Hematological and iron status in female elite athlete players in Albania

Estado hematológico y del hierro en jugadoras atletas de élite en Albania

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Abstract

Background: Iron and hematological condition are important markers of general health and athletic performance. Limited data on iron and hematological status in Albanian female athletes underscores the need for localized research for health monitoring and intervention strategies.
Aim of the Study: The study evaluates the hematological and iron status of female elite athlete players in Albania, identifying deficiencies and underlying causes like inflammation and nutritional factors.
Methodology: A study involving 33 female elite athletes in Albania collected blood samples for a cross-sectional descriptive study, including the summarized data, and independent t-tests compared the mean values to established normal reference ranges. Statistical significance was set at $p<0.05$. Data analysis included hemoglobin, serum iron, erythrocyte count, and hematocrit.
Results: The analysis revealed that Athletes often have hemoglobin and serum iron levels below normal, indicating anemia risk. Iron deficiency may be due to inadequate dietary intake, increased iron loss through menstruation, and training-induced demands. Elevated levels may reflect inflammation or hemoconcentration due to dehydration or intense physical exertion.
Discussion: Iron deficiency in female athletes is linked to nutritional deficiencies, menstrual blood loss, and elite training demands, necessitating targeted interventions to prevent health complications.
Conclusion: The study highlights hematological and iron status abnormalities in Albanian female elite athletes, emphasizing routine screening, personalized nutritional strategies, and further research for effective interventions and integrating hematological monitoring into athlete health management and supporting future longitudinal studies to assess intervention outcomes and health trends among female athletes.

Keywords

Deficiency; female elite athletes; hematological monitoring; iron status.

Resumen

Introducción: El hierro y los indicadores hematológicos son esenciales para evaluar la salud general y el rendimiento deportivo, especialmente en mujeres atletas. La carencia de estudios centrados en jugadoras de élite en Albania resalta la necesidad de investigaciones localizadas que permitan un seguimiento eficaz de su estado fisiológico y estrategias de intervención adecuadas.
Objetivo: El objetivo de este estudio fue evaluar el estado hematológico y del hierro en atletas femeninas de élite en Albania, identificando deficiencias prevalentes y posibles causas subyacentes, como inflamación, deshidratación o factores nutricionales específicos.
Metodología: Se realizó un estudio transversal descriptivo con 33 atletas femeninas de élite en Albania. Se recogieron muestras de sangre en ayunas durante la fase folicular temprana del ciclo menstrual, evitando ejercicio físico 24 horas antes. Se analizaron hemoglobina, hierro sérico, hematocrito y recuento de eritrocitos. Las medias se compararon con valores de referencia mediante pruebas t independientes. El nivel de significación estadística se estableció en $p < 0,05$.
Resultados: Los análisis revelaron niveles bajos de hemoglobina y hierro sérico en la mayoría de las atletas, lo que sugiere riesgo de anemia. Las causas pueden incluir deficiencia dietética, pérdida menstrual o sobrecarga física. En ciertos casos, niveles elevados podrían reflejar inflamación o hemoconcentración asociada al entrenamiento intenso.
Conclusiones: Se identificaron alteraciones hematológicas relevantes en las atletas evaluadas. Se recomienda implementar monitoreo regular, estrategias nutricionales individualizadas e investigaciones longitudinales que optimicen la salud y el rendimiento de las deportistas de élite.

Palabras clave

Deficiencia; deportistas de élite femeninas; estado de hierro; monitorización hematológica.

Introduction

Iron status and hematological parameters are critical for overall health and athletic performance, particularly in endurance sports. Anemia is a prevalent chronic condition, and iron deficiency represents a major concern among athletes engaged in high-intensity training. Research estimates that 3–11% of male athletes and up to 15–35% of female athletes experience iron deficiency (Sims et al., 2022). Embryonic disorders are concerning issues that can impact physical and psychological well-being, often influenced by personal and social perceptions of one's body (Estrada-Araoz et al., 2025a). Female athletes are at greater risk due to factors such as insufficient dietary intake, increased iron demands from strenuous physical activity, and menstrual blood loss. Eumenorrheic women may lose up to 10 mg of iron per menstrual cycle, and studies suggest that up to 60% of female athletes suffer from iron deficiency, which can impair athletic performance (Pengelly et al., 2024; Bozo, 2014). Iron deficiency, even in the absence of anemia, has been shown to hinder aerobic capacity, delay recovery, and reduce endurance. In untrained women, marginal iron depletion is associated with lower aerobic adaptation, highlighting the nutrient's importance in physical performance. Obesity rates are linked to diet changes and sedentary lifestyles, causing global health care systems to express serious concern (Farooqui et al., 2025). Globally, iron deficiency (ID) is the leading cause of anemia, affecting approximately two billion people.

Iron plays a vital role in hemoglobin and myoglobin synthesis, mitochondrial oxidative metabolism, and immune function. Athletes' energy availability is influenced by calculation characteristics, energy expenditure estimation methods, and body composition, potentially leading to measurement errors due to incorrect formula use (Muñoz Aristizábal & Vidarte Claros, 2025). When iron losses exceed absorption, stores become depleted, leading to diminished hemoglobin production and reduced oxygen-carrying capacity. According to the World Health Organization, anemia is diagnosed when hemoglobin levels fall below 120 g/L in women and 130 g/L in men (Houston et al., 2018).

Exercise and training can influence hematological markers such as hemoglobin (Hb), hematocrit (Hct), serum iron (Fe), and red blood cell (RBC) count. Seasonal and training-induced fluctuations have been reported, particularly during periods of intense competition. The term "sports anemia" is often used to describe reductions in Hb and Hct observed during heavy training. This physiological adaptation reflects increased plasma volume rather than true iron deficiency. Training can enhance oxygen transport by increasing red cell mass and total hemoglobin. These changes may be driven by exercise-induced stimulation of erythropoiesis, enhanced bone marrow activity, and cytokine-mediated adaptations (Hu & Lin, 2012). Distinguishing between physiological adaptations and pathological iron deficiency is essential for effective management. Iron depletion in athletes may result from increased demands, dietary insufficiencies, poor absorption, hemolysis, inflammation, sequestration, or gastrointestinal blood loss. Genetic factors may also play a role in anemia susceptibility. Furthermore, nutritional inhibitors (e.g., phytates, polyphenols) and enhancers (e.g., ascorbic acid) influence iron bioavailability (Damian et al., 2021).

Iron metabolism and hematological variables are key physiological determinants of athletic performance. Adequate levels of hemoglobin, erythrocytes, hematocrit, and iron are essential for optimal oxygen delivery. Female athletes are especially vulnerable due to cumulative menstrual blood loss and increased iron turnover during training. Iron supports vital cellular functions, including energy metabolism, DNA synthesis, and oxygen transport. Evidence also suggests a link between vitamin D and iron status, adding further complexity to managing micronutrient health in athletes (Keller et al., 2024). Soccer, a high-intensity intermittent sport, imposes significant physiological demands due to frequent sprinting and prolonged activity. Strength training enhances neuromuscular adaptations by optimizing motor unit recruitment and neural drive, especially when it precedes endurance activities (Rosa et al., 2025). Athletes are exposed to intense training schedules and competitive stressors, which can affect their hematological and biochemical profiles (Anđelković et al., 2014). Despite soccer's global popularity, limited research has explored hematological and biochemical characteristics in elite players, particularly women. Understanding these physiological responses is vital for performance optimization. This study focuses on female elite athletes in Albania, evaluating hematological and iron profiles relative to a reference group.

The aim is to identify potential deficiencies and assess their implications for performance and health. Hemoglobin concentration, hematocrit, and erythrocyte count are direct indicators of aerobic capacity and endurance (Varlet-Marie et al., 2016). Iron is a critical micronutrient for hemoglobin production, mitochondrial activity, and cellular energy. However, ferritin—commonly used to assess iron status—may be elevated by inflammation associated with intense exercise, complicating diagnosis (Toro-Román et al., 2023). Iron deficiency without anemia can still lead to fatigue, reduced stamina, and suboptimal recovery. Although limited, research shows that dietary iron interventions can help female athletes maintain iron levels during heavy training periods (Alaunyte et al., 2015).

In Albania, studies on female elite athletes remain scarce, despite the recognized importance of hematological health in sports performance. Assessing iron status in this population is critical due to unique physiological and dietary challenges. Prior research in other countries reveals geographic and socioeconomic variations in iron deficiency prevalence, yet data specific to Albanian female athletes is lacking (Peeling et al., 2007; Varlet-Marie et al., 2016).

This study aims to fill a critical research gap by evaluating hematological and iron status among elite female athletes in Albania across various sports disciplines. It focuses on key blood health indicators—such as hemoglobin, serum iron, erythrocyte count, and hematocrit—to establish baseline profiles, determine the prevalence of iron deficiency and anemia, compare inter-sport differences, examine associations with training intensity, and provide evidence-based recommendations for maintaining optimal hematological health in this population.

Method

Study design

This study adopted a cross-sectional design to assess the hematological and iron status of elite female athletes in Albania and compare them with standard values from a reference group of non-athletic females. The design captured a single time-point snapshot during the competitive season, allowing identification of associations between physical activity and blood health indicators in a defined population. Cross-sectional studies are particularly effective for identifying trends and prevalence within specific populations.

Participants

A total of 93 participants were recruited: 33 elite female athletes (Group 1) across various sports disciplines and 60 age-matched non-athletic females (Group 2). The overall mean age was 21.63 years (SD = 3.02), with an average height of 166.87 cm (SD = 6.34), body mass of 61.28 kg (SD = 5.06), and BMI of 24.13 kg/m^2 (SD = 3.28). Athlete participants were selected from sports clubs across Albania, including football, volleyball, basketball, athletics, and weightlifting, while controls were university students not engaged in regular athletic training. All participants provided informed written consent. Ethical approval was granted by the Ethics Committee of the Sports University of Tirana (protocol no. 895/2, dated May 14, 2024).

Inclusion criteria

Eligible participants were females aged 18–24. For the athletic group, inclusion required active competition at a national or elite level with a minimum of three years of continuous training in their respective sport. Non-athletes had no history of formal training or competitive participation and matched the athletic group in age, gender, and socioeconomic background.

Exclusion criteria

Exclusion criteria encompassed current pregnancy, recent blood transfusions (within the past 3 months), iron supplementation in the last month, diagnosed hematological disorders, and recent infections, injuries, or surgeries. These criteria were applied to eliminate potential confounding influences on hematological parameters. In particular, infections and surgeries can temporarily alter inflammatory and iron markers (e.g., ferritin, hemoglobin), thereby affecting data validity. Additionally, participants using iron-altering medications or those breastfeeding were excluded.

Data collection Procedure

Instruments and Protocols

Data collection was performed through the following structured steps:

1. Questionnaire: A self-administered, pilot-tested questionnaire adapted from validated sources was used to collect demographic data, training history, dietary habits (including iron-rich food consumption), supplement use, and menstrual cycle characteristics.
2. Anthropometric Measurements: Body height and weight were measured using calibrated equipment, and BMI was calculated to assess physical profile comparability between groups.
3. Training Profile Documentation: Weekly training volume and sports discipline were recorded for the athlete group to contextualize physical demands.
4. Blood Sampling Protocol: Venous blood samples were drawn from the antecubital vein after a 10-hour overnight fast. To minimize hormonal variation, sampling occurred during the early follicular phase (days 2–3 of the menstrual cycle) between 8:00–9:00 AM. Participants refrained from strenuous exercise 24 hours before testing. Blood was collected in EDTA tubes (for hematological analysis) and serum separation tubes (for iron analysis) in accordance with clinical laboratory standards (Osman et al., 2024).

Blood Analysis

The following hematological and biochemical indicators were analyzed, selected for their diagnostic value in assessing iron status and oxygen transport capacity:

1. Hemoglobin (Hb): Indicator of blood's oxygen-carrying capacity.
2. Hematocrit (Hct): Percentage of red blood cells in total blood volume.
3. Red Blood Cell Count (RBC): Reflects overall erythropoietic activity.
4. Serum Iron (Fe): Quantifies circulating iron available in the bloodstream.

All samples were processed in a certified laboratory with quality control measures and duplicate testing to ensure reliability.

Data analysis

Descriptive statistics (mean, standard deviation, and range) were computed to summarize variables. The Kolmogorov–Smirnov and Shapiro–Wilk tests were used to assess data normality, and Levene's test evaluated homogeneity of variances ($p > 0.05$). Independent samples t-tests were used to compare means between athlete and non-athlete groups. Statistical significance was set at $p < 0.05$. Analyses were performed using IBM SPSS version 26.0. This methodological approach offers a comprehensive and reliable assessment of the hematological and iron status of female elite athletes, with implications for health monitoring and sports performance optimization.

Results

The hematological and iron status parameters of the female elite athletic players and non-athletic subjects in Albania are summarized in Table 1.

Serum iron concentrations averaged 106.96 ± 49.8 µg/dL, for female elite athletes with 55% of athletes within the normal limits (40-145µg/dL). Iron levels above the upper normal limit (145 µg/dL) were observed in 30 % of participants, whereas 15% displayed iron deficiency (below 45 µg/dL). Regarding the non-athletic subjects, the results showed that the mean values 89 ± 36.12 µg/dL, with 83% of them within the normal limits, 12 % above the upper limit values and 5% with the iron deficiency. By comparing both groups it is noticed that the values of iron excess in female elite athletes are 3 times higher than those of non-athlete subjects, while iron deficiency is 2.5 times higher, this is mainly due to high-intensity exercise and physical activity as well as other associated factors. The t-test in Table 2 comparing iron levels in athletes with normal versus elevated iron status showed a significant difference (t =

1.964, p = 0.035 < 0.05), suggesting a subset of athletes with elevated serum iron, and a higher iron deficiency for elite players.

Hematocrit (Hct) values averaged 40.44 ± 5.93%, with 70% of athletes within the normal range (37.0 – 54.0). Elevated hematocrit (> 54%) was observed in 9 % of elite athletes, whereas 21% had values below normal limits. The mean values for non-athletic subjects 41.47 ± 6.19 gives a result of 78.3% within the normal range, 1.7 % of them below the lower limit values and 20% above the upper limit of normal values, which is almost the same with the female elite athletes. While the values found in elite athletes below the lower limit of normal are almost 5.3 times greater than those of other subjects. The comparison via t-test yielded no significant difference between groups (t = -0.850, p = 0.397 > 0.05).

Table 1. Results of Blood variables analysis and comparison of norma with below and upper limits values.

Blood variable	Lower and upper limits	Values	Elite Athletes (G1)	Norma	Non-athletes (G2)
Serum Iron (in µg/dL)		Mean value	106.97 ± 49.8	40 - 145	89.32 ± 36.12
	Lower limit values	Below in %	15		5
		Mean + SD	36.2 + 3.8		39 + 0
		Min-Max value	32 ÷ 39		39
		Range	7		0
	Upper limit values	Above in %	30		12
		Mean - SD	162.5 – 17.5		147.71 – 2.71
		Min. value-Max value	147 – 192		149 ÷ 149
		Range	45		2
Hematocrit (in %)		Mean value	40.44 ± 5.93	37.0 ÷ 54.0	41.57 ± 6.19
	Lower limit values	Below in %	21		20
		Mean + SD	35.28 + 1.72		34.18 + 2.83
		Min-Max value	35.5 ÷ 36.1		32.35 ÷ 36.45
		Range	1.6		4.1
	Upper limit values	Above in %	9		1.7
		Mean - SD	55.34 – 1.34		55.2 – 0.0
		Min-Max value	55.00 ÷ 56.01		52.2
		Range	1.01		0
Hemoglobin (in g/dL)		Mean value	12.3 ± 1.06	11 ÷ 16	11.99 ± 1.23
	Lower limit values	Below in %	15		15
		Mean + SD	10.7 + 0.3		10.14 + 0.86
		Min-Max value	10.5 ÷ 10.9		10.02 ÷ 10.09
		Range	0.4		0.07
	Upper limit values	No	0		0
Erythrocyte (in 10^6/uL)		Mean value	4.32 ± 0.32	3.5 ÷ 5.5	4.37 ± 0.62
	Lower limit values	Below in %	3		15
		Mean + SD	3.3 + 0.0		3.39 + 0.11
		Min-Max value	3.3		3.3 ÷ 3.48
		Range	0		0.18
	Upper limit values	No	0		0

Note: Xhufi & Bozo (2025).

The mean hemoglobin (Hb) concentration across the cohort was 12.3 ± 1.06 g/dL, for sports females and 11.99 ± 1.23 g/dL for other subjects with 85% of all participants exhibiting Hb levels within the normal reference range (11.0–16.0 g/dL). Notably, 15% of all subjects that had Hb levels fell below the lower threshold. The t-test analysis, comparing both groups of subjects' players and non-players with Hb below the normal range did not reveal a significant difference (t = 1.198, p = 0.234 > 0.05), indicating that there was not a significant difference between them.

Erythrocyte counts averaged 4.32 ± 0.4 × 10^6/uL, with 97% of elite players within the normal range (3.5–5.5 × 10^6/uL, and only 3% of them below the lower normal limit. Decreased erythrocyte counts (< 3.5 × 10^6/uL), were present in 15% of non-athletic subjects, while 85% of them had counts within the normal limit. The t-test indicated no significant difference between groups with normal and decreased erythrocyte counts (t = -0.401, p = 0.698 > 0.05). As seen from the study results, non-athletic subjects exhibit a 5 times greater reduction in erythrocytes compared to the group of elite female athletes. This is related to the impact of exercise on red blood cells and the effect of physical activity on well-being and health in humans.

Table 2. Pair of variables of elite and students' comparison in t-test analysis

Variable	Pair of variables	Mean ±SD	95 % CI of difference		t-value	p-value
			Lower bound	Upper bound		
Serum Iron	G1 – G2	112.35 ± 42.5	32	192	1.964	0.035
Hematocrit	G1 – G2	45.26 ± 5.04	34.18	56.01	-0.850	0.397
Hemoglobin	G1 – G2	11.23 ± 1.14	10.14	12.32	1.198	0.234
Erythrocyte	G1 – G2	3.84 ± 0.47	3.30	4.37	-0.401	0.689

*Significant differences, p< .05.
Note: Xhufi & Bozo (2025).

Discussion

This study highlights a notable prevalence of iron deficiency and anemia among elite female athletes in Albania, underlining the physiological demands imposed by intense training. The observed reduction in hemoglobin and hematocrit levels in some athletes compared to non-athletes supports existing evidence that strenuous exercise elevates iron turnover and loss, especially in menstruating females (Micail et al., 2021; Nader et al., 2019). The interplay between physical exertion, nutritional inadequacy, and hematological fluctuations is evident, as nearly 15% of athletes exhibited serum iron deficiency, while 30% had elevated levels—likely reflecting inflammatory responses or hemoconcentration due to dehydration (Hayashi et al., 2022).

Iron deficiency in female athletes is a multifactorial condition, driven by factors such as menstrual blood loss, dietary inadequacy, gastrointestinal microbleeding, sweating, and exercise-induced hemolysis (Heisterberg et al., 2012). Studies have showed that a significant number of female students use food as a coping mechanism for negative emotions like stress, anxiety, sadness, or frustration (Estrada-Araoz et al., 2025b). Female players face psychological pressure and stress during competitive matches, affecting concentration, decision-making, and emotional control., despite physical training focus (Ali, 2025). Football requires a balance of aerobic and anaerobic energy systems, with midfielders relying on aerobic endurance for sustained movement and strikers and wingers on anaerobic pathways (Khati et al., 2025).

A subset of athletes in our study demonstrated elevated serum iron levels. This may represent a physiological adaptation to training or an early marker of iron sequestration. Low body iron levels can lead to anemia, limiting oxygen delivery to exercising muscles, and may also hinder muscle oxidative metabolism, affecting performance (Buratti et al., 2015). The findings align with previous reports that link high training loads to fluctuations in red cell indices and iron status, particularly under conditions of functional iron deficiency (FID). Despite adequate iron stores, high hepcidin levels—stimulated by inflammation or intense physical activity—can inhibit iron availability for erythropoiesis (Gafter-Gvili et al., 2019). Hepcidin, an iron-regulatory peptide, is upregulated by interleukin-6 (IL-6), particularly in inflammatory states, leading to decreased intestinal absorption and sequestration of iron in macrophages (Eisenga et al., 2016; Cullis, 2013).

The apparent contradiction between normal or elevated serum iron levels and underlying functional deficiency may be explained by the acute-phase nature of ferritin, which rises in inflammatory conditions (Govus et al., 2016). These biochemical alterations impact erythropoiesis and red blood cell lifespan, potentially impairing oxygen delivery and athletic performance (Karamizrak et al., 1996). Thus, maintaining iron homeostasis is critical for endurance and recovery, especially in sports that rely on both aerobic and anaerobic metabolism (Alaunyte et al., 2015).

However, persistent elevation may also suggest low-grade inflammation, reinforcing the importance of monitoring iron and inflammatory biomarkers over time (Osman et al., 2024). Given the variability in iron demands and responses across sports, establishing sport-specific reference ranges for ferritin and iron biomarkers remains an important research priority (Dellavalle & Haas, 2013; Okazaki et al., 2019).

Routine monitoring, nutritional counseling, and individualized supplementation protocols may help mitigate iron-related performance declines. Monitoring body composition is crucial in cooperative-opposition sports for competitive advantages, but less so in sports with significant physical variability within the same team (Corredor-Serrano et al., 2025).

In regions like Albania, where dietary insufficiencies may be common, early detection of hematological imbalances is essential to safeguard athlete health and optimize performance. Future longitudinal studies are recommended to assess the effectiveness of targeted interventions and to clarify the role of hepcidin modulation in athletic iron metabolism.

Conclusions

The study reveals that while most female elite athletes in Albania have adequate hemoglobin levels and iron stores, a significant subset exhibits subclinical iron deficiency, emphasizing the need for routine monitoring and targeted nutritional interventions to prevent potential health complications. The study confirms high-intensity training affects hematological parameters, emphasizing the need for personalized dietary strategies. It addresses region-specific data and iron deficiency risks among female athletes. Iron supplementation is necessary for optimal erythropoietic response during altitude training, but caution is advised due to increased hepcidin response. Modifying hepcidin levels can improve iron utilization during training and physical performance. Hypoxia-induced reduced hepcidin responses are unclear. Adequate energy and carbohydrates, along with vitamin D and B12 levels, can prevent increased hepcidin levels after training. The study suggests the need for comprehensive screening programs and educational initiatives to improve the health and athletic performance of female athletes in Albania, particularly those with iron deficiency and potential inflammatory responses.

Impact of the study

This study highlights the importance of understanding female elite athletes' hematological and iron status for effective interventions. It emphasizes the need for routine screening protocols and personalized dietary plans to improve athletic performance. Raising awareness about iron intake and health can foster a proactive health management culture, contributing to a more competitive sports environment in Albania.

Limitations

The study's limitations include a small sample size of 33 female elite players, a cross-sectional design that doesn't capture longitudinal changes or causal relationships, and a lack of dietary data.

Future recommendations

To address deficiencies in female athletes' hematological and iron status, regular screening, dietary modifications, iron supplementation, and education on optimal levels are recommended. These interventions help identify deficiencies early, promote iron-rich diets, enhance iron absorption, and promote performance and health.

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Transparency

The authors confirm the manuscript's honesty, accuracy, transparency, and compliance with ethical practices, stating that no vital features were omitted and any discrepancies explained.

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Conflict of interest

The authors declare no conflict of interest.

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