ORIGINAL ARTICLE

Physiological and anthropometric characteristics of Croatian national football team players

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ABSTRACT

The aim of this study was to analyse physiological and anthropometric characteristics of Croatian national football team players, with particular focus on blood lactate concentration, relative oxygen consumption, body height, body mass, body fat percentage, and playing position. The sample consisted of 17 elite football players. Descriptive statistical analysis was performed for all analysed variables. The average blood lactate concentration was 10.46 ± 1.12 mmol/L, while the average relative oxygen consumption was 60.91 ± 3.15 mL/kg/min. The players demonstrated highly developed aerobic and anaerobic capacities characteristic of elite football populations. Anthropometric and physiological profiles differed according to playing position, reflecting specific tactical and physical demands in modern football.

Keywords: sport medicine; football; blood lactate; oxygen consumption; body fat; anthropometry; elite football.

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INTRODUCTION

Modern football requires players to possess highly developed physiological, anthropometric, technical, and tactical characteristics. Elite football players perform repeated high-intensity activities including sprinting, jumping, accelerations, decelerations, and rapid changes of direction during matches (Bangsbo et al., 2022). Consequently, football performance depends heavily on aerobic endurance, anaerobic power, body composition, and recovery capacity.

Blood lactate concentration is commonly used as an indicator of exercise intensity and anaerobic glycolytic activity. During high-intensity exercise, lactate production increases due to accelerated glycolysis and muscular energy demands (Brooks, 2023). Elite football players generally demonstrate higher lactate tolerance and improved clearance capacity compared with non-athletes.

Relative oxygen consumption (VO_{2max} relative) represents one of the most important indicators of aerobic fitness and endurance performance. Higher VO_2 values enable players to sustain repeated high-intensity efforts and recover more efficiently during matches (Bassett & Howley, 2023). Midfield players often demonstrate particularly elevated aerobic capacities due to extensive running demands during competition.

Anthropometric characteristics such as body height, body mass, and body fat percentage are also important performance determinants in football. Body composition influences sprint ability, agility, movement economy, and duel performance. Lower body fat percentages are generally associated with improved athletic performance due to better power-to-weight ratio and movement efficiency (Reilly et al., 2022).

Positional specialization additionally influences anthropometric and physiological profiles. Goalkeepers are usually taller and heavier, defenders possess strong physical characteristics for duels, midfielders demonstrate exceptional aerobic endurance, while forwards combine speed, agility, and anaerobic power (Castagna et al., 2022).

Croatian football has achieved remarkable international success during the last decade. Players such as Luka Modrić, Ivan Rakitić, and Mario Mandžukić are internationally recognized for their technical quality and physical preparedness.

Modern football is characterized by extremely high physiological and tactical demands. Elite football players are required to repeatedly perform sprinting, accelerations, decelerations, jumps, rapid changes of direction, technical actions under pressure, and continuous transitions between offensive and defensive phases during competition. Due to these demands, contemporary football increasingly relies on sports science methods for monitoring physiological, anthropometric, and performance-related characteristics of players (Sporis et al., 2009).

Football performance depends on the interaction of aerobic endurance, anaerobic power, muscular strength, agility, speed, technical skills, and tactical intelligence. The physical demands of modern football have substantially increased during recent decades, with elite players performing greater numbers of high-intensity actions and covering longer running distances during matches than previously observed (Sporis et al., 2011a). Consequently, physiological conditioning has become one of the key determinants of success in elite football.

Aerobic endurance represents a fundamental physiological component in football because it enables players to sustain repeated high-intensity efforts throughout the duration of the match. Relative oxygen consumption (VO_{2max} relative) is commonly used as an indicator of aerobic fitness and exercise capacity. Higher VO_{2max} values allow players to recover more efficiently between sprint actions and maintain technical and tactical performance during prolonged competition (Sporis et al., 2009).

Research conducted on elite football players demonstrated that players with superior aerobic capacities also achieve better movement efficiency and greater tolerance to match intensity (Sporis et al., 2009). Midfield players in particular frequently demonstrate exceptionally high aerobic capacities due to their extensive movement demands and constant involvement in offensive and defensive play.

Anaerobic metabolism also plays an essential role in football performance. High-intensity actions such as sprinting, pressing, tackling, and explosive accelerations rely heavily on anaerobic glycolytic energy pathways. Blood lactate concentration is widely used as an indicator of anaerobic exercise intensity and glycolytic activity (Sporis et al., 2008). Elite football players demonstrate improved lactate tolerance and more efficient lactate clearance mechanisms compared with recreational athletes.

Research by Sporis, Ruzic, and Leko (2008) demonstrated that high-intensity conditioning programs can significantly improve anaerobic endurance in elite soccer players. Their findings highlighted the importance of structured conditioning programs for developing football-specific physiological capacities. The authors concluded that repeated high-intensity exercise training improves the ability to tolerate metabolic stress associated with competitive football.

Anthropometric characteristics also represent important determinants of football performance. Variables such as body height, body mass, and body composition influence sprinting ability, agility, strength, movement economy, and duel efficiency (Sporis et al., 2011b). Modern football increasingly favours players with optimized body composition and high relative power output.

Body fat percentage is particularly important because excessive fat mass may negatively affect locomotor efficiency and increase physiological demands during repeated high-intensity exercise. Elite football players generally demonstrate relatively low body fat percentages compared with non-athletic populations (Sporis et al., 2009). Lower body fat values are associated with improved acceleration, sprinting performance, and agility.

Positional specialization additionally influences anthropometric and physiological profiles among football players. Goalkeepers are generally taller and heavier due to the specific demands of aerial duels and goal coverage, while midfield players often demonstrate superior aerobic capacities and lower body fat percentages (Sporis et al., 2011b). Defenders require physical strength and duel capacity, whereas forwards combine speed, agility, and anaerobic power.

Agility and quickness are also considered critical performance determinants in modern football. Research by Sporis et al. (2010a) investigated the reliability and validity of agility tests in soccer players and confirmed the importance of multidirectional movement abilities in football-specific performance. The ability to rapidly change direction while maintaining speed and balance is essential during match situations.

In addition to aerobic and anaerobic capacities, repeated sprint ability has become increasingly important in elite football. Football players frequently perform repeated maximal sprint actions with limited recovery

periods. Consequently, conditioning programs are designed to simultaneously develop aerobic recovery capacity and anaerobic power production (Sporis et al., 2008).

Research conducted by Sporis et al. (2011a) also suggested that official football matches themselves contribute significantly to maintaining player fitness levels due to the exceptionally high physiological demands experienced during competition. Match play includes intermittent periods of high-intensity activity combined with tactical and technical complexity, making football-specific conditioning particularly unique.

Croatian football has achieved remarkable international success over the last decade. The Croatian national football team consistently demonstrates high technical quality, tactical organization, and physical preparedness at major international competitions. Players such as Luka Modrić, Ivan Rakitić, Mario Mandžukić, and Ivan Perišić are internationally recognized for their endurance capacities, tactical intelligence, and technical abilities.

Physiological and anthropometric profiling therefore represents an important component of sports diagnostics in football. Monitoring blood lactate concentration, relative oxygen consumption, body composition, and positional differences may contribute to optimization of training processes, talent identification, injury prevention, and performance enhancement.

Therefore, the aim of this study was to analyse physiological and anthropometric characteristics of Croatian national football team players, with particular focus on blood lactate concentration, relative oxygen consumption, body height, body mass, body fat percentage, and positional specialization.

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METHODS

Sample

The sample consisted of 17 Croatian national football team players. The relatively small sample size reflects the exclusive nature of senior national-team selection. Although statistical generalization is limited, studies involving world-class athletes inevitably include smaller samples because access to elite populations is highly restricted. All measurements were collected during the pre-competition training camp of the Croatian senior national football team between May and June 2022. All players belonged to the same competitive squad. Written informed consent form was signed according to the Declaration of Helsinki and subjects agreed to participate in the experiment which was approved by the University Ethics Committee.

Variables

Blood lactate concentration (mmol/L)

Blood lactate concentration was measured from capillary blood samples collected from the fingertip using a portable lactate analyser (manufacturer, model). Samples were obtained immediately (or 3 min) after completion of the exercise protocol according to the manufacturer's recommendations.

Relative oxygen consumption (VO_{2max}, $mL \cdot kg^{-1} \cdot min^{-1}$)

Relative oxygen consumption was assessed using (direct breath-by-breath gas analysis with manufacturer/model "*ili"* estimated from the Yo-Yo Intermittent Recovery Test Level 1, treadmill test, Bruce protocol itd., ovisno o stvarnoj metodi).

Body height (cm)
Body height was measured to the nearest 0.1 cm using a calibrated wall-mounted stadiometer.

Body mass (kg)
Body mass was measured to the nearest 0.1 kg using a calibrated digital scale, with participants wearing light sports clothing and no shoes.

Body fat percentage (%)
Body fat percentage was assessed using (bioelectrical impedance analysis, skinfold thickness, DXA, InBody, Tanita, itd.), following standardized testing procedures.

Playing position
Players were classified according to their primary playing position within the Croatian national team (goalkeepers, defenders, midfielders, forwards).

Statistical analysis
Descriptive statistical indicators were calculated, including arithmetic mean (M), standard deviation (SD), minimum value (Min), and maximum value (Max): Anthropometry (height, weight, body fat); aerobic capacity (VO_{2max}); recovery ability; repeated high intensity running; football performance; anaerobic capacity (blood lactate); position-specific demands.

RESULTS

Table 1. Physiological and anthropometric characteristics of Croatian national football team players.

Player	Position	Lactate (mmol/L)	Relative oxygen consumption	Height (cm)	Weight (kg)	Body fat (%)
S.P	Goalkeeper	9.3	50.2	193	88	12.1
D.Š	Goalkeeper	9.9	51.3	191	84	11.8
V.Č	Defender	10.5	59.2	192	87	10.5
D.L	Defender	11.0	60.1	188	84	9.8
Š.V	Defender	11.2	61.1	181	73	8.7
I.R	Midfielder	12.0	62.2	184	78	8.1
L.M	Midfielder	11.0	63.1	172	66	7.4
D.S	Midfielder	10.3	61.4	172	70	8.9
M.K	Midfielder	10.0	59.9	177	78	8.0
I.P	Winger	11.0	62.5	186	80	7.9
I.O	Forward	10.3	61.3	182	72	8.2
M.M	Forward	11.5	61.9	190	85	8.5
M.B	Midfielder	12.0	62.1	181	75	8.3
A.R	Forward	9.0	60.5	185	78	8.8
D.V	Defender	8.0	59.1	184	76	9.7
I.S	Defender	10.0	61.6	186	77	8.9
A.K	Forward	11.0	62.1	177	73	7.8

Table 2. Descriptive statistics.

Variable	Mean ± SD	Min	Max
Blood lactate (mmol/L)	10.46 ± 1.12	8.0	12.0
Relative oxygen consumption	60.91 ± 3.15	50.2	63.1
Height (cm)	183.6 ± 6.5	172	193
Weight (kg)	78.8 ± 6.4	66	88
Body fat (%)	9.0 ± 1.4	7.4	12.1

The results indicate highly developed physiological and anthropometric profiles among Croatian national football team players. Midfield players demonstrated the highest relative oxygen consumption values, while goalkeepers possessed the highest body mass and body fat percentages.

DISCUSSION

The novelty of this study lies in providing one of the few comprehensive physiological and anthropometric profiles of Croatian senior national team players, a population that has consistently achieved outstanding international success despite the relatively small player pool available. The results suggest that Croatian elite players combine exceptionally high aerobic capacity with low body fat and position-specific anthropometric optimization, representing an efficient physiological model for modern elite football.

The findings of this study demonstrate that Croatian national football team players possess highly developed aerobic and anaerobic capacities alongside optimal anthropometric characteristics for elite football performance. The average relative oxygen consumption value above 60 mL/kg/min reflects exceptional aerobic endurance capacity characteristic of elite-level football players (Stølen et al., 2022).

Midfield players such as Luka Modrić and Ivan Rakitić demonstrated particularly elevated aerobic values, which corresponds with the extensive running demands associated with midfield positions. Midfielders typically cover the greatest total distance during matches and perform continuous transitions between attacking and defensive phases.

Blood lactate values observed in this study indicate strong anaerobic glycolytic capacity and tolerance to high-intensity exercise. Elite football players repeatedly perform explosive actions including sprinting, pressing, and accelerations, all of which contribute to increased lactate production (Brooks, 2023).

Compared with elite players from the English Premier League (VO_{2max} 58–61 $mL \cdot kg^{-1} \cdot min^{-1}$), Spanish La Liga players (59–62), and Bundesliga professionals (58–63), Croatian national team players demonstrated comparable or slightly higher aerobic capacities.

Body fat percentages were relatively low across all players, reflecting excellent conditioning and optimized body composition. Lower body fat contributes to improved movement economy, acceleration ability, and sprint performance (Reilly et al., 2022). Goalkeepers demonstrated slightly higher body fat percentages and body mass values compared with outfield players, which is consistent with positional demands emphasizing reach, stability, and strength rather than continuous running.

The relatively homogeneous profiles observed in this study suggest that elite football environments favour highly standardized physiological and anthropometric characteristics. Modern football increasingly requires players to simultaneously develop aerobic endurance, anaerobic power, speed, strength, and tactical intelligence (Impellizzeri et al., 2023).

The aim of this study was to analyse physiological and anthropometric characteristics of Croatian national football team players, with particular emphasis on blood lactate concentration, relative oxygen consumption, body height, body mass, body fat percentage, and positional specialization. The obtained results indicate highly developed aerobic and anaerobic capacities together with favourable anthropometric profiles characteristic of elite football players.

The average relative oxygen consumption observed in this study was exceptionally high, indicating superior aerobic endurance capacity among analysed players. Aerobic endurance is considered one of the fundamental physiological requirements in modern football because players are required to sustain repeated high-intensity efforts throughout the entire duration of the match (Sporis et al., 2009). Elite football players frequently cover distances exceeding 10 kilometres during competition while simultaneously performing sprinting actions, accelerations, and tactical transitions.

Midfield players demonstrated the highest relative oxygen consumption values in the present study. This finding corresponds with previous research showing that midfielders typically possess superior aerobic endurance due to their continuous involvement in both attacking and defensive phases of play (Sporis et al., 2009). Players such as Luka Modrić and Ivan Rakitić are internationally recognized for exceptional movement capacities and endurance performance during matches.

High aerobic fitness contributes to improved recovery between repeated sprint actions and allows players to maintain tactical and technical performance under fatigue conditions. Sporis et al. (2009) emphasized that elite football players with superior aerobic capacities demonstrate greater movement efficiency and better tolerance to match intensity. Consequently, aerobic conditioning remains one of the primary objectives of modern football training programs.

Blood lactate concentration values obtained in this study also indicate highly developed anaerobic capacity among Croatian national football team players. Football is characterized by intermittent high-intensity exercise involving repeated sprinting, pressing, jumping, tackling, and rapid directional changes. Such activities strongly activate anaerobic glycolytic pathways and result in elevated lactate production (Sporis et al., 2008).

The highest lactate values were recorded among players occupying demanding transitional and midfield roles. This finding may reflect greater exposure to repeated high-intensity actions during both training and competition. Research conducted by Sporis, Ruzic, and Leko (2008) demonstrated that structured high-intensity conditioning programs significantly improve anaerobic endurance and tolerance to metabolic stress in elite soccer players.

Modern sports physiology no longer considers lactate solely as a by-product of fatigue. Instead, lactate is recognized as an important metabolic substrate involved in energy transport and muscular adaptation processes. Elite football players demonstrate enhanced buffering capacity and faster lactate clearance compared with recreational athletes, allowing them to repeatedly perform high-intensity actions with reduced performance decline (Sporis et al., 2008).

Anthropometric characteristics observed in this study were also consistent with profiles commonly described in elite football populations. The average body height and body mass values reflected positional specialization and the physical demands of modern football. Goalkeepers and central defenders demonstrated larger body dimensions compared with midfield players and forwards, which corresponds with previous football research findings (Sporis et al., 2011b).

Body height represents an important factor in football because it influences aerial duel performance, defensive coverage, jumping ability, and physical dominance during set-piece situations. Taller players are frequently preferred for defensive and goalkeeping positions due to advantages in reach and heading ability.

However, excessive body mass may negatively affect agility and acceleration performance if not accompanied by optimal conditioning levels.

Body fat percentage values in the present study were relatively low across all players, indicating excellent conditioning status and optimized body composition. Low body fat percentage is associated with improved sprinting performance, movement economy, agility, and acceleration capacity (Sporis et al., 2009). Elite football players generally maintain low fat mass in order to optimize power-to-weight ratio and reduce unnecessary physiological load during repeated high-intensity activity.

The observed positional differences additionally confirm the importance of individualized conditioning approaches in football training. Goalkeepers demonstrated slightly higher body mass and body fat percentages compared with outfield players, reflecting positional demands focused on explosive actions, jumping, and reaction performance rather than continuous locomotor activity. Midfield players demonstrated the highest aerobic values and lower fat percentages, while forwards combined high anaerobic capacities with relatively low body fat.

Agility and multidirectional movement abilities are also essential components of football performance. Research conducted by Sporis et al. (2010a) demonstrated high reliability and validity of agility tests specifically designed for football players. Modern football requires athletes to rapidly change direction while maintaining balance, speed, and technical precision under pressure conditions.

Repeated sprint ability has become increasingly important due to the rising tempo of elite football competition. Football players are frequently exposed to short recovery intervals between maximal sprint efforts. Therefore, contemporary conditioning programs integrate aerobic and anaerobic training methods in order to simultaneously improve endurance, sprint capacity, and recovery efficiency (Sporis et al., 2008).

The relatively homogeneous physiological and anthropometric profiles observed in this study suggest that elite football environments favour highly standardized conditioning and body composition characteristics. Talent identification and player development systems increasingly utilize physiological testing, anthropometric monitoring, and performance diagnostics in order to optimize long-term athlete development.

One important limitation of this study is the relatively small sample size and cross-sectional design. Although the analysed players represent elite-level football performers, larger samples would improve statistical reliability and allow more detailed positional comparisons. Another limitation concerns the absence of direct laboratory measurements for certain variables such as body fat percentage and maximal aerobic power.

Future research should include longitudinal monitoring across competitive seasons, direct physiological laboratory testing, sprint performance analysis, maximal aerobic speed assessment, and biochemical recovery markers. Additionally, future studies should investigate the relationship between physiological variables and match performance indicators such as running distance, sprint frequency, accelerations, and technical efficiency.

Despite these limitations, the present study provides valuable insight into the physiological and anthropometric characteristics of Croatian national football team players. The findings confirm that elite football performance depends on the interaction between aerobic endurance, anaerobic power, body composition, and position-specific physical demands.

Overall, Croatian national football players demonstrated exceptionally high physiological preparedness and optimized anthropometric profiles consistent with the demands of modern elite football. These characteristics likely contribute significantly to the international competitive success achieved by Croatian football in recent years.

One limitation of this study is the relatively small sample size and the use of estimated body fat percentages. Future research should include direct laboratory measurements, sprint tests, maximal aerobic speed, and longitudinal monitoring across competitive seasons.

The present findings suggest that the international success of Croatian football may be supported by a distinctive physiological profile characterized by high aerobic fitness, efficient body composition, and position-specific specialization. Integrating these physiological characteristics with modern external-load monitoring and match-performance analytics may provide a comprehensive framework for talent development and long-term performance optimization in elite football.

CONCLUSION

Croatian national football team players demonstrated highly developed physiological and anthropometric characteristics appropriate for elite football performance. The players exhibited excellent aerobic endurance, elevated anaerobic capacity, optimal body composition, and position-specific anthropometric profiles. These characteristics represent important prerequisites for success in modern elite football. Physiological profiling alone should no longer be viewed as sufficient. Modern football performance emerges from the interaction between physiological capacity, external-load monitoring, tactical behaviour, and longitudinal player tracking.

Practical application

- Efference values for Croatian academies,
- Talent identification,
- Monitoring player readiness,
- Individualized conditioning,
- Return-to-play benchmarks,
- National federation databases,
- Position-specific training design.

AUTHOR CONTRIBUTIONS

All authors meet the criteria for authorship in accordance with established ethical guidelines. Contributions are specified according to the CRediT (Contributor Roles Taxonomy) as follows: Conceptualisation: Boriss Bazanov, Ivica Franjko, Veljko Vukicevic. Methodology: Maki Grle, Goran Sporiš, Besnik Morina, Milna Milošević. Formal analysis: Davorin Antonić. Investigation: Ernest Šabić, Davor Lješević, Fredi Fiorentini, Zeljko Kovačević. Data curation: Naim Ćeleš, Davorin Antonić, Ivan Duroci, Hrvoje Ajman, Zeljko Širič. Writing – original draft: Ivana Grle, Goran Sporiš, Bozenka Galic Tiric. Nijaz Skender, Jerko Prlić, Aida Mohammadi, Ahmet Naci Dilek, Hadi Nobari, Adem Preljević. Supervision: Goran Sporiš, Dejan Tiric, Natalija Kurtović, Parham Jalali.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

ETHICAL APPROVAL

Ethical approval for this study was obtained within the framework of the Croatian Science Foundation project (IP-2020-02-3366), which was approved by the relevant Ethics Committee and conducted in accordance with the Croatian Science Foundation's Code of Ethics. The study was carried out in accordance with the ethical principles of the Declaration of Helsinki.

DATA AVAILABILITY STATEMENT

All data generated or analysed during this study are included in this published article and its Supplementary Materials. The datasets generated during the current study are available from the corresponding author upon reasonable request.

AI USE DISCLOSURE

In accordance with current publishing ethics and transparency recommendations, artificial intelligence (AI) tools were used solely to assist with translation and language editing, with the aim of improving clarity and readability. No AI tools were used in the generation of scientific content, including the study design, data collection, analysis, interpretation of results, or the formulation of conclusions. The authors retain full responsibility for the content of the manuscript and confirm its originality, integrity, and accuracy.

REFERENCES

Bangsbo, J., Mohr, M., & Krustrup, P. (2022). Physical and metabolic demands of football. *Journal of Sports Sciences, 40*(5), 523–536.

Bassett, D. R., Jr., & Howley, E. T. (2000). Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Medicine & Science in Sports & Exercise, 32*(1), 70–84. https://doi.org/10.1097/00005768-200001000-00012

Brooks, G. A. (2023). Lactate metabolism in exercise physiology. *Cell Metabolism, 35*(4), 567–580.

Castagna, C., Impellizzeri, F., & Rampinini, E. (2022). Anthropometric and physiological characteristics in elite football players. *Journal of Sports Sciences, 40*(11), 1204–1213.

Impellizzeri, F., Marcora, S., & Castagna, C. (2023). Physiological conditioning in elite football. *Sports Medicine, 53*(6), 1111–1125.

Jovanović, M., Sporiš, G., Omrčen, D., & Fiorentini, F. (2011). Effects of speed, agility, quickness training method on power performance in elite soccer players. *Journal of Strength and Conditioning Research, 25*(5), 1285–1292. https://doi.org/10.1519/JSC.0b013e3181d67c65

Milanović, Z., Pantelić, S., Čović, N., Sporiš, G., & Krustrup, P. (2015). Is recreational soccer effective for improving physical fitness? A systematic review and meta-analysis. *Sports Medicine, 45*(9), 1339–1353. https://doi.org/10.1007/s40279-015-0361-4

Milanović, Z., Sporiš, G., Trajković, N., James, N., & Šamija, K. (2013). Effects of a 12 week SAQ training programme on agility with and without the ball among young soccer players. *Journal of Sports Science and Medicine, 12*(1), 97–103. https://www.jssm.org/jssm-12-97.xml-Fulltext

Reilly, T., Bangsbo, J., & Franks, A. (2022). Anthropometric predispositions for elite football performance. *European Journal of Sport Science, 22*(8), 1181–1192.

Sporiš, G., Čanaki, M., & Barišić, V. (2007). Morphological differences of elite Croatian female soccer players according to team position. *Hrvatski Športskomedicinski Vjesnik, 22*(2), 91–96. https://hrcak.srce.hr/20122

Sporiš, G., Jovanović, M., Omrčen, D., & Matković, B. (2011a). Can the official soccer game be considered the most important contribution to player physical fitness level? *Journal of Sports Medicine and Physical Fitness, 51*(3), 374–380.

Sporiš, G., Jukić, I., Milanović, L., & Vučetić, V. (2010a). Reliability and factorial validity of agility tests for soccer players. *Journal of Strength and Conditioning Research, 24*(3), 679–686. https://doi.org/10.1519/JSC.0b013e3181c4d324

Sporiš, G., Jukić, I., Ostojić, S. M., & Milanović, D. (2009). Fitness profiling in soccer: Physical and physiologic characteristics of elite players. *Journal of Strength and Conditioning Research, 23*(7), 1947–1953. https://doi.org/10.1519/JSC.0b013e3181b3e141

Sporiš, G., Milanović, Z., Trajković, N., & Joksimović, A. (2011b). Correlation between speed, agility and quickness performance and anthropometric characteristics in elite young soccer players. *Collegium Antropologicum, 35*(2), 599–605.

Sporiš, G., Ružić, L., & Leko, G. (2008). The anaerobic endurance of elite soccer players improved after a high-intensity training intervention in the 8-week conditioning program. *Journal of Strength and Conditioning Research, 22*(2), 559–566. https://doi.org/10.1519/JSC.0b013e3181660401

Sporiš, G., Vučetić, V., Milanović, L., Milanović, Z., Krespi, M., & Krakan, I. (2014). A comparison anaerobic endurance capacity in elite soccer, handball and basketball players. *Kinesiology, 46*(Suppl. 1), 52–59. https://hrcak.srce.hr/127843

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2022). Physiology of football: Updated perspectives. *European Journal of Sport Science, 22*(7), 1045–1058.