Spor Hekimliği Dergisi, 60(4):128-133; 2025
Turkish Journal of Sports Medicine
Turk J Sports Med. DOI: 10.47447/tjsm.0902

Research Article / Araştırma Makalesi

Assessment of differences in lung capacities and hemoglobin levels between professional athletes and healthy non-athlete individuals

Profesyonel sporcular ile sağlıklı sporcu olmayan bireyler arasında akciğer kapasiteleri ve hemoglobin düzeyleri farklılıkların değerlendirilmesi

Nazlı Zeynep Uslu[1], Ayşenur Gençalp[2], Sercan Sakallı[2], Yasin Seçkin[2], İrem Karaman[2], Sebahat Dilek Torun[3], Merih Kalamanoğlu Balcı[1]

[1]*Pulmonary Medicine Section, School of Medicine, Bahçeşehir University, Istanbul, Türkiye*
[2]*School of Medicine, Bahçeşehir University, Istanbul, Türkiye*
[3]*Public Health Section, School of Medicine, Bahçeşehir University, Istanbul, Türkiye*

ABSTRACT

Objective: Intense and regular exercise induces physiological adaptations that improve lung function. This study aims to compare the lung capacities of professional athletes and non-athlete healthy individuals.

Material and Methods: Age, height, weight, PFT and hemoglobin values of 59 adult athletes from four different branches (25 soccer, 19 basketball, 12 handball, three volleyball players) and 51 healthy non-athletes who applied for a yearly checkup clinic at a university hospital were obtained and compared.

Results: There was no significant difference in terms of age and weight of athletes and the control group. The athletes' forced expiratory volume 1 (FEV1) and forced vital capacity (FVC) values were significantly greater than the controls' (Respectively 4.86±0.66 L vs 4.58±0.66 L; p=0.02 and 5.87±0.98 L vs 5.40±0.82 L; p=0.008). There was no significant difference between the FEV1/FVC ratio of athletes and the control group (83.6%±7.7 vs 85.2%±5.8; p>0.05). Hemoglobin levels of the athletes were significantly lower than the control group (14.9±0.9 g/dl vs 15.2±0.8 g/dl; p=0.02).

Conclusion: Compared to non-athletes, professional athletes have considerably higher FEV1 and FVC values, likely resulting from intensive training. Athletes' lower hemoglobin values may be attributed to the physiological changes related to regular exercise. These findings further emphasize the necessity of interpreting athletes' PFTs within the athlete population by using personalized reference values, to prevent potential misdiagnoses.

Keywords: *Lung capacities, hemoglobin, athletes*

ÖZ

Amaç: Yoğun ve düzenli egzersiz, akciğer fonksiyonunu iyileştiren fizyolojik adaptasyonları destekler. Bu çalışmanın amacı profesyonel sporcular ile sporcu olmayan sağlıklı bireylerin akciğer kapasitelerini karşılaştırmaktır.

Gereç ve Yöntemler: Dört farklı branştan (25 futbol, 19 basketbol, 12 hentbol, üç voleybol oyuncusu) 59 yetişkin sporcunun ve bir üniversite hastanesine yıllık kontrol için kliniğe başvuran 51 sağlıklı sporcu olmayanın yaş, boy, kilo, PFT ve hemoglobin değerleri elde edildi ve karşılaştırıldı.

Bulgular: Sporcular ve kontrol grubu arasında yaş ve kilo açısından anlamlı bir fark yoktu. Sporcuların zorunlu ekspirasyon hacmi 1 (FEV1) ve zorunlu vital kapasite (FVC) değerleri kontrol grubundan anlamlı derecede yüksekti (Sırasıyla 4.86±0.66 L vs 4.58±0.66 L; p=0,02 ve 5.87±0.98 L vs 5.40±0.82 L; p=0,008). Sporcuların FEV1/FVC oranı ile kontrol grubu arasında anlamlı bir fark yoktu (83.6%±7.7 vs 85.2%±5.8; p>0,05). Sporcuların hemoglobin düzeyleri kontrol grubundan anlamlı derecede düşüktü (14.9±0.9 g/dl vs 15.2±0.8 g/dl; p=0,02).

Sonuç: Sporcu olmayanlara kıyasla profesyonel sporcuların FEV1 ve FVC değerleri önemli ölçüde daha yüksekti, bu olasılıkla yoğun antrenmandan kaynaklanmaktadır. Sporcuların daha düşük hemoglobin değerleri düzenli egzersizle ilişkili fizyololik değişikliklere atfedilebilir. Bu bulgular, olası yanlış tanıları önlemek için sporcuların PFT'lerinin sporcu popülasyonu içinde bireyselleştirilmiş referans değerleri kullanılarak yorumlanmasının gerekliliğini daha da vurgulamaktadır.

Anahtar Sözcükler: *Akciğer kapasiteleri, hemoglobin, sporcu*

Received / Geliş: 16.01.2025 · **Accepted / Kabul:** 29.03.2025 · **Published / Yayın Tarihi:** 09.10.2025

Correspondence / Yazışma: Nazlı Zeynep Uslu · Bahçeşehir Üniversitesi, Tıp Fakültesi, Göğüs Hastalıkları Anabilim Dalı, İstanbul, Türkiye · nzeynepsuner@gmail.com

Cite this article as: Uslu NZ, Gencalp A, Sakalli S, Karaman I, Torun SD, Kalamanoglu Balci M. Assessment of differences in lung capacities and hemoglobin levels between professional athletes and healthy non-athlete individuals. *Turk J Sports Med.* 2025;60(4):128-133; https://doi.org/10.47447/tjsm.0902

INTRODUCTION

The beneficial effects of physical activity on human health have been well-established across numerous studies. Regular participation in sports and exercise enhances overall health by positively influencing various physiological systems, ranging from the cardiovascular to the musculoskeletal systems (1). In this regard, professional athletes, owing to the rigorous training and conditioning demands of their respective sports, maximize and refine their functional capacities, including those of the respiratory system.

Extensive research has demonstrated that individuals engaged in consistent physical activity exhibit markedly improved pulmonary function comparing to their sedentary counterparts (2). However, due to the variations in the nature, intensity, and specific demands of training across different sports disciplines, the development of respiratory system functions varies significantly among professional athletes depending on the chosen sport (3). These differences reflect the specialized physiological adaptations required for optimal performance within each sport.

It is widely accepted that the respiratory system experiences significant stress during intense physical activity and undergoes a series of physiological adaptations to meet the increased metabolic demands of exercise. Research has demonstrated that regular and intense exercise leads to enhancements in pulmonary function, enabling the respiratory system to efficiently supply oxygen to the muscles during periods of high demand (4).

Rajaure et al. (5) conducted a comparative study by dividing participants into two groups based on their involvement in either aerobic or anaerobic sports. The study revealed that there were big differences between the two groups. Aerobic athletes had higher values for maximum voluntary ventilation (MVV) and forced expiratory flow at 25-75% (FEF25-75). These findings suggest that aerobic exercise, which typically emphasizes sustained cardiovascular endurance, promotes enhanced ventilatory capacity and airflow.

Moreover, the contrasting demands of aerobic and anaerobic sports lead to distinct adaptations in the athletes' respiratory systems. Aerobic activities, which are primarily focused on improving cardiovascular endurance, enhance the efficiency of the respiratory and circulatory systems. Anaerobic sports, on the other hand, focus on strength, power, and short bursts of high-intensity effort. These sports mostly affect the development of muscular strength and power, with less of an effect on respiratory function.

Pulmonary function tests (PFTs) are indispensable diagnostic tools utilized to assess lung performance and airway health. These tests are critical in evaluating how the respiratory functions of professional athletes differ from those of sedentary individuals (6). For example, forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) are often used to check how well and how much an athlete's respiratory system can do. These metrics provide valuable insight into the pulmonary adaptations that occur as a result of athletic training (5).

Regular and intense physical activity has been shown to enhance spirometric values, with athletes demonstrating increased lung capacity and improved respiratory efficiency. In particular, the most important changes are an increase in FVC and tidal volume, both of which indicate better pulmonary function (6). These changes reflect the body's adaptation to the heightened oxygen demands associated with sustained physical exertion.

Additionally, hemoglobin levels are critical biomarkers that indicate the oxygen-carrying capacity of the blood. Hemoglobin concentrations provide essential information regarding an individual's overall health and are widely regarded as indicators of aerobic capacity and endurance. Therefore, professionals frequently use hemoglobin levels to evaluate exercise performance and athletic capability (7).

This study aims to find out how regular and intense physical activity affects both breathing and the ability of the blood to carry oxygen by comparing PFT results and blood hemoglobin levels between professional athletes and healthy people who are not in sports. The anticipated findings will contribute to a deeper understanding of the health benefits associated with sports and exercise, supporting the development of policies that promote physical activity across various populations.

Concerns have been raised in the past about how reliable it is to compare PFT results from athletes with respiratory symptoms during the diagnostic phase to reference values from the general population (8). In light of these issues, this study aims to emphasize the importance of accounting for these differences when clinically evaluating athletes. It highlights the necessity of using PFT values that are tailored to the specific physiological demands of athletes, rather than relying on generalized reference values used for normal, sedentary individuals.

MATERIAL and METHODS

Participants and Study Design

This case-control study included 59 professional male athletes (25 soccer players, 19 basketball players, 12 handball players, and three volleyball players) aged 16-40, who were free from chronic illnesses and engaged in regular training (2 h/wk). The control group consisted of 51 healthy, non-athletic individuals of the same age range and gender, who were non-smokers and had no chronic illnesses. Both groups were recruited from patients undergoing routine annual check-ups at a university-affiliated private hospital. Data for all participants were retrospectively obtained from their annual check-up records, and both groups met the inclusion criteria of being healthy, engaging in regular physical activity, being non-smokers, and having no respiratory or cardiovascular conditions.

Inclusion and Exclusion Criteria

Athlete group: Participants were professional male athletes aged 16-40, including soccer, basketball, handball, and volleyball players, with a minimum of one year of continuous structured training. They had no chronic illnesses and engaged in regular training.

Non-athlete group: Healthy, non-smoking individuals without any history of respiratory or cardiovascular diseases, who engaged in regular exercise (defined as planned, continuous physical activity aimed at maintaining or improving health). Individuals who smoked or had any respiratory or cardiovascular condition of concern were excluded.

The parameters collected included spirometry test results, hemoglobin levels, and body mass index (BMI). Participants were required to engage in regular exercise (planned and continuous physical activities aimed at maintaining or improving an individual's health and overall well-being) to be eligible for inclusion in either the control or athlete group.

Data Collection Tools

All data were collected using the hospital records. Spirometry tests were conducted following the American Thoracic Society (ATS) guidelines to ensure accuracy and reliability. Hemoglobin levels were measured using standard biochemical assays, and BMI was calculated from recorded height and weight measurements. For the athlete group, data were collected retrospectively. We evaluated spirometry, hemoglobin levels, and BMI under the same conditions as the control group to maintain consistency.

Pulmonary function tests (PFT): Pulmonary functions were measured using the NSPIRE HEALTH ZAN 100 spirometry device. Measured parameters included FVC and FEV1. Measurements were conducted with participants in a rested state, adhering to standard spirometry protocols. Spirometry tests included the measurement of FEV1, FVC, FEV1/FVC, and FEF25-75 (9).

Hemoglobin measurement: Hemoglobin levels were obtained retrospectively from the electronic health records of the hospital. They were measured in g/dl.

Height measurement: Height was measured using a stadiometer; height is typically measured in metric units, centimeters (cm). Using a standard measuring device, the individual stands upright with feet together, heels, buttocks, and shoulders against a wall.

Weight measurement: Weight was measured using a digital scale, in kilograms (kg).

BMI: BMI was calculated using the formula: BMI = weight (kg) / height (m)^2, with weight and height measured using standardized equipment.

Data Analysis

The data, compiled into an excel spreadsheet from file reviews, was uploaded to the SPSS version 25.0 (IBM Corp., 2017) software for analysis. We thoroughly checked the dataset for missing data and participants not meeting the inclusion criteria. Once cleaned, the data were analyzed using a combination of descriptive and inferential statistical methods.

Sociodemographic parameters were assessed using descriptive statistics, including frequency (number), percentage, mean, and standard deviation. The normality of quantitative data was tested using the Shapiro-Wilk test and confirmed with graphical assessments (e.g., histograms and Q-Q plots).

To analyze differences in PFT values between the professional athlete and non-athlete groups, chi-square tests were employed for categorical variables. For continuous variables meeting the assumptions of normality, t-tests and ANOVA were used. For variables that did not meet normality assumptions, the Mann-Whitney U test and Kruskal-Wallis H test were used for between-group comparisons. A statistical significance level of $p<0.05$ was considered significant for all analyses.

RESULTS

This case-control study included 59 professional male athletes and 51 healthy, non-athletic matched controls. No statistically significant differences were observed between the athlete and control groups in terms of age and weight. However, athletes were significantly taller than non-athletes. Among the athlete subgroups, basketball players had significantly higher weight and height compared to athletes in other sports disciplines (Table 1).

Table 1. Physiological characteristics and spirometric measures of groups

Variables	Athletes (n=59)	Control group (n=51)	p value
Age (yrs)	28.2 ± 5.4	29.1 ± 5.9	0.404
Weight (kg)	87.4 ± 13.1	85.76 ± 12.0	0.489
Height (cm)	189.5 ± 9.7	184.0 ± 5.7	**0.001**
Hemoglobin (g/dl)	14.9 ± 0.9	15.2 ± 0.8	**0.024**
FVC (L)	5.9 ± 1.0	5.4 ± 0.8	**0.008**
FVC (%)	100.5 ± 12.8	98.5 ± 12.6	0.405
FEV1 (L)	4.9 ± 0.7	4.6 ± 0.7	**0.024**
FEV1 (%)	101.0 ± 11.8	100.7 ± 11.4	0.895
FEV1/FVC (%)	83.6 ± 7.7	85.2 ± 5.8	0.254
PEF (L)	8.5 ± 1.4	7.7 ± 1.6	**0.009**
PEF (%)	81.1 ± 14.2	76.3 ± 14.8	0.088
MEF25-75 (L)	5.0 ± 1.1	5.0 ± 1.0	0.995
MEF25-75 (%)	97.7 ± 22.2	100.4 ± 18.2	0.486

Spirometric tests showed that the athletes' FVC, FEV1 and PEF were much higher than those in the control group. The FVC was higher in athletes (5.9 ± 1.0 L) than in non-athletes (5.4 ± 0.8 L, p=0.008), and the FEV1 was also higher in athletes (4.86 ± 0.65 L) than in non-athletes (4.60 ± 0.70 L, p=0.024). PEF values were also significantly greater in athletes (8.5 ± 1.4 L) compared with non-athletes (7.7 ± 1.6 L, p=0.009). However, we found no significant differences between the two groups in terms of FEV1, FEV1/FVC ratio, PEF, or MEF 25-75. Specifically, FEV1 (%) (p=0.895), FEV1/FVC (%) (p=0.254), PEF (%) (p=0.088), and MEF25-75 (%) (p=0.486) did not differ significantly between athletes and non-athletes. Athletes had significantly lower hemoglobin levels comparing to the control group (Table 1).

Demographic and spirometric values for the three study groups: basketball players, athletes from other sports, and non-athletes. No significant difference was observed in age between the groups (p=0.120). Basketball players exhibited significantly higher body weight compared to athletes from other sports and non-athletes (p=0.002). Basketball players were significantly taller than both athletes in other sports and non-athletes (p<0.001).

Basketball players had significantly higher FVC values compared with athletes in other sports and non-athletes (p=0.006) (Table 2). There was no significant difference in FEV1 values between the groups (p=0.068), although basketball players had slightly higher values compared to athletes in other sports and non-athletes. Basketball players had a significantly lower FEV1/FVC ratio compared to athletes in other sports and non-athletes (p=0.026) (Table 2). Basketball players also revealed significantly higher PEF values comparing to non-athletes (p=0.029). The same was true for other sports' athletes (Table 3).

Table 2. Physiological characteristics and measured spirometric values of basketball players (n=19), other athletes and non-athletes (n=51)

Variables	Athletes (basketball)	Athletes (other sports)	Control group	p value
Age (yrs)	30.1 ± 4.2	27.2 ± 5.7	29.1 ± 5.9	0.120
Weight (kg)	95.4 ± 13.5	83.7 ± 11.2	85.8 ± 12.0	**0.002**
Height (cm)	196.2 ± 9.0	186.4 ± 8.3	184.0 ± 5.7	**0.000**
Hemoglobin (g/dl)	14.9 ± 1.0	14.9 ± 0.9	15.2 ± 0.8	0.076
FVC (L)	6.2 ± 1.0	5.7 ± 0.9	5.4 ± 0.8	**0.006**
FVC (%)	99.6 ± 14.3	101.0 ± 12.2	98.5 ± 12.6	0.656
FEV1 (L)	4.9 ± 0.6	4.8 ± 0.7	4.6 ± 0.7	0.068
FEV1 (%)	97.0 ± 12.1	102.9 ± 11.3	100.7 ± 11.4	0.178
FEV1/FVC (%)	80.5 ± 6.6	85.2 ± 7.8	85.2 ± 5.8	**0.026**
PEF (L)	8.3 ± 1.3	8.5 ± 1.5	7.7 ± 1.6	**0.029**
PEF (%)	75.8 ± 11.8	83.6 ± 14.6	76.3 ± 14.8	**0.035**
MEF25-75 (L)	4.7 ± 0.9	5.1 ± 1.2	5.0 ± 1.0	0.118
MEF25-75 (%)	90.2 ± 17.6	101.3 ± 23.5	100.4 ± 18.2	0.118

Table 3. Comparison of spirometric values between sports (n=40, excluding basketball) and control groups (n=51)

Variables	Athletes (excluding basketball)	Control group	p-value
FVC (L)	5.72 ± 0.94	5.40 ± 0.82	0.085
FVC (%)	101.0 ± 12.2	98.5 ± 12.6	0.347
FEV1 (L)	4.83 ± 0.68	4.58 ± 0.65	0.072
FEV1 (%)	102.9 ± 11.3	100.7 ± 11.4	0.357
FEV1/FVC (%)	85.2 ± 7.8	85.2 ± 5.8	0.996
PEF (L)	8.53 ± 1.45	7.69 ± 1.58	**0.012**
PEF (%)	83.6 ± 14.6	76.3 ± 14.8	**0.021**
MEF25-75 (L)	5.14 ± 1.19	5.01 ± 0.97	0.559
MEF25-75 (%)	101.3 ± 23.5	100.4 ± 18.2	0.852

DISCUSSION

This case-control study aimed to explore the effects of regular physical activity on pulmonary function and hemoglobin levels by comparing professional athletes and non-athletic individuals. Our findings reveal that professional athletes exhibited significantly better pulmonary function compared to non-athletes, with higher values for FEV1 and FVC. However, distinct differences were observed across different sport disciplines, particularly within the athlete group.

Professional athletes demonstrated higher pulmonary function values, including FEV1 and FVC, compared to non-athletes. This finding is consistent with studies such as those by Bernhardsen et al., who observed superior lung function in athletes across different sports, and Mazic et al., who also reported better respiratory parameters in elite athletes (4,10). These findings underscore the positive adaptations of the respiratory system due to structured and sustained training. However, Myrianthefs et al. (11) pointed out that spirometry might not accurately measure how much airway obstruction athletes have. This means that the reference values used in clinical practice might not accurately reflect how athletes' respiratory systems really work.

Among the athletes, basketball players exhibited the highest FVC values but lower FEV1/FVC ratios and PEF values compared with athletes in other disciplines. It's possible that the sustained aerobic demands of the sport, along with the need for explosive anaerobic efforts, are what caused the higher FVC. The lower FEV1/FVC and PEF values, on the other hand, may mean that the athletes depend more on a large tidal volume and less on forced expiratory flow. This finding supports the notion that basketball, as a sport requiring both aerobic endurance and anaerobic power, fosters distinct pulmonary adaptations comparing to other sports. Basketball players, for example, may not engage in prolonged low-intensity endurance activities like long-distance runners, but may still develop significant lung capacity due to their need to perform high-intensity sprints interspersed with periods of recovery. Despite these sport-specific differences in respiratory profiles, all athletes exhibited superior pulmonary function compared with non-athletes. These findings align with previous studies indicating that aerobic exercise enhances lung function and efficiency (12,13).

Our study displayed that hemoglobin levels were significantly lower in athletes compared to non-athletes, which could be attributed to exercise-induced hemodilution. This phenomenon, commonly observed in endurance athletes, results from an increase in plasma volume due to regular intense training (14,15). Researchers Mairbäurl (8) and Convertino (16) showed that this rise in plasma volume is important for getting more oxygen to muscles during long-term exercise, which underlines how important it is in endurance sports. Interestingly, basketball players, who combine both aerobic and anaerobic demands, did not display significant differences in hemoglobin levels compared with athletes from other sports.

The results of our study emphasize the importance of considering sport-specific adaptations when evaluating athletes' pulmonary and hematological health. Our findings suggest that standard reference values for PFTs derived from the general population may not be appropriate for athletes. Clinical evaluations should incorporate sport-specific reference values to improve the accuracy of respiratory and hematological assessments.

This study has some limitations that should be noted. The sample size, which was limited to male athletes due to data availability, restricts the generalization of the findings. Further studies should include larger, more diverse samples, including female athletes, to ensure broader applicability. Additionally, while we focused on four major sports disciplines, there are many other sports that may exhibit different physiological adaptations. Future research should explore these variations in more depth and consider longitudinal studies to better understand how these adaptations evolve over time.

CONCLUSION

Our study provides novel insights into the respiratory and hematological adaptations of athletes from different sports disciplines. While intense and regular physical activity improves pulmonary function and efficiency, the type and intensity of the training regimen lead to distinct physiological responses.

Ethics Committee Approval / Etik Komite Onayı

The approval for this study was obtained from Bahcesehir University Clinical Research Ethics Committee, İstanbul, Türkiye (Decision no: 2023-22/04, Date: 27/12/2023).

Conflict of Interest / Çıkar Çatışması

The authors declared no conflicts of interest with respect to authorship and/or publication of the article.

Financial Disclosure / Finansal Destek

The authors received no financial support for the research and/or publication of this article.

Author Contributions / Yazar Katkıları

Concept Design: NZU, İK; Supervision/ Consultancy: MKB; Materials: AG; Data Collection and Processing: SS, YS, AG; Analysis and Interpretation: İK, SDT; Literature Review: NZU, SDT, AG; Writing: SS, YS, AG, İK; Critical Review: MKB. All authors contributed to the final version of the manuscript and discussed the results and contributed to the final manuscript.

REFERENCES

1. Gupta A, Tran M, Harris T. Exercise and sports participation in pediatrics. *Pediatr Ann.* 2025; 54(2):e64-9.
2. Campoi HG, Campoi EG, RFT Lopes, Alves SA, Regueiro EMG, SCH Regalo, et al. Effects of physical activity on aerobic capacity, pulmonary function, and respiratory muscle strength of football athletes and sedentary individuals. Is there a correlation between these variables? *J Phys Educ Sport*. 2019;19(4):2466-71.
3. Lazovic B, Mazic S, Suzic-Lazic J, Djelic M, Djordjevic-Saranovic S, Durmic T, et al. Respiratory adaptations in different types of sport. *Eur Rev Med Pharmacol Sci*. 2015;19(12):2269-74.
4. Mazic S, Lazovic B, Djelic M, Suzic-Lazic J, Djordjevic-Saranovic S, Durmic T, et al. Respiratory parameters in elite athletes -does sport have an influence? *Rev Port Pneumol (2006).* 2015; 21(4):192-7.
5. Rajaure YS, Thapa B, Budhathoki L, Rana SRI, Khadka M. Comparison of spirometric parameters in athletes engaged in aerobic and anaerobic sports: a cross-sectional study. *Ann Med Surg (Lond)*. 2023;85(6):2502-5.
6. Shashikala K, Sneha J. Assessment of pulmonary functions FVC, FEV1, and FEV1/FVC ratio among athletes and non-athletes. *Nat J Physiol Pharm Pharmacol.* 2022;12(9):1335-8.
7. HajGhanbari B, Yamabayashi C, Buna TR, Coelho JD, Freedman KD, Morton TA, et al. Effects of respiratory muscle training on performance in athletes: a systematic review with meta-analyses. *J Strength Cond Res*. 2013;27(6):1643-63.
8. Mairbäurl H. Red blood cells in sports: effects of exercise and training on oxygen supply by red blood cells. *Front Physiol*. 2013;4:332. doi: 10.3389/fphys.2013.00332.
9. American Thoracic Society. *Standardization of spirometry, 1994 update*. *Am J Respir Crit Care Med.*2005;152(3):1107-36.
10. Bernhardsen GP, Stang J, Halvorsen T, Stensrud T. Differences in lung function, bronchial hyperresponsiveness, and respiratory health between elite athletes competing in different sports. *Eur J Sport Sci*. 2023;23(8):1480-9.
11. Myrianthefs P, Grammatopoulou I, Katsoulas T, Baltopoulos G. Spirometry may underestimate airway obstruction in professional Greek athletes. *Clin Respir J*. 2014;8(2):240-7.
12. Lazovic-Popovic B, Zlatkovic-Svenda M, Djelic M, Durmic T, Zikic D, Zugic V. Is there relationship between dynamic volumes of pulmonary function and cardiac workload (maximal oxygen uptake) in young athletes? *Rev Port Pneumol (2006)*. 2016;22(4):237-40.
13. Kowalski T, Wilk A, Klusiewicz A, Pawliczek W, Wiecha S, Szczepańska B, et al. Reference values for respiratory muscle strength measured with the S-Index Test in well-trained athletes, e-sports athletes and age-matched controls. *Exp Physiol*. 2024. doi: 10.1113/EP091938.
14. Damian MT, Vulturar R, Login CC, Damian L, Chis A, Bojan A. Anemia in sports: a narrative review. *Life (Basel).*2021;11(9):987. doi: 10.3390/life11090987.
15. Sawka MN, Convertino VA, Eichner ER, Schnieder SM, Young AJ. Blood volume: importance and adaptations to exercise training, environmental stresses, and trauma/sickness. *Med Sci Sports Exerc*. 2000;32(2):332-48.
16. Convertino VA. Blood volume: its adaptation to endurance training. *Med Sci Sports Exerc*. 1991;23(12):1338-48.