functional Tests Laboratory of the Human Physiology Chair of the University School of Physical Education in Poznań, two hours after a standard meal. Before the test all participants were informed in detail about its aim, procedure, as well as their right to refuse to continue the exertion at any time. The programme of the study was accepted by the Local Committee for Ethics in Scientific Research. Also, the written consent of the parents of the boys taking part in the tests was obtained.

TABLE 1. ANTHROPOMETRIC CHARACTERISTICS OF THE STUDIED PLAYERS OF KKS LECH POZNAŃ S.A.

Parameter	I	II	III	IV	V
Height (cm)	170.7±7.29	171.1±6.79	172.1±6.96	173.1±7.05	174.5±7.17
Weight (kg)	58.4±9.36	58.5±9.39	60.0±9.56	61.5±9.53	63.6±9.77
BMI (kg/m2)	19.9±2.18	19.9±2.19	20.2±2.24	20.4±2.28	20.8±2.27

Legend: I - the 1st date of tests before the start of the basic preparatory period, II– the 2nd date of tests at the end of the basic preparatory period and the beginning of the spring starting period, III– the 3rd date of tests at the end of the spring starting period, IV– the 4th date of tests at the end of the shortened preparatory period and the beginning of the autumn starting period, V – the 5th date of tests at the end of the autumn starting period.

Aerobic performance test. In order to determine the level of aerobic performance the participants carried out test exertion of increasing intensity on a Woodway mechanical treadmill with a 5% elevation. The initial speed of the belt was 8 km · h^{-1} and it was increased by 2 km · h^{-1} every 3 minutes until exhaustion. During the exercise test the following parameters were registered on an ongoing basis using the Cardio Pulmonary Exercise computer system (Medical Graphics Corporation, USA): current one-minute oxygen uptake ($\dot{V}O_2$), relative value of one-minute oxygen uptake ($\dot{V}O_2 \cdot kg^{-1}$), pulmonary ventilation during exercise (VE), aerobic heart rate ($\dot{V}O_2 \cdot HR^{-1}$), respiratory quotient (RQ), as well as the speed of running (V) and the distance covered. The heart rate was measured using a Polar Accurex Plus sport-tester (Finland). The values of the parameters obtained at the level of the ventilatory threshold (VT) and with maximum load were taken into account in the analysis. On the basis of the above parameters the percentage of the maximum oxygen uptake and maximum heart rate at the ventilatory threshold were calculated.

The ventilatory threshold was determined on the basis of a computer analysis of the following parameters: the amount of exhaled carbon dioxide, respiratory quotient, oxygen and ventilatory quotient, respiratory rate, and end-tidal O_2 tension ($PETO_2$).

Methods of statistical analysis. For all tested parameters the following descriptive statistics were calculated: arithmetic mean ($\bar{x}$)and standard deviation (SD). The assessment of conformity of distribution was tested with the Shapiro-Wilk test. As a critical level of significance p=0.05 was adopted. In order to test the significance of differences in mean values between five dates of tests, Friedman's non-parametric ANOVA was used. Significance of differences between subsequent dates of tests, i.e. 1st vs. 2nd, 2nd vs. 3rd, 3rd vs. 4th, and 4th vs. 5th, was tested using post-hoc Friedman's ANOVA test. Statistical analysis was carried out using the STATISTICA program.

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 exercise capacity of the participating players had a comprehensive character. In the preparatory periods (the basic one and the shortened one), and, first of all, in sub-periods of general preparation, versatile loads prevailed. While in the basic preparatory period the sub-period of general preparation took five microcycles, in the shortened preparatory period it took only two microcycles. The most often used means of versatile preparation were general warm-ups, supplementary sports and continuous and changeable runs. A classic basic microcycle of this sub-period usually included eight training units, of which at least two were carried out outside and had a strict form. Moreover, three training units contained in their structure development of aerobic endurance. However, here a task-oriented, play form, fragment of play, as well as task-oriented and school games were introduced. The scope of intensity during these training units was within individual values of players [HR/AT]. So from the point of view of energy area the exercises were loads carried out in terms of maintaining, aerobic and mixed intensity.

In football the basic training cycle in the starting period is a weekly microcycle defined by the time between matches. Here the selection of appropriate training loads is a significant element supporting exercise capacity developed in the preparatory period, but also not allowing for unfavourable fatigue changes to occur. A training microcycle from this period contained 6-7 training units in which special loads prevailed mainly (training methods directed at developing football skills). On the first day of the week training loads were directed towards aerobic work and their aim was, among other things, levelling fatigue changes arising from playing a competitive match. The greatest loads were used on the second and third days of the week. At this time most exercises were organised in the special area 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 was based on using technical and tactical exercises taking into consideration the next match. In order not to allow chronic fatigue changes the range of loads was at an average and low level, and in training classes anaerobic and non-lactate work prevailed.

RESULTS

Table 2 presents mean values of physiological indicators at maximum load (MAX) and at the ventilatory threshold (VT) in players of KKS Lech Poznań S.A. on subsequent dates of tests. The table also presents the results of Friedman's ANOVA analysis of variance on five dates of tests with the results of post-hoc Friedman's ANOVA test between consecutive dates for comparable physiological parameters.

The analysis of the above material indicates significant differences in the range of changes in effort tolerance of young footballers in individual periods of an annual training cycle. This referred to physiological parameters obtained both at maximum load (MAX) and at the level of the ventilatory threshold (VT).

In terms of the values achieved by young footballers at maximum loads the most favourable changes in reference to effort adaptation of the tested people were noted during tests carried out between the 1st and 2nd dates of tests. Then statistically significant changes in terms of most of the studied physiological indicators were noted. This is confirmed by changes observed in the basic indicator of aerobic performance that is maximum oxygen uptake, where significant differences were noted at the level of $p<0.01$. The highest mean value of the indicator in question was noted in the participants on the 2nd date of tests, namely 58.70 [ml·kg^{-1}·min^{-1}].

A similar tendency of changes was also noted in the case of maximum value of pulmonary ventilation during exercise [VE_{max}], which between the 1st and 2nd date of tests differentiates the participants at the confidence level $p<0.01$.

Observation of changes in selected circulatory and respiratory physiological indicators was focused on the maximum heart rate and maximum oxygen pulse. A detailed analysis [HR_{max}] showed a falling trend in our study. No statistically significant differences in the analysed indicator were noted between successive dates of tests.

TABLE 2. DESCRIPTIVE CHARACTERISTICS (MEAN ± STANDARD DEVIATION) OF PHYSIOLOGICAL INDICATORS AT MAXIMUM LOAD (MAX) AND AT THE VENTILATORY THRESHOLD (VT) IN PLAYERS OF KKS LECH POZNAŃ S.A. WITH VALUES OF SIGNIFICANCE OF DIFFERENCES BETWEEN SUCCESSIVE DATES OF TESTS.

Indicators	I	II	III	IV	V	ANOVA Friedmana test (post hoc)
Physiological indicators at maximum load (MAX)						
VO_{2max} (ml·kg^{-1}·min^{-1})	51.47±3.944	58.70±4.434	56.88±3.770	53.49±4.099	53.65±4.979	28.43** (IvsII**)
VE_{max} (l·min-1)	87.47±17.594	105.40±15.555	103.27±19.470	96.87±17.968	96.00±15.501	27.74** (IvsII**)
HR_{max} (sk·min^{-1})	200.33±5.499	199.00±5.542	198.80±6.178	196.67±5.205	195.80±5.821	26.42** ns
V_{max} (km·h^{-1})	12.53±1.187	14.67±0.976	14.27±0.704	13.87±0.516	14.00±0.000	34.26** (IvsII**)
$VO_{2max}·HR_{max}^{-1}$ (ml)	14.82±2.493	17.52±3.126	17.19±2.862	16.91±2.905	16.83±2.518	26.89** (IvsII**)
Distance (m)	1527.93±292.82	1968.93±438.058	1852.33±88.028	1759.87±108.542	1445.93±188.357	26.81** (IvsII*&IVvsV*)
Physiological indicators at the ventilatory threshold (VT)						
VO_2VT (ml·kg^{-1}·min^{-1})	42.81 ± 3.915	49.64±3.032	47.20±3.992	45.35±4.112	43.57±5.248	28.40** (IvsII**)
VEVT (l·min^{-1})	77.07 ± 13.946	86.93±13.724	78.60±12.182	81.60±12.141	72.20±12.313	20.80** (IIvsIII*)
HRVT (sk·min^{-1})	180.93 ± 5.444	180.53±5.290	178.47±5.125	176.60±4.469	174.60±5.221	42.09** ns
VVT (km·h^{-1})	11.67 ± 0.900	13.60±0.828	12.60±0.828	12.80±0.775	12.27±0.458	32.92** (IvsII**)
$VO_2VT·HRVT^{-1}$ (ml)	13.70 ± 2.385	16.37±2.760	15.71±2.464	15.78±2.458	15.35±2.713	17.48** (IvsII**)
$\%VO_2max$ (%)	83.19 ± 4.744	84.77±4.435	82.97±7.204	84.84±5.021	81.20±6.341	8.43ns ----
$\%HR_{max}$ (%)	90.32 ± 1.060	90.77±0.939	89.69±1.305	89.88±1.043	89.17±1.062	19.93** ns

Note: ** p<0.01; * p<0.05; ns – no statistically significant
I - the 1st date of tests before the start of the basic preparatory period, II– the 2nd date of tests at the end of the basic preparatory period and the beginning of the spring starting period, III– the 3rd date of tests at the end of the spring starting period, IV– the 4th date of tests at the end of the shortened preparatory period and the beginning of the autumn starting period, V – the 5th date of tests at the end of the autumn starting period.

Analysing the maximum value of the oxygen pulse, similar results were obtained by the tested players, and differences were only noted between the 1st and 2nd dates ($p<0.01$).

The mechanical effect of the performed test work was illustrated in our study by the maximum running speed and total distance covered. The highest mean value [V_{max}] was achieved by the young players of KKS Lech Poznań S.A. on the 2nd date of tests with a result 14.67 [km·h^{-1}], which was confirmed by participants covering the longest distance of 1968.93 [m]. On the basis of a detailed analysis its was found that the values of maximum running speed noted on the five dates of tests were similar. They differentiated between the participants only between the 1st and 2nd dates ($p<0.01$). A different nature of changes was also noted in the distance covered by young footballers during the exercise test. Statistically significant differences were noted between the 1st and 2nd and the 4th and 5th tests at the confidence level of $p<0.05$.

A similar direction of changes as in the case of maximum values was noted in observation of threshold values of the studied indicators achieved by young players of KKS Lech Poznań S.A. In the analysis of the value of one-minute oxygen uptake at the ventilatory threshold, the highest value was achieved by the participants on the 2nd date of tests, with a result of 49.64 [ml·kg^{-1}·min^{-1}]. A statistically significant difference was noted only between the 1st and 2nd dates ($p<0.01$).

In terms of threshold one-minute pulmonary ventilation during exercise, statistically significant changes were noted between the 2nd and 3rd dates of tests ($p<0.05$).

The threshold value of heart rate HR_{VT} [beats·min^{-1}] was lower in each consecutive test, reaching its lowest value of 174.60 [beats·min^{-1}] in the 5th test.

While significant differences were noted between the five dates of tests in the case of percentage values of heart rate [%HR_{max}], this trend was not noted in reference to percentage values of one-minute oxygen uptake (% $\dot{V}O_{2max}$).

The threshold running speed V_{VT} [km·h^{-1}], similar to maximum values, showed statistically significant differences only between the 1st and 2nd dates of tests ($p<0.01$). The highest value of the indicator in question was achieved by the players on the 2nd date, with a result of 13.60 [km·h^{-1}]. A course of changes similar to the threshold value of running speed was noted also in the case of threshold values of oxygen pulse, for which there were statistically significant differences between the 1st and 2nd dates of tests ($p<0.01$).

DISCUSSION

An objective assessment of adaptive changes caused in a player's body by training loads requires the application of various tests to precisely specify the nature of these changes. One of the basic elements of physiological diagnosis is aerobic performance [4]. According to Bangsbo and Michalsik [5], aerobic performance is determined by aerobic power and capacity. The former of the two components reflects the ability to produce aerobic energy at high speed and is characterised by a maximum oxygen uptake. The latter expresses the ability to maintain the high intensity effort for a longer time and is synonymous with endurance. According to Reilly [34] and Bangsbo [3], aerobic performance is not only a biological foundation of endurance, but significantly favours acceleration and increase in recovery processes in very intensive interval exertions which take place during a game of football. The above-mentioned maximum oxygen uptake ($\dot{V}O_{2max}$) is generally believed to be the best measure of aerobic performance [43]. According to Bassett et al. [7], the greater the oxygen uptake, the greater the effort tolerance of a player, irrespective of the sport. It is assumed that by using sports training it is possible to improve the above effort tolerance by 20-25% compared to the initial values [40]. In the light of many studies [29,30,38], changes in maximum oxygen uptake in reference to a training cycle are most reliable in young players, with an unstabilised level of their effort tolerance.

The above observations are also confirmed by the current study, indicating high differences in the level of $\dot{V}O_{2max}$ in the players of KKS Lech Poznań S.A. in individual periods of an annual macrocycle. The range of variation in the whole analysed period was from 51.5 ml·kg^{-1}·min^{-1} to 58.7 ml·kg^{-1}·min^{-1} (Table 2). The direction of changes in $\dot{V}O_{2max}$ showed the above-mentioned (after the end of the basic preparatory period) statistically significant increase ($p<0.01$, Table 2), and then a gradual decrease in subsequent tests. Similar changes in this indicator in reference to selected training periods of a many-year macrocycle of training were noted in 16-17-year-old footballers of Szkoła Mistrzostwa Sportowego (SMS Sport Championship School) in Gdańsk [26]. Reilly et al. [33] in their review of literature on physiological determinants of the game of football of young, highly trained players, published data indicating that $\dot{V}O_{2max}$ at the age of 14 to 17 years ranges from 57.7±6.8 to 62.0±2.0 ml·kg^{-1}·min^{-1}. Similar values of $\dot{V}O_{2max}$ in the discussed age (U-14 56±2 ml·kg^{-1}·min^{-1}, U-15 58±2 ml·kg^{-1}·min^{-1}, U-17 62±2 ml·kg^{-1}·min^{-1}) are also confirmed by the recent study of Gil et al. [22]. The studies of Heller et. al. [24] provide interesting information which indicates that 16-year old Czech juniors obtained higher mean values of $\dot{V}O_{2max}$ compared to seniors (59.9 ml·kg^{-1}·min^{-1} vs. 58.2 ml·kg^{-1}·min^{-1}). The results of a number of other reports indicate [33] that $\dot{V}O_{2max}$ in adult footballers ranges from 56 to 69 ml·kg^{-1}·min^{-1} and to some extent is related to the player's position in the field.

One of the basic physiological indicators illustrating the condition of a body's involvement in physical exertion, as well as generally informing about the adaptation of the circulatory system to physical work, is the heart rate. It is generally accepted that its maximum values (HR_{max}) do not undergo great post-training changes [15,16]. In the current study a tendency to a gradual decrease in HR_{max} was noted. The narrow range of variation for the whole material was from 200 to 196 beats·min^{-1}. The above tendency should probably be attributed to developmental processes. The study of Cempla [16] on developmental changes of selected exercise indicators in boys after the pubertal stage of development indicated a clear falling trend in the maximum heart rate with age, and a significant yearly fall in the above values took place in boys in the year before the 15th birthday.

Another characteristic phenomenon in the developmental period is a gradual increase in effectiveness of pulmonary ventilation during exercise. In the current study the changes in maximum pulmonary ventilation during exercise (VE_{max}) were clearly related to the course of maximum oxygen uptake. The lowest values of this indicator (87.5 L·min^{-1}) were noted on the 1st date of tests, and the highest (105.4 L·min^{-1}) on the 2nd date of tests, after which their gradual regression was noted. Similar to $\dot{V}O_{2max}$·kg^{-1}, the greatest differences in VE_{max} related to the tests between the above 1st and 2nd dates of tests ($p<0.01$, Table 2). The studies of Cempla [17] indicate that the values of VE_{max} achieved by non-training boys aged 14-15 years are on average 90-94 L·min^{-1}. During maximum physical exertion in 1st division footballers VE_{max} of 105 to 190 L·min^{-1} was noted, and in juniors of Sports Championship Schools 98-170 L·min^{-1} [41].

Also, maximum aerobic heart rate ($\dot{V}O_{2max}$·HR_{max}^{-1}) remained in close relation with $\dot{V}O_{2max}$·kg^{-1}. It illustrates the relation between the oxygen supply to tissues and the basic value characterizing the functions of the circulatory system, that is the heart rate. The range of changes in the indicators in question was from 14.8 ml to 17.5 ml (Table 2). The difference, as the only one for the whole period of observation, was statistically significant ($p<0.01$, Table 2). The values of $\dot{V}O_{2max}$·HR_{max}^{-1} quoted above are typical for teenagers playing football [1].

The final running speed and the distance covered, which provide a measure of the maximum exercise load, are an effective side of the energy potential of a player. They are in a close relation with the level of aerobic performance, which theoretically determines them. This was also confirmed by the current study indicating identical fluctuations of the above indicators in relation to $\dot{V}O_{2max}$, VE_{max} and $\dot{V}O_{2max} \cdot HR_{max}^{-1}$.

In the latest diagnostics of the process of training management the so-called “anaerobic threshold” (AT) is used more and more commonly [40]. In order to establish the anaerobic threshold a number of both invasive and non-invasive methods are used. In football training practice the most frequently used method is based on establishing the concentration of lactic acid in blood during an exercise test with a gradually increasing intensity and establishing using interpolation a load which corresponds to the level of LA concentration equal to 4 $mmol \cdot l^{-1}$ (called the lactate threshold) [14,25]. Recently non-invasive methods of determining the aerobic threshold have been used more and more commonly. Among them a popular one is the ventilatory threshold (VT), established on the basis of gasometric indicators [11,12].

Among many established threshold indicators – according to Jastrzębski [25] – the threshold running speed (V_{VT}) shows the greatest diagnostic qualities in assessing the effectiveness of the applied football training. It informs about the dynamics of adaptive mechanisms of the body under the influence of applied training loads.

In the current study, as expected, the highest values of this indicator were noted after the basic (the 2nd date of tests) and shortened (the 4th date of tests) preparatory periods, 13.6 and 12.8 $km \cdot h^{-1}$, respectively (Table 2). Lower values of V_{VT} were noted after the spring (the 3rd date of tests) and autumn (the 5th date of tests) starting periods, 12.6 and 12.3 $km \cdot h^{-1}$, respectively (Table 2). Also the studies of other authors [8,19] showed that the level of V_{VT} in senior footballers after starting periods is significantly lower than the one noted after preparatory periods. Significant differences in the analysed indicators in the current study were noted only between the 1st and 2nd dates of tests ($p<0.01$, Table 2).

According to Kindermann et al. [28], high class footballers should be characterised by a level of threshold values expressed as a running speed exceeding 4 $m \cdot s^{-1}$.

Kalapotharakos et al. [27] in a study of three Greek 1st division teams showed that mean values of V_{AT} are at the level of 3.88 $m \cdot s^{-1}$ (in the team at the top of the table), 3.69 $m \cdot s^{-1}$ (in the team in the middle of the table), and 3.66 $m \cdot s^{-1}$ (in the team at the bottom of the table). Significant differences in threshold running speed were noted in 81 Turkish players taking into account their position in the field [44]. Forwards and defenders had higher values of V_{AT} (3.9 $m \cdot s^{-1}$ and 3.8 $m \cdot s^{-1}$, respectively) compared to midfielders and goalkeepers (3.7 $m \cdot s^{-1}$ and 3.5 $m \cdot s^{-1}$, respectively). An identical level of the threshold running speed, 3.6 $m \cdot s^{-1}$, was noted in a 1st division Spanish team after the end of the season [14].

A threshold level characterised by percentage values of maximum oxygen uptake and maximum heart rate (% $\dot{V}O_{2max}$ and % HR_{max}), apart from threshold running speed, is the most frequent measure of training effect given in the literature. The higher the level of metabolic adaptation to a given physical work, the higher the values of % $\dot{V}O_{2max}$ and % HR_{max} at the level of AT. The results of studies by many authors show [9,10,11] that highly trained athletes in various sports disciplines are able to achieve threshold values of $\dot{V}O_2$ and HR at a level exceeding 80% of $\dot{V}O_{2max}$ and 90% of HR_{max}, respectively. It was also noted [9,11] that the values of the above threshold indicators for highly trained young and adult players are practically the same. In the current study, due to the parallel changes in $\dot{V}O_{2max}$ and $\dot{V}O_{2VT}$, referred to above, percentage values of maximum oxygen uptake were characterised by very small changes, from 81.2% $\dot{V}O_{2max}$ (the 5th date of tests) to 84.8% $\dot{V}O_{2max}$ (the 4th date of tests). There was also a narrow range of changes of percentage values of maximum heart rate (from 89.2% HR_{max} on the 5th date of tests to 90.8% HR_{max} on the 2nd date of tests). While significant differences were noted between the five dates of tests for percentage values of heart rate [%HR_{max}], this trend was not noted for percentage values of one-minute oxygen uptake (% $\dot{V}O_{2max}$).

The results indicate that in the aspect of continuous study the indicators do not play such a significant role in the assessment of effort tolerance as they have been attributed [34]. Thus, it seems that using absolute values of a given property is better (e.g. $\dot{V}O_{2VT} \cdot kg^{-1}$, V_{VT}, HR_{VT} etc.).

Threshold values of one-minute oxygen uptake during exercise ($\dot{V}O_{2VT} \cdot kg^{-1}$) remained, as mentioned above, in a close relation with their maximum level ($\dot{V}O_{2max} \cdot kg^{-1}$). The lowest values of this indicator (42.8 $ml \cdot kg^{-1} \cdot min^{-1}$) were noted on the 1st date of tests, while the highest (49.6 $ml \cdot kg^{-1} \cdot min^{-1}$) were noted on the 2nd date of tests, after which their gradual regression was observed.

A significant indicator from the point of view of training practice is recording heart rate at the level of the anaerobic threshold (HR_{VT}). The knowledge of this indicator makes it possible to select training loads individually, as well as to control on an ongoing basis the intensity of exertion in players during a training unit.

As in the case of maximum heart rate, a one-directional course of changes was noted here, characterised by constant lowering of the value on successive dates of tests. The range of variation of HR_{VT} was from 181 to 175 $beats \cdot min^{-1}$. The mean value of HR_{VT} for the whole tested team was 178 $beats \cdot min^{-1}$, which amounted to approximately 90% of HR_{max}.

The recent studies of Emre et al. [21] indicate that mean threshold HR values in young Turkish players from an elite club were at the level of 170.3 $contractions \cdot min^{-1}$ (U-17), 175.3 $contractions \cdot min^{-1}$ (U-19) and 177 $contractions \cdot min^{-1}$ (U-21). The results obtained in the current study confirm a fact well documented in the literature that the level of threshold heart rate in young players is higher than that noted in senior footballers [9,11].

Periodisation of sports training and related changes in training loads in individual training periods therefore have a direct impact on the level of exercise adaptation in players. The analysis of tests of footballers of KKS Lech Poznań S.A. showed significant differences in their aerobic exercise capacity in individual periods of the annual training cycle. The most favourable changes in respect of exercise adaptation of the tested players were noted after the basic preparatory period (Test 2), and taking into account the most diagnostic threshold indicators also after the shortened preparatory period (Test 4). In the analysis of character of training in the preparatory periods a significant domination of loads of the versatile work type in the total load was noted. The above loads and the global volume of work reached here the highest level compared to other training periods. Considering the share of training methods used in the analysed period, the methods of versatile preparation, typical for the accumulation stage, deserve particular attention, i.e. various forms of continuous and changeable running and general warm-ups. Also simplified and task-oriented games were of high significance here, aimed among other things at developing general endurance by appropriately selected technical and tactical elements of the game. It seems, however, that the greatest importance for the improvement of exercise capacity was first of all individualised (at the level of lactate threshold), varied forms of continuous and changeable running. In the starting periods, probably as a result of a shift in training emphasis towards special loads, the level of aerobic performance was gradually lowered. Jastrzębski and Szwarc [26] believe that this is a tendency characteristic for team sport games. This is also confirmed by observations of other authors [8,23,26], who indicate the above changes in aerobic performance during the season, probably resulting from the classic structure of an annual training cycle in football.

In our study the least favourable direction of changes was noted after the autumn starting round (Test 5) when (except for the 1st date of tests) the lowest level of most maximum and threshold physiological indicators was noted (Table 2). According to the training assumptions special loads prevailed in this period. Versatile loads were aimed at maintaining the level of aerobic performance achieved earlier. These observations indicate that the applied loads determine mainly the development of adaptation processes in terms of aerobic performance of young players. Heller et al. [23] suggest that a 20-minute continuous run of an intensity corresponding to the anaerobic threshold applied additionally once or twice a week in the starting periods allows the players to maintain for a longer time a high exercise functional fitness of the body, preventing it from lowering significantly at the end of the starting periods. It seems that this type of training loads (of slightly lower volume) should also take place in individual microcycles of the starting period of young footballers.

CONCLUSIONS

1. Periodisation of sports training and related changes in training loads in individual periods of an annual training cycle of footballers of KKS Lech Poznań S.A. directly affected the course of effort adaptation in terms of aerobic effort tolerance. This related in particular to the basic preparatory period, when favourable statistically significant changes in most physiological indicators were noted. In starting periods their gradual regression took place, probably due to the shift in training emphasis toward special loads.
2. The level of diagnostic physiological indicators recorded in the tested players was good compared to the values obtained by other authors who assessed the level of aerobic performance. This makes it possible to develop later (at the age of a senior) a high level of aerobic endurance and performance.
3. Comprehensive tests of aerobic performance used in monitoring of sports training of young footballers fully meet the requirements in terms of identification of direction and range of changes in exercise adaptation of the studied people, and thus make it possible to individualise training loads.

REFERENCES

1. Apor P. Successful formulae for fitness training. In: T.Reilly, A.Lees, K.Davids, W.J.Murphy (eds.) Science and Football. Spon, London 1988;pp.95-105.
2. Bangsbo J. The Physiology of Soccer – with Special Reference to Intense Intermittent Exercise. August Krogh Institute, University of Copenhagen, Denmark 1993.
3. Bangsbo J. Fitness Training in Football – a Scientific Approach. August Krogh Institute, University of Copenhagen, Denmark 1994.
4. Bangsbo J., Krustrup P. Physical demands and training of top-class soccer players. In: T.Reilly and F.Korkusuz (eds.) Science and Football VI. Routledge 2009;pp.318-330.
5. Bangsbo J., Michalsik L. Assessment of the physiological capacity of elite soccer players. In: T.Reilly, A.Murphy, W.Spinks (eds.) Science and Football IV. Routledge 2002;pp.53-62.
6. Barros R.M.L., Misuta M.S., Menezes R.P., Figueroa P.J., A.Moura F.A., Cunha S.A., Anido R., Leite N.J. Analysis of the distances covered by first division Brazilian soccer players obtained with an automatic tracking method. J. Sports Sci. Med. 2007;6:233-242.
7. Bassett D.R., Howley J.R., Howley E.T. Limiting factors for maximum oxygen uptake and determinants of endurance performance. Med. Sci. Sports Exerc. 2000;32:70-84.
8. Brady K., Maile A., Ewing B. An investigation into the fitness of professional soccer players over two seasons. In: T.Reilly, J.Bangsbo, M. Hughes (eds.) Science and Football III. Spon, London 1997;pp.118-122.
9. Bunc V., Heller J., Šprynarová Š., Zdanowicz R. Comparison of the anaerobic threshold and mechanical efficiency of running in young and adult athletes. Int. J. Sports Med. 1986;7:156-160.
10. Bunc V., Heller J., Horcic J., Novotny J. Physiological profile of best Czech male and female young triathletes. J. Sports Med. Phys. Fitness 1996;36:265-270.
11. Bunc V., Heller J., Leso J., Šprynarová Š., Zdanowicz R. Ventilatory threshold in various groups of higly trained athletes. Int. J. Sports Med. 1987;8:275-280.
12. Bunc V., Psota R. Physiological profile of young soccer players. J. Sports Med. Phys. Fitness 2001;41:337-341.
13. Capranica L., Tessitore A., Guidetti L. Heart rate and match analisis in

pre-pubescent soccer players. J. Sports Sci. 2001;19:379-384.
14. Casajus J.A. Seasonal variation in fitness variables in professional soccer players. J. Sports Med. Phys. Fitness 2001;41:463-469.
15. Cempla J. Aspekty rozwojowe w fizjologii wysiłku. Med. Sportiva 2004;8(Suppl.1):S19-S31 (in Polish).
16. Cempla J. Zmiany rozwojowe wybranych wysiłkowych wskaźników fizjologicznych u dziewcząt i chłopców w popokwitaniwej fazie rozwoju (13-17 lat). Wych. Fiz. Sport 1996;4:3-16 (in Polish).
17. Cempla J. Poziom i zmiany z wiekiem progów metabolicznych, maksymalnego poboru tlenu oraz zależności parametrów fizjologicznych od obciążenia wysiłkiem u 13-15 letnich dziewcząt i chłopców. AWF Kraków 1993, Wydawnictwo Monograficzne 57 (in Polish).
18. Drust B., Atkinson G., Reilly T. Future perspectives in the evaluation of the physiological demands of soccer. Sports Med. 2007;37:783-805.
19. Dunbar G.M.J. An examination of longitudinal change in aerobic capacity through the playing year in Englisch professional soccer players, as determined by lactate profiles. In: W.Spinks, T.Reilly, A.Murphy (eds.) Science and Football IV. Routledge 2002;pp.72-75.
20. Ekblom B. Applied physiology of soccer. Sports Med. 1986;3:50-60.
21. Emre A.K., Yildirim A., Cicek S., Korkusuz F. Comparison of physiological profiles of soccer players in U17, U19, U21 and over-21 age groups. In:T.Reilly and F.Korkusuz (eds.) Science and Football VI. Routledge 2008;pp.360-364.
22. Gil S., Ruiz F., Irazusta A., Gil J., Irazusta J. Selection of young soccer players in terms of anthropometrics and physiological factors. J. Sports Med. Phys.Fitness 2007;47:25-32.
23. Heller J., Procházka L., Bunc V., Dlouhá R., Novotný J. Functional capacity in top league for football players during compatitive period. Communications to the Second World Congress on Science and Football, Eindhoven. J. Sports Sci. 1992;10:139-205.
24. Heller J., Bunc V., Buzek M., Novotný J., Psota R. Anaerobic power and capacity in young and adult football (Soccer) players. Acta Univ. Carol. Gymn. Kinanthrop. 1995;31:73-83.
25. Jastrzębski Z. Obciążenia treningowe i ich wpływ na rozwój sportowy piłkarzy nożnych i ręcznych. AWFiS Gdańsk 2004 (in Polish).
26. Jastrzębski Z., Szwarc A. Struktura organizacyjna i jej wpływ na efektywność szkolenia piłkarskiego na przykładzie Szkoły Mistrzostwa Sportowego w Gdańsku. AWFiS Gdańsk 2003 (in Polish).
27. Kalapotharakos V., Strimpakos N., Vithoulka I., Karvounidis C., Diamantopoulos K.E. Kapreli Physiological characteristics of elite rofessional soccer teams of different ranking. J. Sports Med. Phys. Fitness 2006;46:515-519.
28. Kindermann W., Gabriel H., Coen B., Urhausen A. Sportmedizinische Leistungsdiagnostik in Fußball. Dtsch. Z. Sportmed. 1993;44:232-236.
29. McMillan K., Helgerud J., Macdonald R., Hoff J. Physiological adaptations to soccer specific endurance training in professional youth soccer players. Br. J. Sports Med. 2005;39:273-277.
30. Metaxas T., Sendelides T., Koutlianos N., Mandroukas K. Seasonal variation of aerobic performance in soccer players according to positional role. J. Sports Med. Phys. Fitness 2006;46:520-525.
31. Mohr M., Krustrup P, Bangsbo J. Match performance of highstandard soccer players with special reference to development of fatigue. J. Sports Sci. 2003;21:519-528.
32. Reilly T. Physiological aspects of soccer. Biol. Sport 1994;11:3-20.
33. Reilly T., Bangsbo J., Franks A. Anthropometric and physiological predispositions for elite soccer. J. Sports Sci. 2000;18:669-683.
34. Reilly T. The Science of Training – Soccer. Routledge, London 2007.
35. Rohde H.C., Espersen T. Work intensity during soccer training and match play. In: T.Reilly, A.Lees, K.Davids, W.J.Murphy (eds.) Spon, London 1988;pp.68-75.
36. Stølen T., Chamari K., Castagna C., Wisløff U. Physiology of soccer. An update. Sports Med. 2006;35:501-536.
37. Strøyer J., Hansen L., Klausen K. Physiological profile and activity pattern of young soccer players during match play. Med. Sci. Sports Exerc. 2006;36:168-174.
38. Svensson M., Conway P., Drust B., Reilly T. Performance on two soccer-specyfic high-intensity intermittent running protocols. In: T.Reilly, F.Korkusuz (eds.) Science and Football VI. Routledge 2008;pp.350-356.
39. Thatcher R., Batterham A.M. Development and validation of a sport-specific exercise proctol for elite youth soccer players. J. Sports Med. Phys.Fitness 2004;44:15-22.
40. Tyka A. Wybrane zagadnienia z fizjologii sportu – fizjologiczne aspekty piłkarstwa. Med. Sportiva 2004;8:S5-S17 (in Polish).
41. Tyka A., Żuchowicz A., Pałka T. Ekspertyzy zastrzeżone z badań piłkarzy nożnych I, II i III ligi oraz grup młodzieżowych, przeprowadzonych w latach 1985-2002. Dwadzieścia raportów do wglądu w Instytucie Fizjologii Człowieka AWF Kraków, cytat za: Tyka A. Fizjologiczne aspekty piłkarstwa. Med. Sportiva 2004;8(Suppl.1):S5-S17 (in Polish).
42. Van Gool D., Van Gerven D., Boutmans J. The physiological load imposed on soccer players during real match-play. In: T.Reilly, A.Lees, K.Davids, W.Murphy (eds.) Science and Football. Spon, London 1988;pp.51-59.
43. Wilimore J.H., Costill D.L. Physiology of Sport and Exercise. Human Kinetics, Champaign 1999.
44. Yildirim A., Emre A.K., Korkusuz F., Cicek S. Physiological profiles of soccer players with respect to playing positions. In: T.Reilly and F.Korkusuz (eds.) Science and Football VI. Routledge 2008;pp.370-373.