Physiological parameters of professional football players in teams of various levels

Dragutin Stojmenović¹ABCDE, Tamara Stojmenović²ABCDE

¹Department of Physiology, Faculty of Medical Sciences, University of Kragujevac, Serbia
²Faculty of Physical Education and Sports Management, Singidunum University, Serbia

Authors’ Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim
Soccer is a demanding sport which, in addition to technical and motor characteristics, also requires exceptional functional abilities of athletes to play at a high level. The aim of this study: 1) To analyze the disparities in physiological parameters among professional soccer players in teams of varying levels. 2) To explore potential connections between team ranking positions and the physiological attributes of professional soccer players.

Material and Methods
91 professional soccer players who compete in Serbian Super league (age 24.14±5.15) were included in the study. Participants were classified into two groups. The first group consisted of players from teams that were ranked from third to sixth place at the end of 2021/2022 competitive season (n=49). The second group of participants consisted of the players of the teams that were ranked in the last two places at the end of the above-mentioned season (n=42). Maximal oxygen consumption (VO₂max), as well as running speeds and heart rates at first and second ventilatory thresholds (VT1 and VT2) were obtained by performing maximal cardiopulmonary exercise test.

Results
The results showed a statistically significant difference in terms of VO₂max values, running speeds and heart rates at VT1 and VT2 when the top and bottom ranked teams were compared (p < 0.001).

Conclusions
The results of the study imply that playing high-level soccer requires exceptional functional abilities, which go beyond technical and tactical characteristics. These exceptional abilities enable players to continuously perform at high intensities during the games in order to achieve top results. Coaches should be aware of the importance of high aerobic capacity for achieving top results, especially if the team consists of less talented players.

Keywords: functional abilities, competitive rank, soccer, training thresholds

Glossary:

VO₂max – maximal oxygen consumption;
VT1 – first ventilatory threshold;
VT2 – second ventilatory threshold;
HR at VT1 – heart rate at first ventilatory threshold;
HR at VT2 – heart rate at second ventilatory threshold;
V at VT1 – running speed (km/h) at first ventilatory threshold;
V at VT2 – running speed (km/h) at second ventilatory threshold.

Introduction

Soccer is an intense and physically demanding sport that is characterized by cyclic and acyclic movements, and apart from the technical, tactical, and motor characteristics of athletes, this sport also requires high aerobic and anaerobic endurance [1]. Soccer is primarily an anaerobic sport due to high intensity sprint sections performed in solving technical and tactical tasks in attack and defense. On the other hand, aerobic capacity ensures continuity in the implementation of these high-intensity anaerobic sections, as well as fast recovery after them.

Aerobic capacity represents the organism’s ability to create energy for physical work through aerobic processes [2, 3]. The measure of aerobic capacity is maximal oxygen consumption (VO₂max) which, according to most authors, is the best indicator of athletes’ cardiorespiratory fitness [4, 5]. Expected VO₂max values for professional soccer players range from 55 to 70 mL/kg/min [6, 7]. High VO₂max values enable training at a higher intensity while using oxygen to generate energy, which means reaching the first and second ventilatory thresholds (VT1 and VT2) at higher heart rates and delaying anaerobic fatigue.

The ventilatory (or anaerobic) thresholds represent the moment of increase in lactate and lactate/pyruvate ratio in muscles and arterial blood and occurs at that level of physical activity above which, in addition to the generation of energy in aerobic conditions, the energy is also produced during anaerobic metabolic processes, such as anaerobic glycolysis [8]. In different literature and by different authors, these thresholds are also called “first and second lactate thresholds”,

© Dragutin Stojmenović, Tamara Stojmenović, 2023
doi:10.15561/26649837.2023.0502
“anaerobic thresholds” or “aerobic and anaerobic thresholds” [9]. For this study purposes we use terms first and second ventilatory thresholds since the ergospirometry was performed to obtain these parameters.

Certain research shows that achieved work intensity at VT1 and VT2, in terms of obtained heart rates at these thresholds, is a better indicator of cardiorespiratory fitness in soccer players than VO2max value itself [4]. In other words, the higher the running speed and heart rate at VT1 and VT2, the better the aerobic efficiency and endurance of an athlete [10]. The intensity of effort at which VT1 and VT2 are obtained can be improved by specific training sessions even without raising the VO2max values and this is, according to some authors, much more important for performance of soccer players [11, 12, 13].

Determination of ventilatory thresholds and VO2max is performed with a cardiopulmonary exercise test (CPET) by monitoring direct gas exchange (oxygen and carbon dioxide) [14, 15].

The first threshold is defined as the first increase of lactate in the blood, followed by an immediate increase of ventilation needed to deliver oxygen (O2) to the cells, and export carbon dioxide (CO2) to the outside environment. The second threshold is called the respiratory compensation point because above this threshold the work is performed in 100% anaerobic conditions, and hyperventilation is the only compensatory mechanism by which the body tries to prevent ongoing metabolic acidosis [16].

Previous research shows that the first rise in blood lactate (reaching the first ventilatory threshold) in professional soccer players occurs at average treadmill running speeds of 12.3 km/h (VT1 = 2 mmol/L of blood lactate), while second pronounced rise in blood lactate (second ventilatory threshold) is reached at speeds higher than 15 km/h (VT2 = 4–6 mmol/L of blood lactate) [17].

Heart rates obtained during CPET at first and second ventilatory thresholds are extremely important for adequate dosage of training, which ensures the achievement of supercompensation and positive training effects [18].

**Hypothesis.** Hypothesis suggests that significant differences in physiological parameters, including oxygen consumption, heart rates, and running speeds, will be observable among professional soccer players based on the ranking positions of their respective teams.

**The aim of the study:** 1) To analyze the disparities in physiological parameters among professional soccer players in teams of varying levels. 2) To explore potential connections between team ranking positions and the physiological attributes of professional soccer players.

**Material and Methods**

**Participants**

For the purposes of this research, the sample of participants consisted of 91 professional soccer players from five different Serbian teams (age 24.14±5.15, height 181.84±6.11 cm, weight 75.69±6.62 kg). They were classified into two study groups. The first group was made up of players from 3 different soccer teams (n=49) which were ranked from third to sixth place at the end of competitive season. The participants from the second study group were players who played for two soccer teams which ended up in the last two places at the end of 2021/2022 Serbian Super league. The criteria for inclusion in the study were players age ≥ 18 to ≤ 35 years, training age ≥ 6 years, without recent injury (> 12 months). Cardiopulmonary exercise testing was conducted at the beginning of the macrocycle, as a part of pre-participation medical screening, and before the start of the competitive season. Each participant voluntarily provided written informed consent before participating in the study and performing the CPET. 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). The Research Ethics Committee for human test subjects of Sports Cardiology Association of Serbia approved all study procedures.

**Procedures**

The sample of variables used in the research represent the parameters of morphological and functional abilities of soccer players. Determination of body height was done using a Seca altimeter (unit of measure is 1 cm). The Tanita® BC-418MA scale (bioimpedance method) was used to determine body weight (kg), BMI (kg/m²), and FAT%. An electrocardiogram of the heart at rest was performed using a 12-channel ECG (Fukuda®). To implement CPET, a treadmill (HP-COSMOS®) was used, while VO2max, as a measure of aerobic capacity, and heart rates and running speeds at VT1 and VT2, were determined by using the Quark CPET system (Cosmed®) while direct monitoring of gas exchange (O2 and CO2). A protocol for professional soccer players was used to perform the test, with an initial speed of 6 km/h and an elevation of 3%. The treadmill running speed was increased by 1 km/h every 40 seconds until the player had reached volitional exhaustion, as well as maximal heart rate is achieved (at least 90% of maximal heart rate in theory according to formula 220 – age), plateau in oxygen consumption is obtained and respiratory quotient is above 1.10. Heart rate was continuously monitored with a short-range telemetry HR monitor and 12-lead Stress ECG.
Determination of first and second ventilatory thresholds (VT1 and VT2) were obtained during CPET by using Wasserman 9-Panel Plot and Omnia software. The VT1 and VT2 are usually obtained by analyzing all Wasserman panels, with particular attention to VO₂ vs. VCO₂ (V-slope method), ventilatory equivalents for O₂ and CO₂ (VE/VO₂; VE/VCO₂), respiratory quotient (RQ = CO₂/O₂), and PetO₂ and PetCO₂ panels. The VT1 was determined according to different validated methods: modified V-slope method, ventilatory equivalent method (VE/VO₂ panel), and end tidal O₂ pressure method (PetO₂ panel). The VT2 was determined by using the ventilatory equivalent method (VE/VCO₂ panel), at the point where ventilation (VE) increases out of proportion to VCO₂ and RQ is ≥ 1 and end tidal PetCO₂ method (PetCO₂ panel) [19].

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. The Shapiro Wilk tests were used, to test the normality of the distribution, as well as the graphs: histogram and normal QQ plot. To test the differences in maximal oxygen consumption, running speed and heart rates at ventilatory thresholds between the study groups of soccer players the Independent simple T test with Levene’s Test for Equality of Variances was used, as well as Mann Whitney U test. 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

A comparative statistic of measured variables which represent functional abilities (cardiorespiratory fitness) of soccer players is shown in Table 1. In the field of functional abilities, a statistically significant difference (p < 0.001) was observed in terms of VO₂max values (Figure 1), and heart rates at VT1 and VT2, respectively (Figure 2 and Figure 3). Furthermore, a statistically significant

Table 1. A comparative statistic of functional abilities of soccer players from top and bottom ranked teams.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Top ranked teams</th>
<th>Bottom ranked teams</th>
<th>t value</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of participants</td>
<td>49</td>
<td>42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO₂max (mL/kg/min)</td>
<td>61.37±5.07</td>
<td>54.57±5.96</td>
<td>10.109</td>
<td>0.000</td>
</tr>
<tr>
<td>HR at VT1 (bpm)</td>
<td>157.49±11.21</td>
<td>150.52±12.06</td>
<td>3.469</td>
<td>0.001</td>
</tr>
<tr>
<td>HR at VT2 (bpm)</td>
<td>176.18±10.27</td>
<td>170.76±8.04</td>
<td>3.510</td>
<td>0.001</td>
</tr>
<tr>
<td>V at VT1 (km/h)</td>
<td>12.53±1.52</td>
<td>9.57±1.57</td>
<td>11.020</td>
<td>0.000</td>
</tr>
<tr>
<td>V at VT2 (km/h)</td>
<td>16.41±1.91</td>
<td>12.83±1.87</td>
<td>11.212</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Abbreviations: VO₂max (maximal oxygen consumption); HR (heart rate); HR at VT1 (heart rate at first ventilatory threshold); HR at VT2 (heart rate at second ventilatory threshold); V (running speed).

Figure 1. Distribution of VO₂max values within different ranked soccer teams at the end of the competitive season.

Figure 2. Distribution of HR values at VT1 within different ranked soccer teams at the end of the competitive season.
difference (p < 0.001) was also found in running speed at VT1 and VT2 (Figure 4 and Figure 5).

**Discussion**

**Aerobic capacity**

The results of our study showed that functional abilities (cardiorespiratory fitness) are very important for playing top level soccer, which agrees with previous research on this topic [1, 6, 9]. Primary findings of this research support the fact that players from the top ranked teams, during competitive season, had statistically better results in terms of all functional (cardiorespiratory) parameters compared to soccer athletes from bottom ranked teams. Although evaluated athletes played in the same level of competition, where the physical demands of the sport are equal, the difference in VO2max values was obvious, which could explain the differences in ranking during and at the end of the competition. The study showed that players from top ranked teams had a statistically much better aerobic capacity (VO2max 61.37 mL/kg/min vs. 54.37 mL/kg/min) than players from the bottom ranked teams. Soccer players from lower ranked teams had similar aerobic abilities as professional basketball players from the EuroLeague basketball competition [20], even though it is expected for soccer players to obtain much higher VO2max values than senior basketball players. At the same time, the results of maximal oxygen consumption obtained by top ranked players were within the values for the sports discipline, described in earlier studies [21, 22, 23]. Furthermore, considering aerobic capacity, soccer players from Serbian top ranked teams achieved higher VO2max values than professional soccer players from Croatia, Brazil and Greece [24, 25, 26]. Comparing the aerobic capacity of bottom ranked teams from our research, a lower oxygen consumption values are obtained compared to semi-
professional soccer players of the 3rd and 4th League from Italy, which could also explain low ranking at the end of the season [27].

Running speed at ventilatory thresholds

In terms of running speed at ventilatory thresholds a statistically significant difference (p < 0.001) was obtained comparing soccer players from the top and bottom ranked teams. Soccer athletes from the top ranked teams were reaching the first and second ventilatory threshold at much higher running speeds, which means that they were using oxygen for energy production much longer during the effort and were postponing absolute anaerobic metabolic onset and fatigue. These results could be explained by the fact that top ranked teams are usually playing certain qualifying matches for different European competitions, and therefore they must be prepared to compete at a higher level of intensity in those matches. Compared to other studies, the Serbian soccer players from the top ranked teams were reaching ventilatory thresholds at higher running speeds [15, 26], but compared to elite football players from Croatia, the average running speeds at ventilatory thresholds were the same [24]. At the same time, soccer players from the lower ranked teams were achieving anaerobic fatigue much faster and at lower running speeds, and these results are weaker compared to the soccer players from other countries [28].

Heart rate response on ventilatory thresholds

Considering heart rate values at the first and second ventilatory thresholds a statistically significant difference was observed between the two study groups of players. Athletes who played for top ranked teams were reaching ventilatory thresholds at much higher heart rates. This means that they were able to perform physical activity in aerobic conditions at much higher effort intensity compared to players from low ranked teams. Oxygen, as a substrate for the creation of adenosine triphosphate, was used significantly longer and at a higher intensity during CPET, which is a good indicator of a great cardiorespiratory fitness [5, 6]. These results could explain better ranking position at the end of competition since high level of aerobic capacity and efficiency, with prolonged utilization of oxygen during matches makes it possible to perform anaerobic tasks in soccer during the entire 90 minutes of the game at the same intensity level [16].

The obtained results of the study showed that the achieved heart rate values at the second ventilatory threshold match the results obtained with Greek soccer players [15, 26]. At the same time, Serbian soccer players who played for top ranked teams were achieving second ventilatory threshold much earlier (at lower heart rates) compared to soccer players from Brazil and Croatia, which could generally explain the better results of these countries on the world soccer scene compared to Serbia [9, 29, 30].

The limits of this study are the tests performed only before the beginning of the competitive season, and it is not known how and with what intensity the players from both groups trained during the one-year competitive macrocycle. The implications for further research should address the importance of regular functional screening of soccer players (pre-season, after pre-season training camps, half-season, and at the end of the competitive season) to follow changes in functional capacity of athletes, which enables adequate training corrections with the aim of improving sports results.

Conclusion

The research rejected the H° hypothesis which stated that there would be no difference between the two study groups in terms of functional abilities. The results of the study confirmed the H° hypothesis and statistically significant difference in terms of VO₂ max values and heart rates, as well as, running speeds achieved at first and second ventilatory thresholds. Professional soccer players who played for top ranked teams in Serbian Super league had better aerobic both capacity and economy. Furthermore, these players were able to postpone the onset of absolute anaerobic metabolic pathways for producing energy for work, which can explain better ranking at the end of competitive season, since they could utilize O₂ much longer and more efficiently compared to players from bottom ranked teams. This means that VO₂ max is not the only value important for sports success, but also the intensity of effort at which ventilatory thresholds are reached. Very often, a lack of talent, as well as technical and tactical elements of a sport can be compensated by adequately developed cardiorespiratory fitness. Considering this fact, the practical application of this research could lead to the implementation of specific training by soccer teams (especially bottom ranked ones) with the aim of increasing the VO₂ max values and both heart rates and running speeds at which ventilatory thresholds are reached during the effort.

Acknowledgement

The authors would like to thank the soccer players (and their teams) who participated in the study, as well as, to medical stuff of outpatient sports medicine clinic "Vita Maxima", Belgrade, Serbia, where the tests were performed.

Conflicts of Interest

The authors declare no conflict of interest.
References


22. Slimani M, Nikolaidis PT. Anthropometric and physiological characteristics of male soccer players according to their competitive level, playing position and age group: a systematic review. J Sports
Information about the authors:

Dragutin Stojmenović; (Corresponding Author); https://orcid.org/0000-0001-5772-5692; dragutin.stojmenovic@gmail.com; Department of Physiology, Faculty of Medical Sciences; University of Kragujevac, Serbia.

Tamara Stojmenović; https://orcid.org/0000-0001-9584-9027; tstojmenovic@singidunum.ac.rs; Faculty of Physical Education and Sports Management; Singidunum University, Serbia.

Cite this article as:

https://doi.org/10.15561/26649837.2023.0502

This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited (http://creativecommons.org/licenses/by/4.0/deed.en).

Received: 24.06.2023
Accepted: 09.08.2023; Published: 30.10.2023