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Zbigniew Jastrzebski
Jędrzej Śniadecki Academy of Physical Education and Sport in Gdańsk, Poland, zb.jastrzebski@op.pl

Robert Dargiewicz
Jędrzej Śniadecki Academy of Physical Education and Sport in Gdańsk, Poland

Wojciech Ignatiuk
Jędrzej Śniadecki Academy of Physical Education and Sport in Gdańsk, Poland

Lukasz Radziminski
Jędrzej Śniadecki Academy of Physical Education and Sport in Gdańsk, Poland

Pawel Rompa
Jędrzej Śniadecki Academy of Physical Education and Sport in Gdańsk, Poland

See next page for additional authors

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Lactate Threshold Changes in Soccer Players during the Preparation Period

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Zbigniew Jastrzębski [(A, B, D, E, G)], **Robert Dargiewicz** [(C, D)], **Wojciech Ignatiuk** [(A, B, D, E)], **Łukasz Radzimiński** [(B, D, E, F)], **Paweł Rompa** [(C, D)], **Anna Konieczna** [(E, F)]

Jędrzej Śniadecki Academy of Physical Education and Sport in Gdańsk, Poland

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

Key words: football, lactate threshold (LT), specific endurance, preparatory season

Abstract

Background: *The aim of the study was to assess the anaerobic threshold (lactate threshold LT) changes during winter and summer preparation period in soccer premier league and first division players. It was assumed that the index value varies depending on the stage of a one-year training cycle.*

Material/Methods: *Tests were conducted on the premier league and first division soccer players. Physical capacity tests were carried out at the beginning and at the end of the winter and summer preparation period. The tests covered 3 years: 2008 – 2010. Subjects performed an incremental running test according to Jastrzębski's method. The most important data obtained from this test are: running speed (V/LT) and heart rate (HR/LT) at LT.*

Results: *At the beginning of summer preparations the players' speed corresponding to LT reached the value of 3.69 m/s ± 0.31 m/s, while at the end of this period it increased to 3.86 m/s ± 0.29 m/s. During the winter preparatory season the values of this index were 3.81 m/s ± 0.3 m/s and 3.80 m/s ± 0.21 m/s, respectively.*

Conclusions: *Tested subjects showed lower values of running speed at LT level at the beginning of the summer preparatory season than at its end. At the final stage of the winter preparatory season HR values at LT were significantly lower than at the initial stage of this period.*

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Address for correspondence:
Dr hab. prof. nadzw. Zbigniew Jastrzębski
Academy of Physical Education and Sport, 80-336 Gdańsk, Poland, ul. K. Górskiego 1
Phone: +4858 554-71-38, e-mail: zb.jastrzebski@op.pl

Introduction

Anaerobic threshold was first defined by Wasserman and McIlroy in 1964 [1]. It was described as "an oxygen consumption level above which aerobic energy release is supported by the anaerobic system" [2]. On the graph it was marked by the point at the beginning of a nonlinear increase in lungs ventilation in relation to oxygen consumption during the incremental effort. In this phase oxygen demand exceeds oxygen supply and most of pyruvic acid transforms into lactic acid. This substance is buffered by the bicarbonate system. Nevertheless, there are some side effects: an increase in carbon dioxide compressibility in blood and a concentration of hydrogen ions (H+). Furthermore, the compensatory reaction for metabolic acidity starts which engages a sudden increase in lungs ventilation [3].

In 1976 Mader [in Pilis et al., 1996] described this term as the maximal training load at which, nonaccumulating lactate reaches the volume of about 4 mmol/l in arterial blood.

The evolution of physical capacity tests based on anaerobic (lactate) threshold was enabled by the development of lactate assessment methods in blood microsamples which occurred in the 1970s. Earlier, very dangerous brachial artery puncture was used, and only in laboratory. This development contributed significantly to creating many tests based on an assumption that LA = 4 mmol/l of blood, which was used to assess physical capacity of sportsmen as well as non-active people.

Research on the lactate threshold in Poland began in the 1970s. Jaskólski was the first to compare ventilatory breakpoint values in sportsmen and a control group [3].

There are many terms in literature regarding the issue. Some of them are: Anaerobic Threshold – AT or AnT, Lactate Threshold – LT, Onset of Blood Lactate Accumulation - OBLA. Such a diversity in terminology derives from different methods of determining this index. While comparing the results, it is crucial that the data be obtained according to the same method [3].

Physical effort performed at LT intensity significantly influences cardio-vascular fitness as well as energy processes in cells. Therefore, LT is considered the best diagnostic index for aerobic capacity assessment [4].

Many authors confirmed a correlation between the LT level and an ability to perform long-lasting, intensive work ($r > 0.90$) [5], the aerobic capacity of skeletal muscles, the percentage of slow twitch fibers (STF) and the density of capillaries in muscles [5]. The LT index simplifies an effective assessment of endurance training. Its value increases under the influence of endurance training applied for some to several dozen weeks in professionals and beginners as well. It is also stated that the period of six weeks of inactivity causes a significant decrease in the LT level. LT is sensitive to even minor post-training changes; therefore, it can be used to trace the subjects' current endurance level. LT determination enables easier individualization in sports team games. The coach can divide the team into several groups so that the players of similar endurance performance could develop this motor ability at their individual level [7].

Another advantage of LT application in sports training is evident in the fact of its high correlation with metabolic indices: adrenalin (A), noradrenalin (NaA), human growth hormone (hGH), glucose or indices of aerobic capacity: running time, lactic acid level (LA), workload, PWC170 index. LT can be easily established during performance (a small blood sample is taken - a comfortable procedure in comparison with other invasive methods). LT can be tested during submaximal work, or moderate intensity. Test results are presented as measurable indices of physical work (running time, running speed, work volume [W] or [kgm]), which can be compared with results of previous tests, other teams' results or other disciplines' results [5,6].

LT value might be important information for soccer coaches. A higher level of LT means that a player is able to work with higher intensity during the game avoiding such fatigue effects as lactate accumulation. Due to sensitivity to the applied training loads, LT is a very useful index in determining the endurance level in sports like soccer.

A verification of players' aerobic capacity changes is an indispensible factor to evaluate the effectiveness of the training process particularly during the pre-season. The aim of the study was to assess the lactate (anaerobic) threshold changes in professional soccer players during the summer and winter preparatory seasons.

Material and methods

Polish "Ekstraklasa" [the highest level league] and the first league soccer players were submitted to the tests in years 2008-2010 (Table 1). Physical capacity tests were conducted during preparatory seasons: winter (at the beginning of the season – 433 subjects, at the end – 79) and summer (at the beginning – 292 soccer players, at the end – 51).

Tab. 1. Players' physical characteristics

Part of the season	Age [years]	Height [cm]	Weight [kg]
B W (n = 433)	24.74	181.60	77.52
E W (n = 79)	25.48	181.85	77.20
B S (n = 292)	24.89	182.13	78.16
E S (n = 51)	23.75	182.24	77.41

B – beginning of the preparatory season
E – end of the preparatory season
W – winter preparatory season
S – summer preparatory season

Soccer players were submitted to the incremental running test according to Jastrzębski's method [7]. No warming-up activity was applied beforehand due to low intensity of performance at the initial stage of the test. During resting time the heart rate (HR) was measured in a sitting position using a short-wave telemetry device (Polar Electro OY, Finland), and a blood sample was taken from the finger tip of the subjects in order to determine the lactacid level. The test started with a run at 2.8 m/s speed along an elliptic lane on the football pitch (length range: 300 m) – Figure 1. In order to confirm the running pace four sound signal control points were arranged (at the starting line, in the middle of the distance, at ¼ and ¾ of the distance). Each next course was conducted at speed higher than the previous one by 0.4 m/s. After each course of run, HR was measured and a blood sample taken. HR at the end of each stage was considered as a corresponding value to the running speed and the blood lactate concentration. The subjects continued running until exhaustion. After completing the test subjects rested for 5 min. Then HR was measured and a blood sample was taken for the last time. Blood samples were analyzed for lactate concentrations in a laboratory using EPOLL 200 spectrophotometer. The Beaver method [8] was used to determine the lactate threshold.

For more efficient organization the players were running in groups of three simultaneously. The second group started when the first one reached the point of ¾ of the distance. The amount of laps in subsequent courses was ordained so that the running time span of 1 course ranged from 3 min 45 s to 4 min 30 s. It is assumed that physiological functions dependent on physical effort stabilize within this time period. Time needed to cover subsequent laps can be calculated by this formula:

$$t = \frac{s}{v}$$

v – running speed
s – distance covered
t – running time

Time needed to cover the next lap equals the ratio of the distance covered (one lap length) to the running speed (from 2.8 m/s to 5.2 m/s, increased by 0.4 m/s).

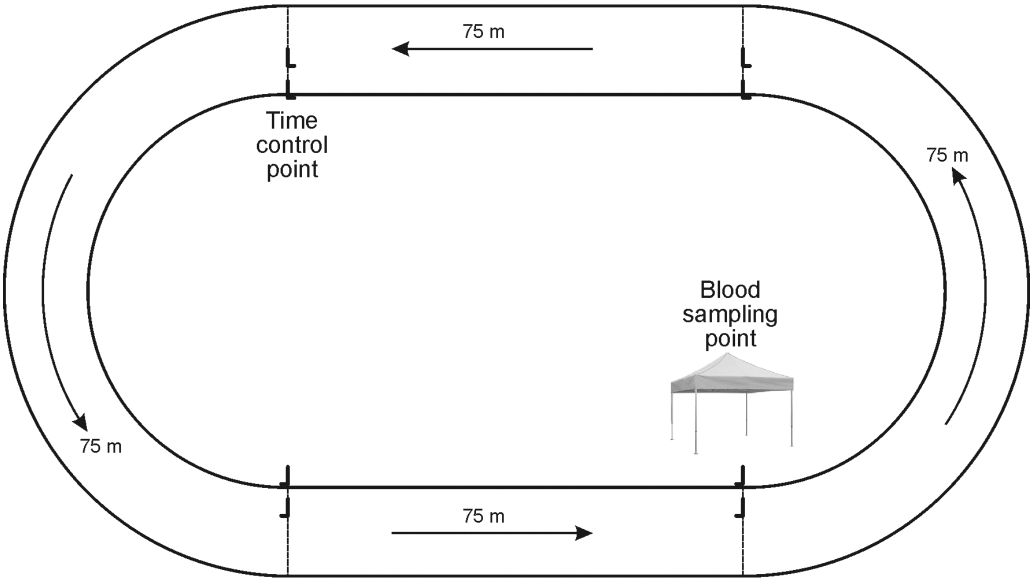

Fig. 1. Scheme of the running lane during an incremental running test

The most important indices determined by this test are: the running speed (V/LT) and the heart rate (HR/LT) performed at LT intensity. For practical reasons, the subjects of similar V/LT values were allocated to the running group of similar abilities.

Statistica 9 version was used for data analysis. Homogeneity of variables dispersion with normality was checked with Shapiro-Wilk test. Significant differences were stated by Mann-Whitney U test at $p \leq 0.05$.

Results

Table 2 presents Shapiro-Wilk test results verifying V/LT and HR/LT variables dispersion. No homogeneity with normality was stated at the beginning and at the end of each preparatory season ($p<0.05$). Therefore, non-parametric statistical techniques were used for data comparison.

Tab. 2 Shapiro-Wilk test results for the heart rate and the running speed at LT at the beginning and the end of the summer and winter preparatory season.

Variable	p
HR/LT B W [beats/min]	0.006*
V/LT B W [m/s]	0.000*
HR/LT E W [beats/min]	0.050*
V/LT E W[m/s]	0.001*
HR/LT B S [beats/min]	0.004*
V/LT B S [m/s]	0.000*
HR/LT E S [beats/min]	0.269
V/LT E S [m/s]	0.047*

B – beginning of the preparatory season; E – end of the preparatory season
W – winter preparatory season; S – summer preparatory season
* statistically significant differences at $p \leq 0.05$

An analysis of the running speed at LT changes during the summer preparatory season shows that the players achieved significantly ($p=0.002$) higher values of this index at the end of this season (Fig. 2). No significant differences between mean values of HR/LT index (171 vs 170 bpm) at the beginning and at the end of the summer preparatory season were stated. The range of results at the end of the summer preparatory season is fully encompassed by the results range at the beginning of this season. Quarter deviations of both groups reached similar values (Fig. 3).

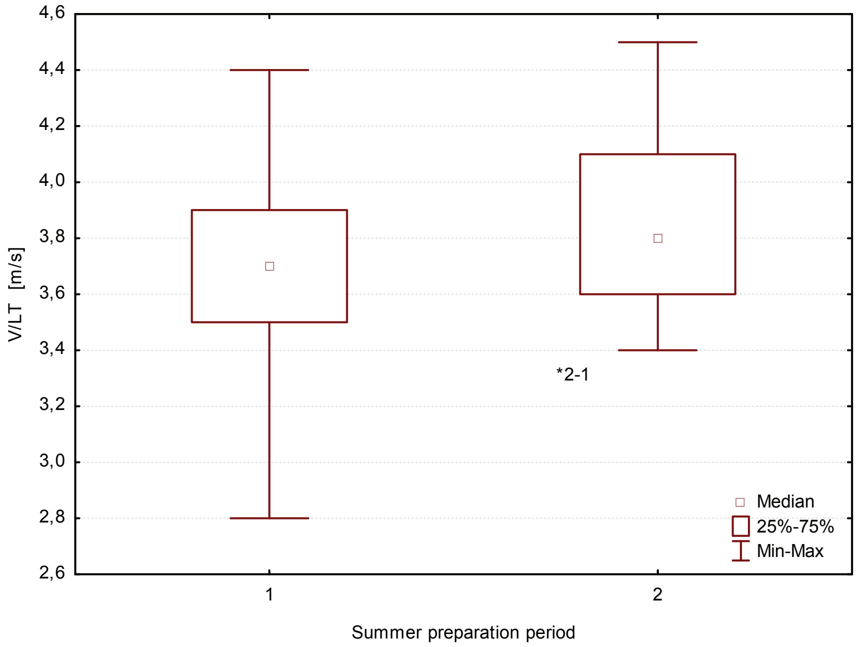

Fig. 2. Quarter deviations and results range of running speed at LT at the beginning (1) and at the end (2) of the summer preparatory season (*statistically significant differences at p≤0.05)

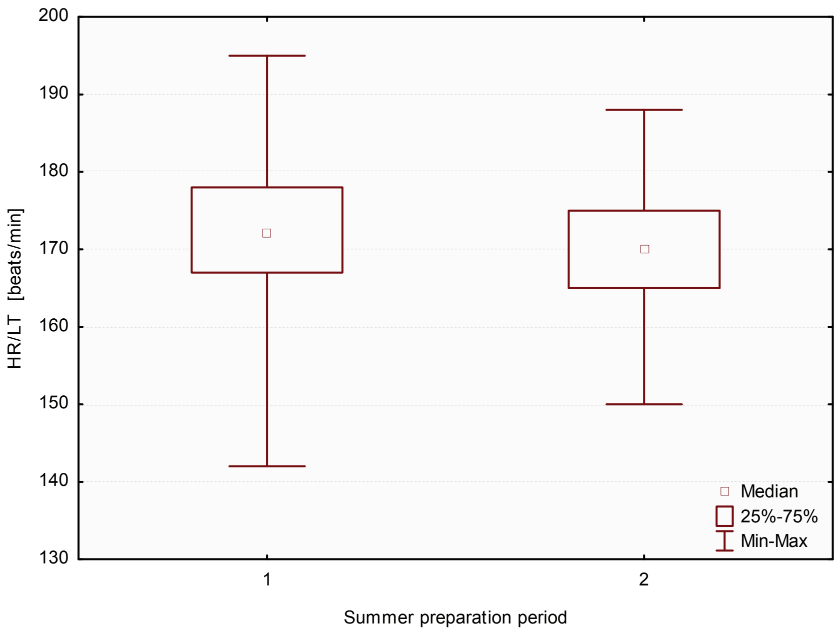

Fig. 3. Quarter deviations and results range of the heart rate at LT of soccer players at the beginning (1) and at the end (2) of the summer preparatory season

No significant differences were stated between mean values of V/LT index (3.74 vs 3.77 m/s) in the tested subjects during winter preparations (Fig. 4). The range of results at the end of the winter preparatory season is entirely encompassed by the results range at its end. Quarter deviations for both groups show similar values. An analysis of the heart rate at LT intensity during the winter preparatory season confirmed significantly (p=0.0001) lower values reached by the tested subjects at the end of this season (Fig. 5). HR at LT decreased from 173 bpm before the pre-season to 166 bpm after preparations. Additionally, changes in lactate concentration and the heart rate during the incremental running tests carried out at four different season time points are presented in Tables 3 and 4.

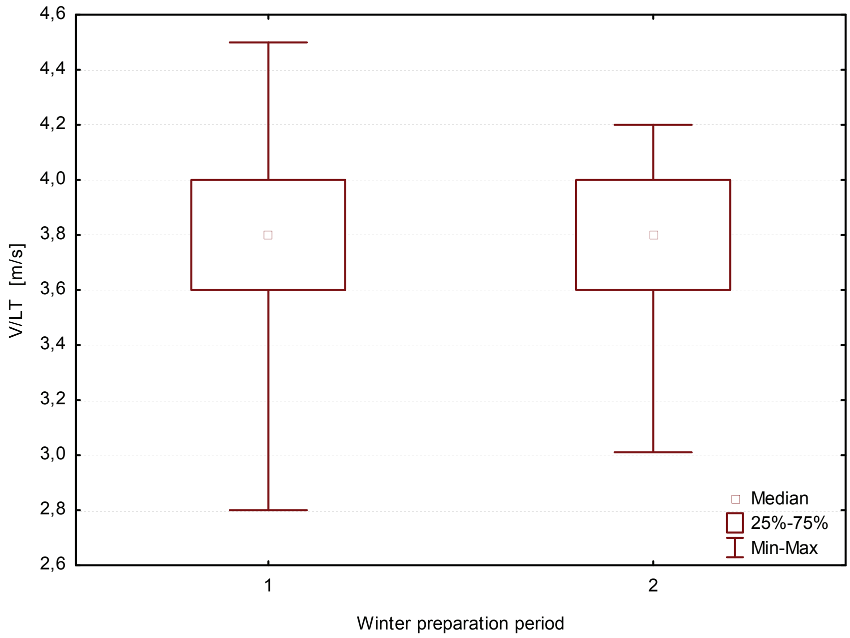

Fig. 4. Quarter deviations and results range of the running speed at LT in footballers at the beginning (1) and at the end (2) of the winter preparation period

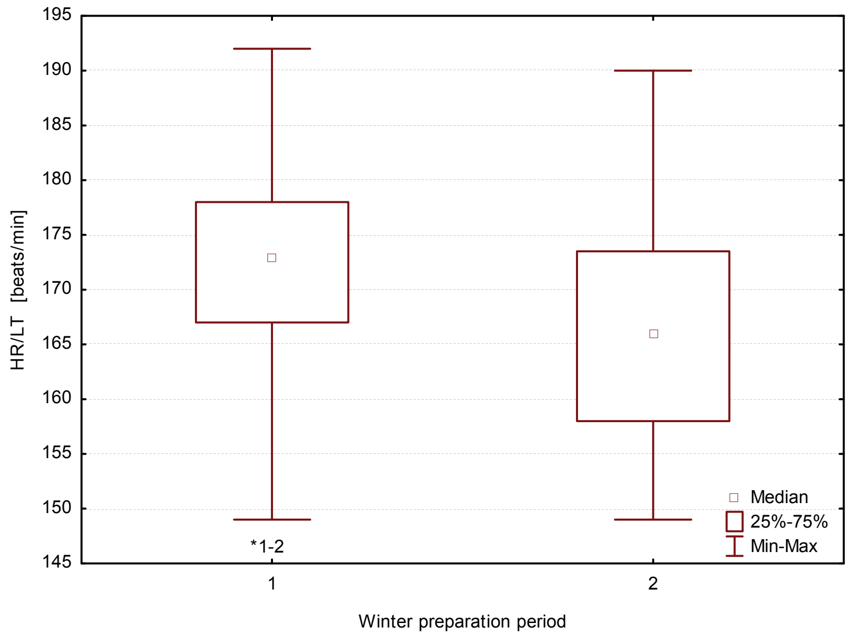

Fig. 5. Quarter deviations and results range of HR/LT index [bpm] in soccer players at the beginning (1) and at the end (2) of the winter preparation period

Tab. 3. Mean values of lactate concentration (LC) [mmol/l] according to the running speed

Part of the season	Rest	2.8 m/s	3.2 m/s	3.6 m/s	4.0 m/s	4.4 m/s	4.8 m/s	After 5 min
LC at B W [mmol/l]	1.54	2.22	2.75	3.85	5.57	8.71	11.15	10.86
LC at E W [mmol/l]	1.56	2.23	2.79	3.78	5.55	8.34	10.80	10.95
LC at B S [mmol/l]	1.61	2.38	3.06	4.19	6.17	9.13	11.56	10.50
LC at E S [mmol/l]	1.40	1.94	2.39	3.47	4.93	7.59	10.45	9.10

B – beginning of the preparatory season; E – end of the preparatory season; W – winter preparatory season
S – summer preparatory season

Tab. 4. Mean values of HR [bpm] according to the running speed

Part of the season	Rest	2.8 m/s	3.2 m/s	3.6 m/s	4.0 m/s	4.4 m/s	4.8 m/s	After 5 min
HR at B W [bpm]	68	144	157	170	179	187	190	104
HR at E W [bpm]	61	136	150	163	173	182	188	99
HR at B S [bpm]	71	145	160	172	181	188	192	108
HR at E S [bpm]	66	137	151	164	173	182	187	102

B – beginning of the preparatory season; E – end of the preparatory season; W – winter preparatory season
S – summer preparatory season

Discussion

The main conclusion of this study is that running velocity at the lactate threshold significantly increased during the summer preparation period. No significant changes were observed during winter preparations. The effectiveness of summer pre-season training was higher than in winter.

It is widely known that aerobic training increases the heart size and the stroke volume [9], which provokes lower values of the resting heart rate. This thesis is confirmed by our results. Resting values of HR decreased after completing both winter (-7 bpm) and summer (-5 bpm) preparations. That might indicate that pre-season training included a large volume of aerobic intensity exercises.

In Poland the winter preparation period is usually longer. At the beginning of the winter pre-season training there is more time for low intensity aerobic efforts while the summer preparations involve a large amount of exercises improving speed-endurance. This might be a reason for HR/LT index decrement during the winter preparation period. A significant improvement in speed velocity at LT during the summer preparations might be caused by applying numerous high-intensity aerobic efforts.

According to Bangsbo, during a match 70% of ATP is released by aerobic processes [10]. Ekblom [11] estimates this value at 80%. Nevertheless, both aerobic and anaerobic capacity should be developed in football players. During a match aerobic work is performed below the LT level, e.g. while dribbling the ball. Anaerobic performance occurs while accelerating, changing direction fast, sliding, jumping up or shooting goals [12]. Repeated practice of these techniques leads to anaerobic capacity improvement – both lactacid (anaerobic glycolytic) and alactacid (ATP-CP system). A high level of lactate in blood proves this claim. During a match LA concentration in blood can even exceed the value of 10 mmol/l in professional footballers [10,11].

Aerobic and anaerobic capacity increment is the usual effect of pre-season training [13,14,15]. In our study this assumption was completed only during the summer preparation period. Results of Clark's et al. [16] studies show that oxygen uptake corresponding to the anaerobic threshold is a more changeable index than the maximal oxygen uptake. Additionally, they observed the lowest level of AT prior to pre-season training.

Śledziewski [17] conducted tests with footballers on a mechanical treadmill. The lowest values of indices concerned were evident in LT intensity work at the beginning of the preparatory season. This tendency occurs not only among the highest level football divisions but in lower level leagues as well. According to this author, the mean value of the running speed at LT in premier league footballers reached 3.62 ± 0.48 m/s at the beginning of the preparatory season and 3.59 ± 0.52 m/s in the first league players. These test results as well as ours prove the fact that during the preparatory season soccer players achieve lower index values at the beginning of this period (3.69 ± 0.31 m/s) than at its end (3.80 ± 0.29 m/s). By contrast, no significant differences were stated between tests in winter (3.73 ± 0.30 m/s and 3.74 ± 0.21 m/s respectively).

Jastrzębski [7] carried out studies according to the same method as in the present work on football premier division team Amica Wronki at the beginning of the preparatory season before autumn competitions. The mean value of running speed at LT was 3.51 ± 0.23 m/s. The result was worse by 0.18 m/s than in subjects tested in this study.

Zarzeczny et al. [18] tested Odra Wodzisław football players (a premier league team) at the end of the winter preparatory season. The subjects were submitted to a run on an electrical treadmill (Jaeger brand) with 3° inclination. The test started with the initial speed of 6 km/h (1.66 m/s) and gradually increased every 3 minutes by 2 km/h (0.56 m/s). After the termination maximal oxygen uptake (VO2max) was determined by a gas analyser (Jeager brand). Moreover, during rest time and the third minute of each course the heart rate (HR) was registered based on electrocardiographic curve and a blood sample was taken from a finger tip to estimate lactate concentration using the enzymatic method. Next, LT level was determined based on LA concentration according to Beaver log-log method [19]. Mean values of running speed at LT obtained by Odra Wodzisław footballers were 3.74 ± 0.4 m/s and exceeded our results by 0.1 m/s. Their results also deviated more from the mean value (3.64 ± 0.21 m/s).

McMillan et al. [20] analyzed changes in indices typical of LT in 18-year-old Scottish soccer players. The subjects were submitted to a submaximal lactacid test on a treadmill. At the beginning of the summer preparatory season the mean value of the running speed at LT was 3.78 ± 0.25 m/s and exceeded the average value (median) from our studies by 0.09 m/s. The heart rate at LT results differed significantly. In Scots the mean value was 190 bpm while in Polish professionals it reached 172 bpm.

Jastrzębski and Laurentowska [21] conducted studies among triathletes, evidently endurance sport participants, on a treadmill. The results proved that the running speed at LT values registered in the athletes were 5.15 m/s. This means about 1.5 m/s higher than in soccer players.

Ronikier [22] claims that untrained persons reach LT level at the running speed of 3.0 m/s ± 0.5 m/s, poorly trained at 4.0–4.7 m/s and well trained 5.3–5.6 m/s. According to this scale, the tested footballers take place between untrained and poorly trained subjects.

Conclusions

At the beginning of the summer preparation period soccer players reached lower values of the running speed corresponding to LT than at the final stage of this period.

Significantly lower HR values at LT were evident at the end of the winter preparation period than at the beginning of this season.

References

1. Wasserman K, McIlroy MB. Detecting the threshold of anaerobic metabolism in cardiac patients during exercise. *Am J Cardiol* 1964;14:844-52.
2. Zdanowicz R. Znaczenie progu beztlenowego w rozwoju zdolności wysiłkowych człowieka [in Polish] [The significance of lactate threshold in the development of human effort capabilities]. In: Stupnicki R, editor. Wybrane zagadnienia fizjologii wysiłku fizycznego [Selected issues of the physiology of physical effort]. Warszawa: Instytut Sportu; 1992, 9-37.
3. Pilis W, Zarzeczny R, Langfort J. Próg przemian beztlenowych [in Polish] [Lactate threshold]. Katowice: AWF; 1996.
4. Jaskólski A, Jaskólska A. Podstawy fizjologii wysiłku fizycznego z zarysem fizjologii człowieka [in Polish] [Basics of the physiology of physical effort with an outline of human physiology]. Wrocław: AWF; 2005.
5. Kozłowski S, Nazar K, editors. Wprowadzenie do fizjologii klinicznej [Introduction to clinical physiology]. Warszawa: PZWL; 1999.
6. Ronikier A. Fizjologia sportu [in Polish] [Physiology of sport]. Warszawa: COS; 2001.
7. Jastrzębski Z. Zakres obciążeń treningowych w piłce nożnej i ręcznej a ich wpływ na rozwój sportowy zawodników [in Polish] [The range of training loads in soccer and handball and their influence of the athletes' sports development]. Gdańsk: AWFiS; 2004.

8. Beaver WL, Wasserman K, Whipp BJ. Improved detection of lactate threshold during exercise using a log-log transformation. *J Appl Physiol* 1985;59:1936-40.
9. Ekblom B. Effect of physical training in adolescent boys. *J Appl Physiol* 1969;27(3):350-355.
10. Bangsbo J. Energy demands in competitive soccer. *J Sport Sci* 1994);12:5-12.
11. Ekbolm B. Applied physiology of soccer. *Sport Med* 1986;3:50-60.
12. Malarecki I. Zarys fizjologii wysiłku i treningu sportowego [in Polish] [An outline of the physiology of effort and sports training]. Warszawa: Sport i Turystyka; 1981.
13. Caldwell BP, Peters DM. Seasonal variation in physiological fitness of a semi-professional soccer team. *J Strength Cond Res* 2009;23(5):1370-1377.
14. Wong P-L, Chaouachi A, Chamari K, Dellal A, Wisloff U. Effect of preseason concurrent muscular strength and high-intensity interval training in professional soccer players. *J Strength Cond Res* 2010;24(3):653-660.
15. Aziz AR, Newton MJ, Tan HY, Teh KC. Variation in fitness attributes of players during a competitive season in an Asian professional soccer league: a field-based investigation. *Asian Journal of Exercise & Sports Science* 2006;3(1):40-45.
16. Clark NA, Edwards AM, Morton RH, Butterly RJ. Season-to-season variations of physiological fitness within a squad of professional male soccer players. *J Sport Sci Med* 2008;7:157-165.
17. Śledziewski D. Indywidualizacja w procesie treningu sportowego [in Polish] [Individuation in the process of sports training]. Rocznik Naukowy AWFiS 2002;12:101-108.
18. Zarzeczny R, Kłapcińska B, Wąs *R*, Pilis K, Manowska B, Pilis W. Wydolność fizyczna I-ligowych piłkarzy nożnych w różnych okresach treningowych [in Polish] [Physical efficiency of first-league soccer players in various training periods]. *Medycyna Sportowa* 2007;2(6):95-98.
19. Beaver WL, Wasserman K, Whipp BJ. Blood lactate concentration in exercise. *J Appl Physiol* 1988;64(3):1290-1.
20. McMillan K, Helgerud J, Grant SJ, et al. Lactate threshold responses to a season of professional British youth soccer. *Br J Sport Med* 2005;39:432-436.
21. Jastrzębski A, Laurentowska M. Próg przemian anaerobowych w różnych dyscyplinach sportu [in Polish] [Lactate threshold in various sports disciplines]. *Trening* 1995;2(26):77-78.
22. Ronikier A. Kwas mlekowy a wysiłek fizyczny. Poradnik dla trenera [in Polish] [Lactic acid and physical effort]. Warszawa: Instytut Sportu; 1987.