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Original Article

Assessment of the level of somatic indicators and aerobic physical capacity in first league footballers

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Abstract
Problem statement: A high level of aerobic capacity in footballers enables them to develop intense activity during the match and maintain it during the game for a longer period. It also promotes better tolerance to increasing fatigue, as well as faster body regeneration during and after the match. The aim of the study was to assess the level of somatic indicators and aerobic capacity in Polish top league footballers. **Approach:** The study involved 20 Polish top league football players. Measurements of somatic indicators were taken and a graded treadmill test was performed. Additionally, the footballers' speed capacity was measured by the WITTY test, implemented before and after the graded test. Post-exercise changes in lactate concentration were assessed. **Results:** The average maximal oxygen uptake (VO_2max) expressed in absolute values was 4.3 ± 0.5 $L·min^{-1}$; at the level of the second ventilatory threshold, oxygen uptake equalled 3.5 ± 0.4 $L·min^{-1}$, which accounted for 81,40% VO_2max. The average VO_2max expressed in values relative to body mass was 55.9 ± 2.8 $mL·min^{-1}·kg^{-1}$; at the level of the second ventilatory threshold, oxygen uptake relative to body mass equalled 44.6 ± 3.6 $mL·min^{-1}·kg^{-1}$. An improvement was observed in the WITTY test results: the subjects obtained a score of 23.4 ± 3.1 s in the first trial and 21.0 ± 2.9 s in the second test. **Conclusions:** There was no significant relationship between the absolute or relative VO_2max values and the WITTY test results or between the absolute VO_2max and the difference of lactate levels in 0'–3' and 3'–20'. However, as the value of VO_2max increased, the restitution processes expressed in the 3'–20' lactate level accelerated.
Key words: aerobic capacity; football; graded exercise test; somatic indicators

Introduction

The constant interest in the training process, as well as in the control of the physical preparation of the Polish football representatives prompts many reflections. Football is played by 265 million people worldwide, of whom only about 30% are footballers allied in sports associations and the remaining 70% are amateurs. Football is a global phenomenon that has begun to be considered also in the social dimension. In Poland, there is exceptional activity in this field; according to the statistics, there are over 2 million active footballers (Wąs et al., 2009). Football is a demanding sport whose performance is determined by physiological, technical, tactical, psychological, and social factors. Aerobic capacity is also a key component of success in football (Bekris et al., 2016). Athletes are required to meet the physical demands with the highest level of physical fitness throughout the competition season (Aziz et al., 2006); therefore, a continuous assessment and feedback on fitness play a crucial role in the success of any team (Bekris et al., 2016). The higher the level of physical capacity, the lower the physiological cost of the work performed, which is important in most sports (Michalski and Małolepszy, 2012). The bioenergetics of a football player's effort is complex, involving both the aerobic and anaerobic pathways of adenosine triphosphate resynthesis, and the size of their participation varies and depends on the player's level of training (Wąs et al., 2009). In studies analysing the game of football, the scale of the generated physical effort is usually taken into account. This is defined as a complex process (Bloomfield et al., 2007), and there are only sporadic periods of work of similar intensity. Usually, both time and distance aspects are alternating, with different work intensities and lengths of the covered distance. These complex sequences can be unpredictable during the game because they depend on many variables occurring during the player's actions (Rampinini et al., 2007), especially on the large number of sprint sections covered, which have a significant impact on the athletes' systemic processes (Little and Williams, 2005).

In football, aerobic processes play a very important role, particularly those of high intensity (Sotiropoulos et al., 2009) – these should be monitored by players on an ongoing basis. In his research conducted among Polish footballers, Ozimek (2007) stated that their optimal capacity occurred at the level of maximal oxygen uptake (VO_2max) equal to 50–57 $mL·min^{-1}·kg^{-1}$. However, in a study among foreign footballers carried

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out by Magalhães Sales et al. (2014), this level of VO_2max was significantly higher (62.3 ± 5.1 mL·min^{-1}·kg^{-1}). Most actions performed by football players are based on low- to medium-intensity efforts. A high level of aerobic capacity allows the athlete to develop high activity during the match and to maintain it over a longer period of the game. It also promotes better tolerance of increasing fatigue and faster regeneration of the body during and after the match (Tjelta and Enoksen, 2010).

In relation to the speed abilities necessary during a football match, it is not without significance, especially for coaches, to control psychomotor skills through tests that assess the level of development of specific motor skills or special football skills. Evaluating reaction time, decision-making, and attention selectivity is essential in a 90-minute football game. The reaction to external stimuli significantly influences the sports result (Lyakh et al., 2012).

Owing to the nature of the game, i.e. a significant amount of acceleration, dribbling, quick changes in running directions, sliding, jumps, or ball shots during a match, lactate concentration increases and in high-level football players, may even exceed 10 mmol/L (Tjelta and Enoksen, 2010). Research confirms that the average lactate concentration during a football match ranges 3–9 mmol/L (Arnason et al., 2004; Jastrzębska and Piesiewicz, 2002). The rate of lactate removal depends on its concentration, physical activity during the recovery period, and physical capacity (Impellizzeri et al., 2004). Hence, in research, apart from determining VO_2max in footballers, it is important to establish the threshold of anaerobic changes, reflecting the involvement of the aerobic and anaerobic adenosine triphosphate resynthesis pathways (Michalski and Małolepszy, 2012). In football academies, objective data from physical and technical tests or subjective data from coaches are usually used to evaluate players, the latter being more important for decision-making during assessments (Barrero et al., 2020; Lazaro Paulina et al., 2022). Intuition, together with coaches' perception, developed through observing players, is the most widely used means of assessing sports performance and selecting talented athletes in football (Barrero et al., 2020; Lazaro Paulina et al., 2022). In the Polish literature, studies on the capacity of the Poland Ekstraklasa footballers performed with laboratory testing methods are scarce. The presented research attempts to change this state of affairs.

The aim of the study

The study purpose was to assess the level of somatic indicators and aerobic capacity in footballers training at the level of the Polish top league.

Material and methods

Research material

The study involved 20 football players who took part in the games of the Polish top league. The subjects belonged to the first line-up of the team, and the experiment was carried out during the preparatory period for the winter season. The tested athletes were thoroughly acquainted with the course of the study. The condition for admission to laboratory tests was that the competitors had current sports and medical tests performed. The players were informed about the possibility to withdraw from the research project at any time, and their participation was confirmed with their written consent. The research site was the University of Physical Education in Krakow, Laboratory of Physiological Attitudes of Adaptation. The measurements were carried out in November 2020, during the COVID-19 pandemic, in compliance with all the rules of the sanitary regime.

Test methods

The tests were executed under the constant supervision of a physician, and the entire research project followed the guidelines of the Declaration of Helsinki. The experiment involved performing somatic measurements, two laboratory standardized physiological tests: a graded test until exhaustion and the WITTY test, and biochemical analyses (based on blood samples from the subjects' fingertips). The sequence of the tests is presented in Figure 1.

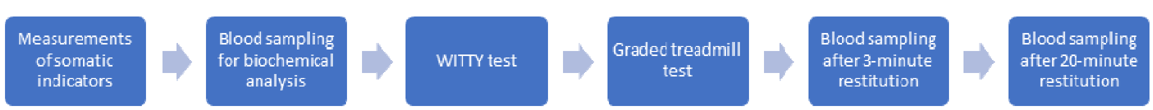

Figure 1. Research design diagram

Anthropometric measurements

Before the aerobic capacity tests, the following somatic indicators were measured: body height, body mass, body cell mass, fat mass, percentage of body fat, lean body mass or fat-free mass, total body water, percentage of total body water, and extracellular water. Body height was determined with an accuracy of the Martin anthropometer (USA) to the nearest 1 mm. Body mass was evaluated with the Tanita BC 545 scales. Body composition assessment by using the bioelectrical impedance technique was performed with an Akern BIA 101 analyser.

WITTY test

The WITTY test was performed before and immediately after the test of increasing intensity. The outcome measure of the test was time, and WITTY itself determined the level of coordination motor skills, the speed of reaction and perception. The WITTY semaphore board was placed within the subject's reach. The task of each surveyed player was to move their hand to one of the nine photocells as quickly as possible; the photocells displayed number 3 on the board (the LED matrix displayed letters and numbers in different colours on the remaining 8 photocells). During one WITTY test, the number of impulses was 20. Measurements of the coordination capacity were carried out by using the WITTY SEM device (Microgate, Italy). The WITTY semaphore system consisted of an LED matrix, with the ability to display different colours, numbers, and characters. The WITTY SEM displays the following colours: green, blue, red; arrows in 3 colours and different directions; letters in 3 colours. The semaphores were equipped with proximity sensors that detected the presence of an object in the area of the indicator ± 40 cm without the need to touch it. The real-time response delay is 1 ms. The optical range of the WITTY system is 12 m, while the radio transmission range is 150 m, with radio transmission at the level of 10 mW.

Graded test

The indicators used to assess aerobic capacity were VO_2max and the second ventilatory threshold (VT2). A treadmill test with a gradually increasing load until exhaustion was applied. The test effort was preceded by a 4-minute warm-up, during which the subject ran at a constant speed of 8.0 $km \cdot h^{-1}$ with the treadmill inclination angle of 1°.

Every 2 minutes, the running speed was increased by 1.0 $km \cdot h^{-1}$. When the exercise intensity approached the maximum level, the platform inclination angle was increased by 1° every minute. The trial was carried out until the competitor refused to continue running owing to extreme fatigue.

The aim of the test was to determine the value of VO_2max and other physiological indicators characterizing the effort of increasing intensity, as well as to establish the ventilatory threshold in accordance with the concept by Reinhard et al. (1979) and Bhambhani and Singh (1985), which corresponds to VT2.

The level of VT2 was verified on the basis of the dynamics of changes in selected indicators of the respiratory system; the following criteria for determining the threshold were adopted: the ventilatory equivalent for oxygen (i.e. the volume of inhaled air to absorb 1 L of oxygen), the ventilatory equivalent for carbon dioxide (i.e. the volume of exhaled air needed to exhale 1 L of carbon dioxide), minute ventilation, and the percentage of carbon dioxide in the exhaled air.

After exceeding VT2, a rapid and non-linear increase in minute ventilation, an increase in the ventilatory equivalent for carbon dioxide, and a decrease in the percentage of carbon dioxide in the exhaled air were observed. The work intensity at the VT2 level was expressed as the percentage of VO_2max and the percentage of the maximum heart rate. A CORTEX MetaLyzer R3 ergospirometer was used to record the analysed indicators.

The record of the results was carried out continuously, with the data being printed out at 30-s intervals. Heart rate was monitored with the use of a Polar S610 pulse oximeter (Finland) and telemetry belts at 15-s intervals; the recording was started 3 minutes before the trial commencement and completed after 3 minutes of restitution. The graded test was performed on a Saturn 250/100R treadmill (h/p/Cosmos, Germany).

Biochemical analyses

Blood samples for lactate concentration analysis were collected prior to the graded test, and 3 and 20 minutes after its termination. To assess the concentration of lactate in the capillary blood, the colorimetric method was used, with Lactate PAP enzymatic tests (BioMerieux) and a Spekol 11 spectrophotometer (Carl Zeiss, Jena, Germany).

Statistical analysis

Basic measures of descriptive statistics were used to elaborate the results of the performed assessments: the arithmetic mean, standard deviation, and the Pearson correlation coefficient (r). The normality of the variable distribution was verified with the Shapiro-Wilk test.

The significance of differences in the mean values of the observed indicators was evaluated with the Excel formulas of the Office 2013 program (Microsoft) and the Statistica 13.3 program (StatSoft Polska).

Results

Table 1 presents the arithmetic means and standard deviations of the results of the players' anthropometric characteristics and body composition indicators. The average body height of the examined players was 181.8 ± 7.9 cm. Their mean body mass equalled 78.1 ± 9.5 kg.

Table 1. Arithmetic means and standard deviations of somatic indicators

Indicator	**x̄**	**SD**
BH [cm]	**181.8**	**7.9**
BM [kg]	**78.1**	**9.5**
BCM [kg]	**56.3**	**10.8**
FM [kg]	**31.4**	**9.4**
FFM [kg]	**27.8**	**23.2**
%F [%]	**18.9**	**2.9**
TBW [L]	**45.9**	**5.0**
%TBW [%]	**40.7**	**2.0**
ECW [L]	**18.7**	**2.5**

x̄ – arithmetic mean; SD – standard deviation; BH – body height; BM – body mass; BCM – body cell mass; FM – fat mass; FFM – fat-free mass; %F – percentage of body fat; TBW – total body water; %TBW – percentage of total body water; ECW – extracellular water

Table 2 presents the parameters of the capacity test. The average level of aerobic capacity turned out to be 55.9 ± 2.8 mL·min^{-1}·kg^{-1}. During the graded test, the athletes covered the average total distance of 3916.1 ± 283.1 m. The average percentage of the maximum heart rate at the VT2 level was 88 ± 3.7%, while the average percentage of VO_2max at the VT2 level equalled 81.40 ± 5.6%.

Table 2. Arithmetic means and standard deviations of parameters of the graded test

Indicator	**x̄**	**SD**
t VT2 [min]	**11.9**	**1.2**
t max [min]	**20.4**	**1.1**
v VT2 [km·h^{-1}]	**11.5**	**0.6**
v max [km·h^{-1}]	**15.6**	**0.4**
HR VT2 [beats·min^{-1}]	**163.1**	**13.5**
HR max [beats·min^{-1}]	**185.5**	**13.3**
VO_2 VT2 absolute [L·min^{-1}]	**3.5**	**0.4**
VO_2max absolute [L·min^{-1}]	**4.3**	**0.5**
VO_2 VT2 relative [mL·min^{-1}·kg^{-1}]	**44.6**	**3.6**
VO_2max relative [mL·min^{-1}·kg^{-1}]	**55.9**	**2.8**
VE VT2 [L·min^{-1}]	**91.1**	**10.4**
VEmax [L·min^{-1}]	**154.3**	**16.3**
s VT2 [m]	**1906.9**	**253.7**
s max [m]	**3916.1**	**283.1**
% VO_2max	**81.4**	**5.6**
% HRmax	**88.0**	**3.7**

x̄ – arithmetic mean; SD – standard deviation; VT2 – second ventilatory threshold; max – the final phase of the exertion (maximal indicator level); t – time of graded test performance; v – running speed; HR – heart rate; VO_2 – minute oxygen uptake: absolute (L·min^{-1}) and relative to body mass (mL·min^{-1}·kg^{-1}); VO_2max – maximal oxygen uptake: absolute (L·min^{-1}) and relative to body mass (mL·min^{-1}·kg^{-1}); VE – minute ventilation; s – distance covered;

The comparative analysis covered the results obtained by the 20 competitors, who underwent the WITTY test twice. The data in Table 3 reveal an improvement in the score despite the body exhaustion associated with the preceding treadmill test. The average time of performing the WITTY test was 23.4 ± 3.1 s before the graded test and 21.0 ± 2.9 s after the graded test.

Table 3. Arithmetic means and standard deviations of parameters of the WITTY test, and blood lactate concentrations after the graded test

Indicator	**x̄**	**SD**
WITTY test result after the graded test [s]	**21.0**	**2.9**
Difference in the WITTY test results [s]	**2.4**	**2.5**
La^{-} at baseline [mmol·L^{-1}]	**1.75**	**0.24**
La^{-} after 3' [mmol·L^{-1}]	**11.81**	**3.03**
La^{-} after 20' [mmol·L^{-1}]	**5.74**	**3.26**
Difference in La^{-} [mmol·L^{-1}]	**6.07**	**1.49**

x̄ – arithmetic mean; SD – standard deviation; La^{-} – blood lactate concentration;

The collected measurement results were statistically processed by calculating the basic indicators and Pearson correlations. The Shapiro-Wilk test confirmed the normal distribution of the analysed variables (Table 4).

Table 4. Shapiro-Wilk test evaluation of the normality of the variable distribution

Variable	**p***
VO_2max absolute [L·min^{-1}]	0.3857
VO_2max relative [mL·min^{-1}·kg^{-1}]	0.9909
WITTY test result	0.9748
La$^-$ 0'–3'	0.0541
La$^-$ 3'–20'	0.6243

VO_2max – maximal oxygen uptake: absolute (L·min^{-1}) and relative to body mass (mL·min^{-1}·kg^{-1}); La$^-$ – blood lactate concentration
* statistical significance level at $p < 0.05$

On the basis of the Pearson linear correlation test, no significant correlation was found between VO_2max absolute values (L·min^{-1}) or those relative to body mass (mL·min^{-1}·kg^{-1}) and the difference in the WITTY test results (Table 5).

Table 5. Correlation coefficients of VO_2max values and WITTY test results

Variable	**WITTY test**
VO_2max absolute [L^{-1}·min^{-1}]	0.147
	N = 20
	p = 0.536*
VO_2max relative [mL·min^{-1}·kg^{-1}]	–0.142
	N = 20
	p = 0.552*

VO_2max – maximal oxygen uptake: absolute (L·min^{-1}) and relative to body mass (mL·min^{-1}·kg^{-1})
* $p > 0.05$

The Pearson linear correlation test did not indicate any significant correlation between VO_2max absolute values or those relative to body mass and the difference in lactate concentration. However, a trend was observed that as VO_2max increased, the difference in lactate levels in 3' and 20' was raised (Table 6).

Table 6. Correlation coefficients of VO_2max values and lactate concentrations

Variable	**Lactate 0'–3'**	**Lactate 3'–20'**
VO_2max absolute [L·min^{-1}]	–0.342	0.209
	N = 20	N = 20
	p = 0.140*	p = 0.376*
VO_2max relative [mL·min^{-1}·kg^{-1}]	–0.044	0.331
	N = 20	N = 20
	p = 0.855*	p = 0.154*

*** p > 0.05**

Discussion

The aim of the study was to assess the level of somatic indicators and aerobic capacity in players training football at the level of the Polish top league. The championship level of football performance involves a combination of high physical indicators, which, in turn, depend on a variety of anthropometric properties and physiological aspects of the body, as well as on the training and health of individual athletes (Kutáč, 2013; MacArthur and North, 2005). Currently, criteria are being searched for that would help select players with particular predispositions to practise football at the championship level (Duda, 2016; Soroka, 2011). These selection criteria are presented with the use of indicators which, in a rational and understandable way, enable forecasting the player's development. One of the directions of data acquisition is the knowledge of the athletes' somatic structure. Body height and mass are among the most frequently obtained data when it comes to the morphological aspect of footballers. It has been noticed that there are significant differences between the players of individual formations in terms of body height and mass indicators. These features often determine the role played by an individual on the pitch (Andrzejewski, 2015; Duda, 2016; McArdle et al., 2007; Soroka, 2011). Researchers believe this to be justified as it has to do with energy expenditure during the game (Bloomfield et al., 2007). Somatic indicators are among the factors determining the level of physical condition and basic motor capacity (McArdle et al., 2007).

As shown by the analysis of somatic indicators of the studied group of footballers, body height was at the level of 181.8 ± 7.9 cm, while the percentage of body fat equalled 18.9 ± 2.9%, with fat-free mass of 27.8 ± 23.2 kg. The investigated somatic features indicate a great similarity of the studied athletes to those of other football teams (Gil et al., 2010; Hazir, 2010). Radzimiński et al. (2020) confirm in their research that a lower content of adipose tissue has a positive effect on endurance indicators, as well as on the length of the distance covered during a sprint in championship matches. The significance of somatic indicators was also emphasized by Soroka (2011) and Duda (2016) when analysing the 2010 World Cup in South Africa. Soroka (2011) claims that morphological features, especially body height, should be treated as a stable and genetically determined criterion for assessing the suitability of a player for the discipline of football.

Commercialization of football causes its dynamic development, forcing the improvement of the game quality. It is associated with the development of physical capacity, as well as motor, technical, tactical, and speed skills. Therefore, methods of controlling the physical and mental preparation of a footballer are being sought. As it is commonly known, highly developed physical capacity of a footballer influences the precision of their technical actions, increases the tactical opportunities of the team, and lowers the number of injuries during the professional careers (Michalski and Małolepszy, 2012).

The energy characteristics of a football player's physical effort are crucial owing to the high intensity developed during the game. An important aspect, although not as important as a game, is anaerobic effort, when the footballers move with very high intensity at different times of the game, producing large amounts of lactate, which can reduce the intensity of the game (Michalski and Małolepszy, 2012). After exceeding the threshold intensity of running, the concentration of lactic acid increases dynamically. The amount of work performed above the threshold of anaerobic changes reflects the tolerance level of the increasing fatigue during the match (Michalski and Małolepszy, 2012). In the conducted study, the observed difference in the lactate levels in footballers was 6.07 ± 1.49 mmol·L^{-1}. Before the effort, the values were very close to one another. It is commonly recognized that endurance training contributes to the reduction of lactate concentrations under the influence of submaximal exercise. The reason for such a phenomenon may be that players who have a lower oxygen debt exhibit a greater ability to utilize metabolic products in the form of lactic acid (Lyakh et al., 2012). The basic component of football activities lasting for 90 minutes, however, are efforts based on aerobic metabolism, i.e. standing, walking, jogging. Lactate diffusion then occurs from working muscles, and this part of physical capacity is best illustrated by VO_2max or the size of the load at which ventilatory thresholds occur (Michalski and Małolepszy, 2012). From a physiological and practical point of view, a high level of aerobic capacity allows the player not only to cover a greater total distance and to perform sprints, starts, and jerks more often, but also to develop greater dynamics of the game and to maintain it for an extended period of the match. It promotes greater tolerance of increasing fatigue and take-off loads. It speeds up the course of restitution processes during rest breaks and during low-intensity parts of the game. The shorter regeneration time of the body after high-intensity exercise allows the athlete to engage earlier and more effectively in the next action of maximum intensity (Stankiewicz and Środa, 2016). It also influences the achievement of the threshold of psychomotor fatigue with a higher intensity of the match effort (Andrzejewski, 2015).

The analysis of the maximum and threshold values of aerobic capacity indicators in the process of planning sports training allows to determine the optimal individualized intensity of loads that cause the desired metabolic reactions leading to an increase in aerobic capacity (Ambroży et al., 2015). The level of aerobic capacity in the tested competitors was 55.9 ± 2.8 mL·min^{-1}·kg^{-1}. In other sports disciplines, the average level of VO_2max equals 40.8 mL·min^{-1}·kg^{-1} among judo players (Pałka et al., 2013), 58.4 mL·min^{-1}·kg^{-1} among mixed martial arts players (Tota et al., 2014), and 57.38–60.97 mL·min^{-1}·kg^{-1} among middle-distance runners (Zieliński, 2004). In this study, no significant correlation was found between the values of the VO_2max indicator, either absolute or relative to body mass, and the results of the WITTY test or the difference in the lactate level between 0'–3' and 3'–20'. This is probably due to the small size of the group of respondents.

The analysis of the results of similar trials is used by coaches for short- and long-term planning of the training process (Ambroży et al., 2015). The training effects in sport are the consequences of training activities, which are characterized by short-term, medium-term, and long-term athlete responses to loads (Issurin, 2010). These reactions should be analysed by coaches and players in order to pursue a consequence to the planned effects of individual units, cycles, or entire training periods (Lyakh et al., 2012). Efforts made at a maximum running speed are an extremely important element of the match game.

Although the total duration of sprint actions taken by a player during a match does not exceed 1 minute, they are necessary and can sometimes determine the match result (Lyakh et al., 2012). In combination with high aerobic capacity, considerable speed skills increase the potential of economic energy expenditure during a sports competition (Lyakh et al., 2012). The WITTY test carried out among the footballers allowed to improve their speed abilities in the second trial. The difference in the WITTY test results equalled 2.4 ± 2.5 s. In a game at the highest level, the player is expected to move efficiently and quickly, think, as well as control the ball under the pressure of time and the opponent in a shortened and narrow field of play (Duda, 2016).

In order to better understand and more consciously plan and control the training process of footballers, it is necessary to regularly repeat the research presented in this article. Comprehending the training effects is of key importance for the analysis of the further training process, especially at the top league level, to make them more controllable and predictable (Lyakh et al., 2012).

Conclusions

Improving and training endurance are central to the development of any athlete (Esposito et al., 2019). To assess and monitor this ability, special tests are applied, mainly laboratory examinations, which, owing to their precision, allow obtaining important information at different time points of the season. In the presented results, there was no significant correlation between VO_2max, either absolute or relative to body mass, and the WITTY test results. Also, no significant relationship was found between the absolute VO_2max values and the difference of lactate concentration in 0'–3' and 3'–20'. However, a tendency was observed that with the increase of absolute VO_2max, an acceleration occurred in the restitution processes expressed in the level of lactate between minutes 3 and 20.

Summarising the investigations presented in the paper, one can conclude on the significance of applying evaluation tests during the football season in order to assess players' fitness and sports endurance. The data obtained during the tests provided very important information that will allow to develop individualized training programs in accordance with the characteristics of each athlete. Comparing the test results in the future will indicate the changes in individual competitors brought about by the specialized training. The study of the performance of football teams, as well as developing different physiological profiles and their evaluation can provide useful measures and facilitate the work of coaches and analysts in the process of assessing the achievements of teams and/or players (Pastore et al., 2019).

Declaration of interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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