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Original Article

A comparative study of aerobic capacity among elite basketball players according to five different positions in the team

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Abstract
The subject of this paper is the comparison of the obtained values of maximum oxygen consumption for senior basketball players in relation to their different positions and roles in the team. Sixty senior basketball players from four Serbian basketball clubs (BC Red Star n=14, BC FMP n=16, BC Mega n=15, and BC Borac n=15) participated in the study. The basic sports medical examination was performed in the "Vita Maxima" sports medicine clinic in Belgrade, which provided insight into their health conditions, and an assessment of their health capacity for participation in the study – i.e., for the implementation of maximum CPET (Cardiopulmonary Exercise Testing) – was carried out. The basic sports medical examination included: determination of body height, assessment of complete body composition (body weight, height-to-weight ratio (BMI), percentage of body fat (FAT%), 12-channel electrocardiogram (ECG) at rest with determination of heart rate, as well as measurement of arterial blood pressure on both arms and auscultation of the heart and lungs. After the introductory part of the test, which served as a warm-up, the speed of the conveyor belt increased to 9 km/h, and did not change during the test, while the elevation of the belt was raised by 2º every one minute in order to achieve the maximum load. The results of the study showed that maximal oxygen consumption as a measure of aerobic capacity is higher among players playing the positions of point guard and shooting guard compared to centers, but that it differs neither between point guards, shooting guards, and small forwards, nor between small forwards, power forwards, and centers. Furthermore, no difference in maximal oxygen consumption was observed between teams competing in different league ranks.
Keywords: endurance, V02max, maximal oxygen uptake, cardiopulmonary exercise testing

Introduction

Basketball is one of the most dynamic sports in the world, involving constant changes in typical and atypical situations which players must predict, analyze, and adequately react to in the shortest possible time. (Karalejić & Jakovljević, 2001). Basketball is considered a predominantly anaerobic sport, given that energy for activities that include jumping, sprinting, rapid changes of direction, acceleration and sudden braking, shooting and driving the ball is obtained using the creatine-phosphate system, under exclusively anaerobic conditions (Köklü, Alemdaroğlu, Koçak, Erol, & Fındıkoğlu, 2011). However, after intense anaerobic activities, aerobic metabolism and high aerobic capacity are crucial for the recovery process (Klisouras, V. 2013; Kenney, L. et al, 2012) Therefore, it can be concluded that basketball is an anaerobic-aerobic sport, and that work on improving both of these abilities is the key to achieving top sports results (Marinkovic & Pavlovic, 2013; Ransone, 2016). Maximal oxygen consumption is a measure of aerobic capacity, and can be affected by the time spent on the floor, because playing matches significantly affects the improvement of aerobic and anaerobic abilities. Scanlan at. al (2021) proved that professional basketball players who spent more time on the floor had significantly better V02 max than basketball players who were on the bench or played less.

Also, playing basketball at a young age contributes to better aerobic capacity compared to children who have only moderate unprogrammed physical activity (Stojmenović, T. et.al 2018, Mancha-Triguero, et. al; 2020). Maximal oxygen consumption (V02max) in basketball players is, according to some authors, in the range of 42 to 59 ml/kg/min (Stappf, 2000), while certain authors in a recent study show VO2max values in basketball players between 45 and 65 ml/kg /min (Midgley, McNaughton, R, & Marchant, 2007). These values, of course, also depend on the level at which senior basketball players compete. At the same time, young basketball players aged 18 showed that they have quite a solid level of maximal oxygen consumption (51.32 ml/kg/min), which is within the limits of professional basketball players (Cengizel, E. et. al; 2022). These values can be the starting point for the subsequent selection of young talents (Trunić, N., & Mladenović, M. 2014). Given that basketball is a team sport of a polystructural type in which it is possible to distinguish five positions and different roles in the game, the primary goal of this paper is to compare the obtained values of maximal oxygen consumption for senior basketball players in relation to their different positions and roles in the team. Also, the obtained average

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values of maximal oxygen consumption will be compared between different teams participating in the research, with the aim of assessing aerobic capacity in relation to different competition ranks. The classification of players into different positions in the team is most often determined by the anthropological characteristics of players (Masanovic, B., Popovic, S., & Bjelica, 2019), but also by their basic and specific motor abilities, as well as by their personality traits and cognitive properties (Masanovic, B., Vukcevic, A., & Spaic, S. 2018).

If it is taken into account that aerobic ability belongs to basic motor abilities, the determination of it in basketball players is aimed at easier definition of the positions played by individuals in the team, as well as the roles assigned to them on the court. Outside player positions on the team (i.e., positions outside the paint) involve playing roles that usually require more aerobic capacity compared to inside player positions (i.e., positions inside the paint). Therefore, the general goal of this research is aimed at determining the aerobic capacity of senior basketball players and comparing the obtained values in relation to different positions in the team in order to confirm or reject the above statements. The obtained results can have a practical application for basketball coaches and strength and conditioning coaches in terms of observing the functional characteristics of their players. Based on the information received, and with an individual approach, coaches can improve the basketball abilities of players according to the different positions and roles they have in the team, all with the aim of achieving the best possible sports results. Recent research has shown that Vo2max in basketball players can be evaluated more quickly with some field tests such as the YoYo recovery test for basketball players (Gottlieb, R., et, al; 2022). Also, a field test called the Cooper test is used, which can give indirect results for Vo2max (Wijaya, ST, & Sudijandoko A. 2019). However, the most reliable method of measuring aerobic capacity is the CPET (cardiopulmonary exercise test) (Petek, B. J. et.al; 2022).

Each position in the team entails corresponding anthropological, functional, and motor characteristics of the players on the basis of which each coach creates a division of roles and tasks in the game. Most of the research that examined differences in the aforementioned characteristics of players was based on differences between the three following positions in the team: guards, forwards, and centers (de Araujo et al., 2014; Köklü et al., 2011; Marinkovic & Pavlovic, 2013; Pojskic et al., 2015; Sallet, Perrier, Ferret, & Baverel, 2005), while there are virtually no studies that have examined differences in aerobic capacity using the division of players into five positions in the team (point guard, shooting guard, small forward, power forward, and center), which will be used in this paper. The literature data support better aerobic abilities in guards than in power forwards, centers, and even small forwards, which can also be explained by the roles that players at the respective positions hold on the court (de Araujo et al., 2014; Gocentas, et. al;, 2011; Köklü et al., 2011; Marinkovic & Pavlovic, 2013; Pojskic et al., 2015). Players at the outside positions of the team (point guard, shooting guard, and small forward) spend more time during the game running, sprinting, and dribbling compared to forwards and players at inside positions (power forward and pivot/centre). On the other hand, power forwards and centers jump more during training and matches, though they also spend more time walking and standing compared with players at outside positions (Köklü et al., 2011). However, despite the aforementioned different roles in the team that include different functional player characteristics, there are also studies that have not proven a difference in VO2max between players in relation to different positions on the team. Research from one study showed that there was no difference in VO2max values between players at outside and inside positions, but a difference in aerobic efficiency was observed, which was superior among guards and forwards compared to center positions (Sallet et al., 2005). Another study showed that differences in aerobic capacity exist, but are minimal (Milanović, L. et. al; 2019, Ransone, 2016). The literature data related to the examination of aerobic capacity and differences in VO2max in relation to different positions of Serbian basketball players are limited. Data from one study support a statistically significant difference in VO2max values between guards and centers (Ostojic, Mazic, & Dikic, 2006), but there has been no recent research. Therefore, the aim of this study is to evaluate the aerobic capacity of senior basketball players in Serbia, and to compare VO2max values in relation to different positions in the team. The obtained values will indicate the average aerobic capacity of Serbian basketball players, and potential differences in VO2max in relation to different positions in the team will be used by coaches as a guideline for assigning appropriate roles to players. This includes an individual approach during the training process, with the aim of achieving the best possible sports results (Wright et al, 2004). It is widely assumed that basketball players, depending on their different positions in the team (point guard/playmaker, shooting guard, small forward, power forward, center), achieve varying levels of fitness, both aerobically and anaerobically, which also determines their role on the court (Pojskic et al., 2015). Therefore, the value of maximal oxygen consumption can be treated as a physiological discriminative variable between players at different positions and with different roles in the team.

Material and methods

Procedures

The conducted empirical-experimental research included a sports medical examination of senior basketball players, as well as a cardiopulmonary physical load test. The aim of the sports medical examination was to determine the general health ability of athletes. Body height and body composition were determined as part of a sports medical examination. A proper sports medical examination was a prerequisite for participating in the study, as was performing CPET on a treadmill. CPET was used to determine the maximal oxygen

consumption (VO2max) of senior basketball players. Prior to being carried out, this study was approved by the ethics committee of the Sports Medicine Association of Serbia. Each participant voluntarily provided written informed consent before participating. The conducted research does not violate the rights of the examined players, according to the ethical standards of the Helsinki Declaration of the Committee on Human Rights (WMA Declaration of Helsinki, 2013).

Participants

Sixty elite senior basketball players from four basketball clubs (BC Crvena zvezda, BC FMP, BC Mega, and BC Borac) participated in the study, of which 14 players were from BC Crvena zvezda, 16 players from BC FMP, 15 players from BC Mega, and 15 players from BC Borac. At the time of conducting the study, the players from BC Crvena zvezda competed in the Euroleague and the ABA league, while BC Mega and BC FMP competed in the so-called Adriatic ("ABA") league, and basketball players from BC Borac played in the domestic Basketball League of Serbia (KLS league). All tests were performed at the beginning of the preparation period. Before each determination of the investigated parameters, all respondents filled out a questionnaire about their basic data, including their personal and family history. The basic sports medical examination was performed in the "Vita Maxima" sports medicine clinic in Belgrade, which provided insight into their health condition. Furthermore, an assessment of the health capacity for participation in the study – i.e., for the implementation of the maximum CPET – was also carried out. The basic sports medical examination included as follows: determination of body height, assessment of complete body composition (body weight, height-to-weight ratio (BMI), percentage of body fat (FAT%), a 12-channel electrocardiogram (ECG) at rest to determine heart rate, measurement of arterial blood pressure on both arms, and auscultation of the heart and lungs.

Test protocol

Body height was determined using a Seca altimeter (with a measurement unit of 1 cm). To determine body weight (kg), BMI (kg/m2), and FAT%, the bioimpedance method was used using a Tanita® BC-418MA scale. The electrocardiogram of the heart at rest was performed using a 12-channel ECG (Fukuda).

A treadmill (HP-COSMOS®) was used to perform CPET. VO2max as a measure of aerobic capacity was determined using the Quark CPET system (Cosmed®) by directly monitoring gas exchange (oxygen and carbon dioxide). To conduct the test, a modified Nowacki protocol was used with an initial speed of 5 km/h and an elevation of 0º. After the introductory part of the test, which served as a warm-up, the speed of the conveyor belt increased to 9 km/h, and did not change during the test, while the elevation of the belt was raised by 2º every one minute in order to achieve the maximum load. Subjects wore face masks and mobile ECG devices (Quarck® T 12x, Wireless 12-lead ECG) on their backs in order to directly monitor gas exchange and heart rate during exercise. The test was considered maximal if at least three of the following four criteria for stopping the test were met:

- the value of the reached heart rate of 90% or more of the predicted theoretical maximum heart rate for gender and age, which is calculated based on the formula: 220 - number of years
- respiratory exchange ratio (RER)> 1.10
- plateau in maximal oxygen consumption despite increasing loads (differences in VO2max values less than 150 mL/min near the end of CPET)
- subjective feeling of exhaustion

The cardiopulmonary exercise test was performed by trained and expert persons, as was calibration, which was performed according to the so-called STPD criteria (ST-standard temperature/standard gas temperature: 0º; P-pressure/pressure: 760 mmHg; D-dry equivalent/dry air) of the Quark CPET system (Cosmed®) after every fifth test in order to adequately determine the measured parameters.

Statistical analysis

To describe parameters of importance, depending on their nature, the following were used: frequency, percentages, sample mean value, sample median, sample standard deviation, rank and 95% confidence intervals. To test the normality of the distribution, the Shapiro-Wilk tests were used, as well as the graphs: histogram and normal QQ plot. To test the differences in maximal oxygen consumption between basketball players at different positions in the team, as well as to examine the difference in aerobic capacity between basketball teams, the Analysis of Variance (One-Way ANOVA) test was used, as was the Bonferroni post hoc test for multiple comparisons. Statistical data processing was performed in the statistical package SPSS 20.0 for Windows. Differences were considered significant when the p value was less than 0.05.

Results

The anthropometric characteristics and body composition of all basketball players who participated in the study and the anthropometric characteristics and body composition of basketball players in relation to different positions in the team are shown in **Tables 1 and 2**, respectively.

Table 1. The anthropometric characteristics and body composition of basketball players who participated in the study:

Variables	$\bar{X}$± SD
N (number)	60
Age	22.38±3.79
height (cm)	199.47±8.09
body mass (kg)	96.12±10.80
BMI (kg/m2)	24.21±2.07
FAT %	10.48±3.93

Table 2: The anthropometric characteristics and body composition of basketball players in relation to different positions in the team:

	Point Guard	Guard	Small Forward	Power Forward	Center
Variables	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD
N (number)	11	18	11	8	12
Age	22.54±4.74	21.61±3.40	21.82±3.46	21.5±2.67	24.5±4.06
height (cm)	188.0±6.24	196.61±4.63	202.82±3.12	204.25±3.84	208.0±3.46
body mass (kg)	88.56±6.33	89.54±5.98	96.02±4.17	99.19±8.21	110.97±10.03
BMI (kg/m2)	24.85±2.20	23.20±1.91	23.37±1.50	24.61±1.75	25.60±1.98
FAT %	9.27±3.48	9.30±3.39	8.14±4.06	10.59±4.03	12.69±3.54

The average VO2max values of basketball players in relation to different positions in the team, along with the average value of maximal oxygen consumption for all the 60 basketball players who participated in the study, are shown in **Table 3.**

Table 3: VO2max values in relation to different positions in the team and the average VO2max value for the total number of subjects who participated in the study:

	Point Guard	Shooting Guard	Small Forward	Power Forward	Center	Total
Variables	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD
N (number)	11	18	11	8	12	60
VO2max (mL/kg/min)	57.94±4.74	56.96±4.92	56.15±3.78	56.67±2.17	50.75±5.84	55.71±5.17

The One-Way ANOVA test showed a statistically significant difference in maximal oxygen consumption values between basketball players at different positions in the team ($p < 0.01$). However, the post hoc Bonferroni test showed a statistically significant difference in values of VO2max between outside (point guards, shooting guard) and center positions ($p < 0.01$), as seen in **Table 4**. There was no statistically significant difference between point guards, shooting guards, small forwards, and power forwards, nor was there a statistically significant difference between small forwards, power forwards, and center positions ($p > 0.05$), as seen in **Tables 5 and 6.** On the other hand, the average VO2max values for each team individually are shown in Table 7.

Table 4: VO2max values in relation to the positions of pointguards, shooting guards, and centers:

	Point gGuard	Shooting Guard	Center
Variables	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD
N (number)	11	18	12
VO2max (mL/kg/min)	⋆ 57.94±4.74	⋆ 56.96±4.92	50.75±5.84

⋆ Statistically significant difference in VO2max values between positions ($p < 0.01$), which was also confirmed by the post hoc Bonferroni test ($p < 0.01$).

Table 5: VO2max values in relation to the of positions point guards, shooting guards, small forwards, and power forwards:

	Point Guard	Shooting Guard	Small Forward	Power Forward
Variables	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD
N (number)	11	18	11	8
VO2max (mL/kg/min)	57.94±4.74	56.96±4.92	56.15±3.78	56.67±2.17

T**able 6:** VO2max values in relation to the positions of small forwards, power forwards, and centers:

	Small Forward	Power Forward	Center
Variables	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD
N (number)	11	8	12
VO2max (mL/kg/min)	56.15±3.78	56.67±2.17	50.75±5.84

No statistically significant difference in VO2max values between positions ($p > 0.05$), which was also confirmed by the post hoc Bonferroni test ($p > 0.05$).

Table 7: VO2max values in relation to the different basketball teams that participated in the study:

	BC Red Star	BC FMP	BC Mega	BC Borac
Variables	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD	$\bar{X}$± SD
N (number)	14	16	11	8
VO2max (mL/kg/min)	55.54±4.76	55.82±5.20	55.26±5.51	53.93±6.22

Discussion

The results of the research indicate the existence of a statistically significant difference in the values of maximal oxygen consumption between basketball players at outside and inside positions in the team. It is evident that point guards and shooting guards have a better aerobic capacity than players in central positions (power forwards, and centers), which coincides with the results of a study that was also conducted in Serbia (Ostojic et al., 2006). It further coincides with the results of a study that evaluated the differences in VO2max in relation to different positions in the team by dividing basketball players into only two groups: players at outside positions and the so-called post players (Gocentas et al., 2011). The largest number of studies dealing with the assessment of the functional abilities of basketball players divided players into three positions: guards, forwards, and centers. The results of these studies are in favor of better aerobic abilities in guards and forwards compared to center positions, which also coincides with the results of our study (Pojskic et al., 2015; Ransone, 2016; Marinkovic & Pavlovic, 2013; de Araujo et al., 2014).

The higher VO2max values observed in outside players compared to centers can be explained by the different training process experienced by guards and forwards compared to inside players. Guards spend significantly more time during training in running, most often using the length of the entire court (dribbling, passing the ball, organization of the game, defensive roles, etc.). On the other hand, centers spend more time in the paint, where shorter runs are carried out on a smaller surface of the court. Sections and exercises are more based on contact play (Pojskic et al.; 2015). BMI and FAT% values are significantly higher among centers than in guards and forward players.

Therefore, the lower values of VO2max in players at inside positions can potentially be explained by this fact, because it is clear that a higher percentage of body fat represents a "burden" that reduces the amount of oxygen that reaches the muscles during physical activity, and, therefore, less energy is produced for performing work, which results in a lower aerobic capacity (Karalejić & Jakovljević, 2001). On the other hand, the results of the study did not show a statistically significant difference in VO2max values between guards, forwards, and power forwards, nor did they show it between forwards, power forwards, and centers. Our results showed that professional basketball players from Serbia have better oxygen consumption than Turkish football and handball players (Mehmet, S et. al; 2017). Furthermore, this study supports the fact that Serbian basketball players have a better aerobic capacity than first- and second-league players in Lithuania (Dragonea P et. al; 2019). Also, this study coincides with the results of a study from Croatia (Milanović, L. et. al; 2019) that found a difference in V02 max between center positions (power forwards and centers 54.8 ml/kg/min) and outside positions (guards and forwards 56.7ml/kg/min). Also, the results of this study do not match the research from India on their elite basketball players (Machado, NA et. al; 2021) which concluded that power forwards have the best oxygen consumption compared to centers, small forwards, shooting guards, and point guards. At the same time, the

Indian basketball players generally had a significantly lower level of aerobic capacity than the Serbian ones. Today's modern basketball involves playing multiple positions so, in practice, the rough division of players into a point guard, shooting guard, small forward, power forward, and center is increasingly disappearing.

The requirements of the basketball game are such that players at outside positions very often have to find their way under the basket itself, and vice versa: it is not rare for a power forward or a center to dribble the ball across the court or make a three-point shot. The multiple roles on the court bring with them the burden of better physical abilities and, therefore, aerobic abilities. This explains the absence of a statistically significant difference in VO2max values between different positions within the group of those who play on the outside (point guard, shooting guard, small forward) and between different positions within the group of those who play inside the paint (power forward, center). This is supported by the results of a study that indicates that there is a small difference in VO2max values between basketball players in different positions, but that it is not statistically significant (Sallet et al., 2005). On the other hand, the authors of this study obtained a statistically significant difference in aerobic efficiency between guards, forwards, and centers. If you consider the fact that aerobic capacity is defined by aerobic endurance, aerobic power (VO2max), and aerobic efficiency, it is clear that a guard and a center can have the same VO2max, but they are very likely to differ in aerobic efficiency, that is, the way their bodies use oxygen during the same intensity of work (Flockhart, M., & Larsen, F. J. 2019). In other words, because of the role they play on the court, basketball players at outside positions will have better aerobic efficiency than players at inside positions, which was confirmed by the above study. This can explain the lack of difference in VO2max values, especially between players within the same group on the court (outside vs. inside group of players in relation to different positions and team) and in addition to the evidently better aerobic capacity of players at outside positions (at the expense of aerobic efficiency), as is also the case with our research.

By comparing the VO2max values between four different teams, no statistically significant difference was obtained. Although at the time of conducting the study, BC Crvena zvezda, BC Mega, and BC FMP competed in the so-called Adriatic League (ABA League) and European competitions, with BC Borac competing in the domestic basketball league of Serbia, which is inferior in terms of competition levels compared to the former, no difference in aerobic capacity between the teams was observed. These results are in support of other studies that conducted research on this topic, and in which there was also no difference VO2max values in relation to different levels of competition (Köklü et al. 2011). Sallet et al. (2005) demonstrated in their study that there is no difference in aerobic capacity between the players who play in the first and second division of France, but that the differences were statistically significant in terms of their anaerobic abilities. As already mentioned earlier, basketball is a predominantly anaerobic sport and, therefore, the level of competition to which the players are subjected can potentially affect the level of their anaerobic abilities.

This makes a difference between teams from different ranks of the competition in terms of anaerobic determinants. On the other hand, aerobic ability is an important, but definitely not a dominant, factor that determines the sports abilities of both basketball players and the entire team, which can explain the fact that there is no difference in VO2max values between the teams in our study. Additionally, the research was conducted at the beginning of the preparation period, after the rest phase, so the length of recovery, as well as the implementation or non-implementation of an appropriate training regime in the form of an active break, could very well affect the results obtained. Also, basketball players and other athletes improve their functional abilities during the season after a large number of games and as a result of growing training intensity as the season unfolds (Ferioli, D.et.al; 2020. Matulaitis, K. et.al; 2021). Furthermore, a small sample of subjects, or teams, can give a false impression of the absence of difference in VO2max values between teams of different competitive ranks. The fact is that only VO2max was determined as a measure of aerobic fitness, and it cannot be said with certainty that there is no difference in overall aerobic fitness between the above positions in the team.

Therefore, further research could go in the direction of assessing the aerobic efficiency of basketball players, which refers to the ability of the body to use O2 more efficiently, that is, more "sparingly," in order to create energy for a given intensity of work. Oxygen consumption (VO2) for a given work intensity will be significantly lower in a person with higher aerobic efficiency, while, during CPET, the aerobic and anaerobic threshold will be reached much later, that is, at higher heart rates (Kenney, Wilmore, & Costill, Energy Expenditure and Fatigue, 2012).

Conclusion

The results of the study showed that maximal oxygen consumption, as a measure of aerobic capacity, is higher in players at the positions of point guard and shooting guard compared to centers, but that it differs neither between point guards, shooting guards, and small forwards, nor between small forwards, power forwards, and centers. Furthermore, no difference in maximal oxygen consumption was observed between teams competing in different league ranks. It is evident that basketball players at outside positions have different playing requirements and roles compared to those at central positions and, therefore, a greater aerobic capacity. However, modern, "fast" basketball is slowly leading to the equalization of players who play different positions in terms of maximal oxygen consumption. In any case, basketball coaches, in cooperation with the entire professional staff, should design training sessions according to the different positions and roles of players in the

team, especially during the preparatory period when aerobic capacity is developed to the greatest extent. Only with an individual approach during training, both in terms of physical and technical-tactical abilities, can players realize their full sporting genetic potential. In other words, only basketball players who perfect their individual abilities to the maximum can make up the "perfect" team. In order to more accurately assess the existence of differences in VO2max between different positions in the team, it would be desirable to perform CPET, both at the beginning and at the end of the preparation period, so as to avoid the effects of a longer or shorter break (active, or a break that includes absolute rest) on the value of maximal oxygen consumption. Additionally, determining VO2max during the competitive phase of the macrocycle could potentially show a difference in aerobic capacity between teams participating at different levels of competition. Since the results of our study did not show a statistically significant difference in terms of maximal oxygen consumption between the teams, and the research was conducted before the beginning of the preparatory period, the influence of "severity", i.e., the level of competition, on aerobic capacity, at the given time of the study, was definitely absent.

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