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SPORT EXERCISE CAPACITY OF SOCCER PLAYERS AT DIFFERENT LEVELS OF PERFORMANCE

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ABSTRACT: The aim of the study is to compare the level of exercise capacities to the loads occurring at the lactate threshold among soccer players representing different levels of sport mastery. The research included 51 soccer players representing different levels of sport mastery. The research was conducted at the beginning of the preparatory period for the spring season. A field exercise test of increasing intensity was performed to check the players' exercise capacities on the soccer pitch. The test enabled us to determine the 4 millimolar lactate threshold (TLA 4 $mmol \cdot l^{-1}$) on the basis of lactate concentration in blood (LA), and to define the threshold running speed and the threshold heart rate (HR). The lactate level in blood was measured using a Lactate Scout photometer with the enzyme-amperometric method from capillary blood for 20 seconds after each load. The threshold running speed at the level of the 4 millimolar lactate threshold was marked using the two-point form of the equation of a straight line. The conducted tests showed significant differentiation of the threshold running speed among individual teams. The soccer players of a leading first league club were expected to achieve the best result. The conducted tests did not confirm this assumption. Juniors reached the highest threshold running speed of 3.61 $m \cdot s^{-1}$. Lower values of the analysed indicator were acquired by players of the first league team (3.50 $m \cdot s^{-1}$) and the lowest by players of the second league team (3.28 $m \cdot s^{-1}$). Statistically significant differences were noted between the junior group and second league team ($p \leq 0.01$) and between the first and the second league soccer players ($p < 0.05$).

KEY WORDS: endurance capacity, threshold speed, lactate threshold

INTRODUCTION

Soccer, like every other team game, is a discipline of remarkably acyclic type of movement. In recent years this sport has manifested special development dynamics in the sphere of exercise capacity. The play becomes more and more sophisticated in tactical and technical terms, requiring proficient endurance capacity preparation.

During a match the players of the best European teams cover a distance of about 9-13 km [1,4,14,21,23,25,29], with the average intensity approximated to the lactate threshold (LT) [17,22,27,30]. The biggest part of the distance is covered by marching and low intensity running (about 8-9 km), with 1.5-2.5 km of running at a very quick pace and sprints [4,7,8,15]. The distance covered during the match depends, among other things, on the biological potential, level of training, tactical assumptions and the formation a specific player belongs to. It should be emphasized that the covered distance is not the exact form of work performance done by a player because of very frequent changes in physical activities. The study by Carling and Dupont [12] showed that a ball is in play for about 60 minutes during a match, which means that each team has the ball for 30 minutes at an aligned level of the opponents. For comparison, Dellal et al. [13] noted that the average time of ball possession of world class soccer players is from 55 to 75 seconds. Apparently, team play effectiveness must depend on the players' performance without a ball during the remaining 60 minutes of a match. Players' endurance training has the dominant role during that time. Because of the duration of a soccer game, i.e. 90 minutes, and a player's physical exertion intensity during a game (about 70% $\dot{V}O_{2max}$), a good level of aerobic endurance enables a soccer player to use aerobic energy resources to a greater extent during a match. The study by Bangsbo et al. [2] proved that 98% of energy used during a match is covered by aerobic metabolic processes which supply energy indispensable for moving with low and average running pace. A player also gains tolerance for the cumulative fatigue process arising due to physical exertion of high (above LT) and very high (sprints) intensity. High level of endurance capacity enables a player to develop a quicker pace of play which may be sustained during the whole competition time.

The heart rate, among different physiological data, is the most sensitive indicator of quick metabolic change that occurs during physical activities. Referring to a recent study, myocardium reaction during the game is about 80-90% HR max [24,31,32]. These values together with the distance covered during the match indicate very strong metabolic commitment of a player during the match.

In modern soccer, endurance training cannot exist without the physiological-biochemical control, energy support and an effective increase of the renewal processes. Since the researchers found different distances that are covered during a match by soccer players with similar values of the maximum oxygen absorption ($\dot{V}O_{2max}$) and playing in the same position, they started to seek new physiological indicators corresponding with the level of endurance capacity training. The expertise of theorists and practitioners indicates that one of the most precise exercise tests aiming to assess physical capacities as well as aerobic endurance is a generally applied test of increasing intensity. It enables one to distinguish the anaerobic threshold (AT), which is commonly known as the lactate threshold [16,33]. The basic criterion of the anaerobic threshold is the running speed, power or percentage of $\dot{V}O_{2max}$ during exercise when the lactate concentration increases rapidly and constantly. A frequently used criterion for determining the anaerobic threshold is defining the value of physical activity load with the lactate concentration of 4 $mmol \cdot l^{-1}$ in blood [3,6,20,34]. It should also be remembered that there are soccer players who experience AT below as well as above the arbitrarily adopted lactate value.

The aim of the study is to compare the level of exercise capacities to the loads occurring at the lactate threshold in soccer players presenting different levels of sport mastery.

MATERIALS AND METHODS

The programme of the study was accepted by the Local Committee for Ethics in Scientific Research. All participants were informed about the aim of the study and methodology as well as about the possibility of immediate withdrawal from the study at any time. Subjects agreed to the above conditions in writing.

The study included 51 soccer players representing different levels of sport mastery, i.e.: group 1 – juniors (n=14); group 2 – leading team of the second league (n=17); group 3 – leading team of the first league (n=20).

The anthropometric characteristics and the length of training of players are presented in Table 1.

The research was conducted at the beginning of the preparatory period for the spring season. The field exercise test of increasing intensity was performed to check the players' exercise capacities on the soccer pitch. The test enabled us to determine the 4 millimolar lactate threshold ($T_{LA\ 4\ mmol \cdot l^{-1}}$) on the basis of the lactate concentration in blood (LA), and to define the threshold running speed and the threshold heart rate (HR). An ellipsis of 250-m circumference was created on the pitch with poles placed every 50 m (Fig. 1). A player started the exercise test from a run at 2.8 $m \cdot s^{-1}$ speed which increased by 0.4 $m \cdot s^{-1}$ with each successive load. The structure of applied loads used in the test of increased intensity is presented in Table 2. The running speed was determined by a sound signal emitted from a CD. The aim of the testee was to run at the speed that coincided with the sound signal at the level of a pole (every 50 m).

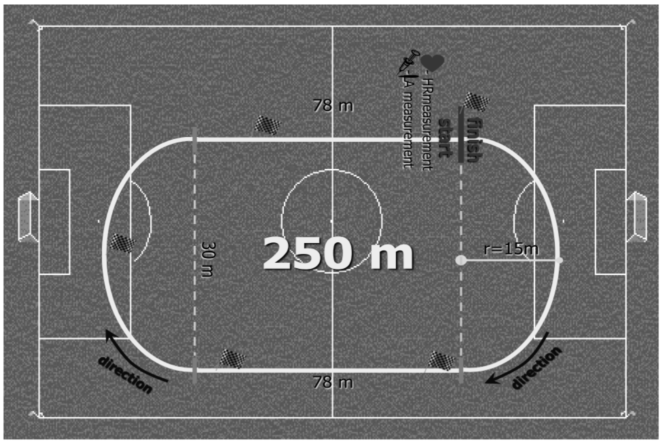

FIG. 1. DIAGRAM OF EXERCISE TEST PERFORMANCE TO ASSESS THE LACTATE THRESHOLD (LT) AND DETERMINE THRESHOLD SPEED (V/AT) IN SOCCER PLAYERS

TABLE 2. SCHEDULE OF LOADS IN A TEST OF INCREASING INTENSITY TO DETERMINE THE LACTATE THRESHOLD (LT)

Run speed ($m \cdot s^{-1}$)	Time to run the distance of 250m (s)	Number of repetitions	General run time (min;s)
2.8	89 s	3 x	4min 27 s
3.2	78 s	3 x	3min 54 s
3.6	69 s	4 x	4min 36 s
4.0	63 s	4 x	4min 12 s
4.4	57 s	4 x	3min 48 s
4.8	52 s	5 x	4min 20 s
5.2	48 s	5 x	4min 00 s

TABLE 1. ANTHROPOMETRIC CHARACTERISTICS AND TRAINING EXPERIENCE OF THE STUDIED PLAYERS

	N	Age [years]	Height [cm]	Weight [kg]	Training experience [years]
JUNIORS	14	16.8 ± 1.353	181.9 ± 6.192	71.8 ± 5.796	8.3 ± 2.322
SECOND LEAGUE	17	25.4 ± 4.343	183.2 ± 6.764	73.8 ± 6.853	16.3 ± 3.221
FIRST LEAGUE	20	26.5 ± 4.398	184.6 ± 5.453	76.2 ± 5.442	17.2 ± 3.435

After completing each load, blood was collected from a fingertip to indicate the lactate concentration in capillary blood and the heart rate was measured. The exercise test was stopped when a player did not sustain the running speed with the current load. The heart rate frequency during the tested physical activity was registered with a Polar sport-tester telemetry meter. The lactate level in blood was measured using a Lactate Scout photometer with the enzyme-amperometric method from capillary blood for 20 s after each load. The threshold running speed at the level of 4 millimolar lactate threshold was marked using the two-point form of the equation of a straight line. On the basis of the calculated threshold speed, applying the condition of straight lines parallelism, the threshold frequency of heart rate (HR) was determined as well as the distance (below and above 4 millimolar lactate threshold) covered by the testees during a progressive test.

Statistical analysis was performed with the STATISTICA program. The compliance of the distribution of all parameters with a normal distribution was done with the Shapiro-Wilk test. The critical level of significance was $p=0.05$. The following descriptive statistics were calculated for all parameters: arithmetic mean, minimum, maximum, standard deviation. The analysis of variance (F) was used to check the significance of differences of mean values between the three tested groups for the parameters of the normal distribution and homogeneous variances. *Post hoc* comparison was performed using the Tukey-Kramer test.

The significance of differences in mean values between the three tested groups for the parameters of distribution different from the normal one or of heterogeneous variances was checked with the nonparametric Kruskal-Wallis test (H). For verification of the differences between mean values, multiple comparisons of mean ranges were applied for all tests.

RESULTS

Descriptive analysis of mean values of the lactate [LA] concentration registered in resting conditions indicated significant statistical differences between group 1 and 2 and group 1 and 3 ($p < 0.05$). It is worth noting that there is no statistically significant difference between lactate values obtained at the maximum load of exercise (LA_{max}) and during restitution with the heart rate at the level of 120 beats$\cdot$min^{-1} (Table 3).

Heart rate values, presented in Table 3, obtained at the end of the test (HR_{max}) and at the level of the 4 millimolar lactate threshold (HR_{AT}), did not show any significant statistical differences between the tested groups. Heart rate values registered in the pre-training exercise conditions showed a significant statistical difference between group 1 and 3 players ($p \leq 0.01$).

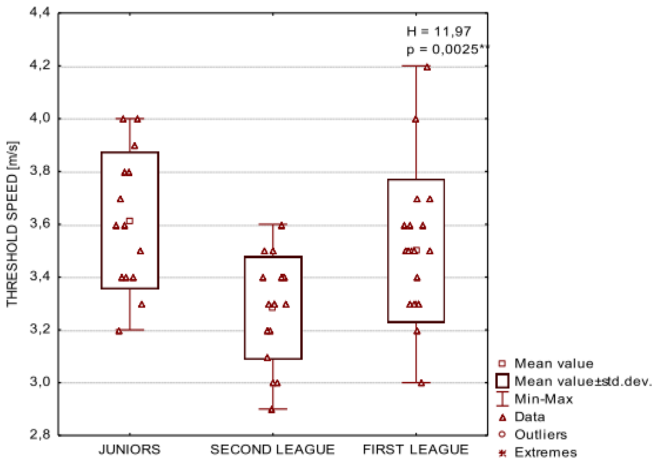

FIG. 2. VALUES OF THRESHOLD RUNNING SPEED [VAT] ACHIEVED BY THE TESTED PLAYERS

TABLE 3. MEAN VALUES OF LACTATE CONCENTRATION [LA] OBTAINED IN THE ANALYSED RESEARCH GROUPS AND RESULTS OF ANOVA TEST OF KRUSKAL-WALLIS RANGES AND THE SIGNIFICANCE OF MULTIPLE COMPARISONS

Variable	Group 1	Group 2	Group 3		Significance of multiple comparisons		
	JUNIORS	SECOND LEAGUE	FIRST LEAGUE		1-2	1-3	2-3
LA rest. [mmol$\cdot$l^{-1}]	1.57 ± 0.40	1.21 ± 0.29	1.20 ± 0.35	8.35*	*	*	ns
LA [mmol$\cdot$l^{-1}] max	10.12 ± 2.18	10.36 ± 1.93	10.22 ± 2.32	0.29^{ns}	-	-	-
LA [mmol$\cdot$l^{-1}]- HR120 [beats$\cdot$min^{-1}]	9.87 ± 2.97	9.11 ± 1.72	9.22 ± 2.04	0.25^{ns}	-	-	-

Note: significant differences; $p < 0.05$*, $p \leq 0.01$ **, non-significant differences $p \geq 0.05$ ns

TABLE 4. HEART RATE MEAN VALUES [HR] OBTAINED IN ANALYSED RESEARCH GROUPS AND RESULTS OF ANOVA TEST OF KRUSKAL-WALLIS RANGES AND SIGNIFICANCE OF MULTIPLE COMPARISONS

Variable	Group 1	Group 2	Group 3		Significance of multiple comparisons		
	JUNIORS	SECOND LEAGUE	FIRST LEAGUE		1-2	1-3	2-3
Rest. HR [beats$\cdot$min^{-1}]	70.57 ± 8.79	64.24 ± 10.18	60.45 ± 7.99	8.95*	ns	**	ns
HR max [beats$\cdot$min^{-1}]	197.14 ± 6.56	196.47 ± 8.93	191.30 ± 10.30	3.32^{ns}	-	-	-
HR - AT [beats$\cdot$min^{-1}]	181.41 ± 7.19	180.57 ± 10.18	175.57 ± 8.33	5.18^{ns}	-	-	-

Note: significant differences; $p < 0.05$*, $p \leq 0.01$ **, non-significant differences $p \geq 0.05$ ns

One of the best indicators of individual loads of a player during the aerobic endurance training is the threshold speed (V_{AT}). Figure 2 presents mean values of this parameter obtained by the groups of tested players. It is clear that the highest level of run threshold speed is represented by highly selected juniors, whose mean value is 3.61 $m \cdot s^{-1}$. The first league players reached the threshold speed at 3.50 $m \cdot s^{-1}$, and the second league players at only 3.28 $m \cdot s^{-1}$.

Descriptive analysis of run threshold speed revealed statistically significant differences between group 1 and 2 ($p \leq 0.01$) and group 2 and 3 ($p < 0.05$). No significant difference was identified between group 1 and 3.

An important measure obtained from the test of increased intensity performed by a player is the total value of the covered distance. It indicates the global range of work performed by a testee during a trial where aerobic as well as anaerobic metabolism occurs. Research results indicate that during the exercise test junior group players covered a longer distance (4696 ± 482.16 m) than the first (4112.50 ± 581.94 m) and the second (3264.71 ± 511.36 m) league players. Comparative analysis showed that significant differences at the statistical level ($p \leq 0.01$) were noted between group 1 and 2, and group 2 and 3. However, there was no significant difference between group 1 and 3. Graphical representation of this value is shown in Figure 3.

The research shows that, during an exercise test, juniors covered the longest distance up to the moment of reaching the 4 millimolar lactate threshold (2554.31 ± 660.13 m). The senior players covered a shorter distance: both the first league (2248.35 ± 660.26 m) and the second league (1687.14 ± 411.12 m). Homogeneity of variance carried out with Levene's test demonstrated the existence of statistical significance of the difference ($p \leq 0.01$) between group 1 and 2 and group 2 and 3 ($p < 0.05$). The differences are presented graphically in Figure 4.

A similar picture was observed during the assessment of the distance covered by the subjects, which was above the arbitrarily selected level of the lactate threshold. Junior team players covered the longest distance (2142.12 ± 449.07 m). This value proved to be statistically significant ($p < 0.05$) when compared to the result achieved by the second league players (1577.57 ± 629.24 m).

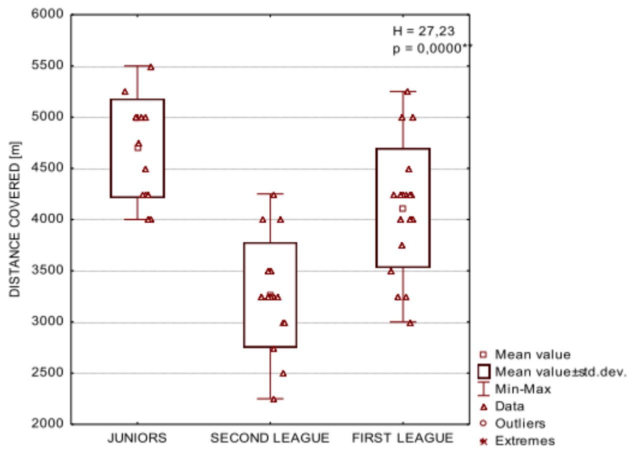

FIG. 3. VALUES OF TOTAL DISTANCE COVERED DURING A TEST BY THE TESTED PLAYERS

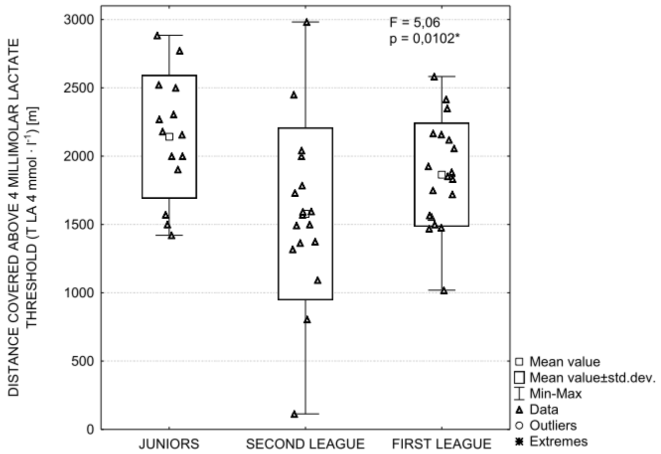

FIG. 5. VALUES OF THE DISTANCE COVERED ABOVE 4 MILLIMOLAR LACTATE THRESHOLD (T LA 4 $mmol \cdot l^{-1}$) OBTAINED BY THE SUBJECTS DURING THE TEST

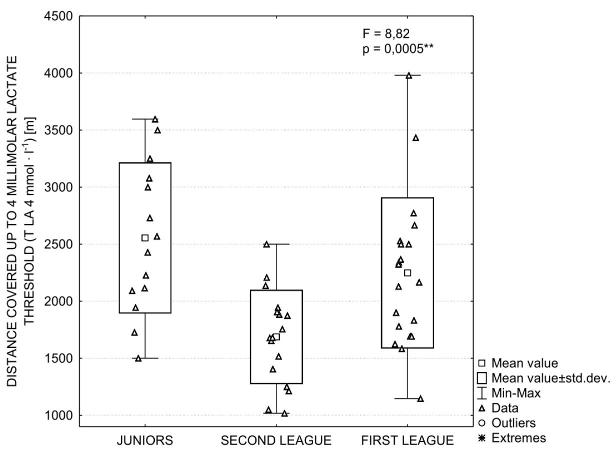

FIG. 4. VALUES OF THE DISTANCE COVERED UP TO 4 MILLIMOLAR LACTATE THRESHOLD (T LA 4 $mmol \cdot l^{-1}$) OBTAINED BY THE SUBJECTS DURING A TEST

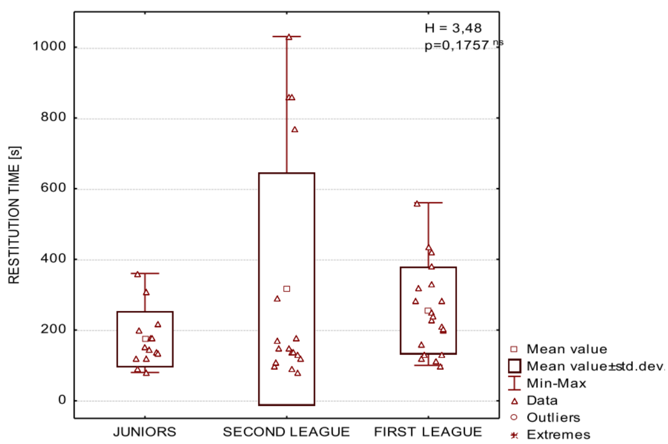

FIG. 6. RESTITUTION TIME REVEALED WITHIN THE TESTED GROUPS AFTER COMPLETING THE TEST

The result of the first league players (1864.15 ± 377.93 m) was not statistically significant in comparison to group 1 and 2. Figure 5 shows the differences graphically.

Important information which emerges from the progressive exercise test is the restitution time indicating the range of changes occurring within hemodynamic factors which characterize adaptive efficiency of the circulatory system. The time that passed from the end of the exercise test to the moment when the systolic value of the testee reached 120 beats per minute was analysed. Juniors were the quickest to gain the value of 120 beats·min^{-1} (173.93 ± 79.21 s). For comparison, the first league players needed 255.25 ± 123.65 s, and those of the second league needed 315.88 ± 329.22 m. Comparative analysis did not confirm any statistically significant differences between the tested groups (Fig. 6).

DISCUSSION

Soccer is one of the most popular sport disciplines in the world. It can be practised by men as well as women or children at various levels of mastery. It is a very dynamic discipline characterized by the growing number of direct duels required from the players' expertise motor, technical, tactical and mental skills preparation [28]. Recently, more and more attention has been devoted to selecting players with an appropriate anthropometric and fitness profile enabling systematic training to reach the highest sport level. A soccer player's preparation is very often concentrated on the improvement of their technical or tactical skills at the expense of developing their motor skills [8,11,26,31].

Characteristics of the match physical activity reveal how important it is for a player to have motor skills preparation for the season. It is directly responsible for the application of technical and tactical skills during a soccer game.

The enumerated arguments clearly demonstrate that endurance is one of the leading motor skills in a player's physical preparation. A player with a high potential for aerobic endurance is highly tolerant and resistant to cumulative fatigue as well as quickly regenerating during a game after very intensive, short sprints, quick counterattacks, and eventually regenerating more quickly after competitions and intensive training sessions. Therefore, a careful evaluation of a player's physical capacity is a basic element of sport coaching management.

The lactate threshold as a common criterion of endurance capacity assessment [5,16,33] was focused on and estimated from the moment when the lactate concentration during the submaximal exercise was considered a better indicator of aerobic physical capacity than the maximum oxygen absorption ($\dot{V}O_{2max}$), especially among well-trained people. It should also be noted that lactate concentration is currently the most sensitive threshold indicator applied in training practice.

During effective aerobic endurance development, defining threshold load intensity and its control with the use of physiological–biochemical indicators becomes especially crucial. Heart rate is the only physiological indicator possible to apply directly in training conditions. It is sufficiently precise in reflecting the physiological body state during increasing intensity of exercise and, at the same time, it gives information about the intensity of energy metabolism. The study indicates that regardless of the clearly varied level of sport mastery, maximum and threshold heart rate are at a similar level.

The analysis of lactate concentration of the soccer players in the present study emphasizes the lack of variability within this parameter at the moment of maximum exercise load as well as during the post-exercise restitution time. It is worth noting that the values of the maximum lactate concentration in blood corresponded to the values acquired during a match and reported by other authors [3,9,20,34].

The threshold running speed (V_{AT}) is, on the one hand, one of the elementary indicators assessing the level of aerobic endurance and, on the other hand, is the upper limit of exercise intensity enabling the formation of aerobic endurance. It bears the best diagnostic values during the assessment of effectiveness of the applied soccer training. It provides data about the dynamics of the body's adaptive mechanisms under the influence of training loads. The conducted tests showed significant differences in the threshold running speed among individual teams. The soccer players of the leading first league club were expected to achieve the best result. The performed tests did not confirm this assumption. Juniors reached the highest threshold running speed of 3.61 m·s^{-1}. Lower values of the studied indicator were acquired by the players of the first league team (3.50 m·s^{-1}) and the lowest values by those of the second league (3.28 m·s^{-1}). Statistically significant differences were noted between the junior group and the second league team ($p \leq 0.01$) and between the first and the second league soccer players ($p<0.05$). Kalapotharakos et al. [18] observed much better results and reported that the players of one of the leading clubs of the Greek league table got a mean V_{AT} value at the level of 3.88 m·s^{-1}. As recent observations imply, the lactate threshold ($T_{LA\ 4\ mmol \cdot l^{-1}}$) of a well-trained player occurs most often at the running speed of 4 m·s^{-1} [19]. Therefore, the tested players, especially those of the first and the second league at the beginning of the preparatory period, presented significantly different average values of this indicator compared to the standards adopted by the European clubs. The research unequivocally indicates that the juniors show better motor abilities than the senior group players do, which is evidenced by the total distance covered in a progressive test. Young soccer players' distance was 584 m longer than the distance covered by the first league team and 1432 m longer than the distance covered by the second league players ($p \leq 0.01$). We can suppose that it is a consequence of, on the one hand, applying the current control and load individualization in the aerobic endurance development and, on the other hand, the participation of highly selected young soccer players from the Polish population. The surprisingly low values of the tested indicators within the senior groups may show that less attention is paid to the aerobic load implementation during the annual training period, which is unacceptable from the motor point of view.

The research proves that the largest scope of work up to the moment of reaching the 4 millimolar lactate threshold was performed by the junior group players. It is assumed that the lactate threshold is the upper limit of running intensity. First, at that limit there appears the compensation of metabolic acidosis and secondly, it is possible to shape aerobic endurance. Thus, the scope of the performed work – that is the distance covered until the moment of reaching ($T_{LA\ 4\ mmol \cdot l^{-1}}$) – shows the represented level of aerobic endurance of a player. It is vital information for coaches because the level of aerobic endurance decides on numerous neurophysiological reactions and the game effectiveness. The soccer players of the second league team gained the 4 mmol·l^{-1} level of lactate concentration in blood at the distance of 1687 m, that is 867 m earlier in comparison to the junior group ($p \leq 0.01$). Such a small scope of work performed up to the arbitrarily selected value of 4 mmol·l^{-1} is further proof of the low exercise capacity of the second league players at the beginning of preparations for the new season. Against the background of the studied groups, the performance of the first league team players is average and the value of the covered distance is 306 m worse than the distance covered by juniors, and 561 m better than the distance covered by the second league soccer players ($p \leq 0.01$). After crossing the lactate threshold ($T_{LA\ 4\ mmol \cdot l^{-1}}$), the lactate concentration increases dynamically in a player's body. The scope of work done above the lactate threshold – that is the distance covered above the occurrence of ($T_{LA\ 4\ mmol \cdot l^{-1}}$) – indicates the level of tolerance for cumulative fatigue during maximum intensity exercise, and anaerobic endurance of the players. It must be remembered that the distance covered with the speed above the lactate threshold makes up about 15% of the total distance covered during championship matches [1,10,21]. It proves that the motor skills potential of a soccer player should be characterized by aerobic preparation as well as the appropriate level of anaerobic physical capacity, which is crucial during the key fragments of a game. The tests conducted in field conditions indicated that the obtained values do not differentiate the testees to the extent of the earlier analysed indicators. The difference in distance covered by the junior players compared to the first league players is 278 m (ns), and is twice as small as the distance covered by the soccer players representing the second league team ($p<0.05$).

One of the indicators corresponding to the general physical capacity of our body is the heart rate assessment during the post-training restitution. Results presented in figure 6 show that despite the fact that the juniors performed the hardest work in terms of the covered distance during the exercise test, they were the fastest to reach the level of 120 beats·min^{-1}. Soccer players of the leading first league team needed much more time to reach the same level of 120 beats·min^{-1} and the second league players needed even more time – respectively 51 and 221 s in relation to the junior team. These results confirm very average body adaptation to the maximum intensity exercise of the first and the second league players, at similarly low level of the total distance covered. The lack of quick possibility to renew the body powers after high intensity exercises may result from the low motor skills potential of the presented research groups or from the wrong application of physical load structure during the endurance capacity development. Such slow regenerative processes during a match do not make it possible to develop a high rate of a match and to create a game .

CONCLUSIONS

Defining the threshold intensity in a test of increasing load enables one to state precisely the endurance level of a player. A coach obtains reliable information allowing a full individualization in the formation of a player's aerobic endurance. From the practical point of view, the threshold load helps to conduct inter-individual comparisons of the registered results between teams. It also enables one to make an assessment of team preparation according to aerobic endurance in certain micro- and mesocycles of training, and avoid the states of body overtraining and too low load application in relation to the physical capabilities of a player. All these facts clearly support the implementation of periodical control in the scope of the motor skills preparation of a soccer player using the progressive lactate test.

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