



Iron deficiency, functional performance and nutritional status in healthy adolescent male athletes

Deficiencia de hierro, rendimiento funcional y estado nutricional en deportistas masculinos adolescentes sanos

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Received: 09-06-25

Accepted: 28-01-26

How to cite in APA

Egas-Miraglia, M. A., González-Narváez, M., Villacis, M., Ripalda, D., Montijano, G., Arteaga Pazmiño, C., Frias-Toral, E., & López Ruiz, E. (2026). Iron deficiency, functional performance and nutritional status in healthy adolescent male athletes. *Retos*, 77, 399-411. <https://doi.org/10.47197/retos.v77.116553>

Abstract

Introduction: Iron deficiency is a common nutritional issue with potential impacts on physical performance, particularly in young athletes.

Aim: To analyze the relationship between iron deficiency, physical performance, and nutritional status in adolescent male athletes.

Methodology: This cross-sectional study involved 126 healthy male soccer players from two local professional clubs, divided into groups: M1 ≤ 12 (n=61) and M2 > 12 (n=65). The athletes participated in training sessions six days a week. Blood tests included hemoglobin (Hb), serum iron, and ferritin levels. Physical performance was evaluated using VO2max (Course Navette Test), and nutritional status was assessed through BMI and dietary intake from Hem and non-Hem iron sources.

Results: One athlete (0.79%) was diagnosed with iron deficiency anemia (IDA); 23.02% (n=29) had ferritin levels <30 ng/mL, and 11.11% (n=14) showed signs of iron deficiency (ID). VO2max values indicated adequate performance for age: M1 = 69.17 ml/kg/min and M2 = 76.90 ml/kg/min. A high intake of Hem iron foods was recorded, with 96.90% consuming meat and 96.03% consuming poultry. A positive correlation was observed between VO2max and Hb (r=0.430, p=0.01) in M2.

Discussion: Despite the low prevalence of iron deficiency anemia, a considerable proportion of athletes showed reduced ferritin levels, indicating a subclinical risk of iron deficiency.

Conclusions: This population demonstrated iron storage deficiencies despite adequate performance levels and average weight-for-age.

Keywords

Adolescents; athletes; iron deficiency anemia; nutritional status word; physical performance.

Resumen

Introducción: La deficiencia de hierro es un problema nutricional común con posibles repercusiones en el rendimiento físico, especialmente en atletas jóvenes.

Objetivo: Analizar la relación entre la deficiencia de hierro, el rendimiento físico y el estado nutricional en atletas adolescentes de sexo masculino.

Metodología: Estudio transversal en 126 jugadores de fútbol masculinos sanos de dos clubes profesionales locales, divididos en grupos: M1 ≤ 12 (n = 61) y M2 > 12 (n = 65). Los atletas participaron en sesiones de entrenamiento seis días a la semana. Los análisis bioquímicos incluyeron hemoglobina, hierro sérico y ferritina. El rendimiento físico se evaluó mediante el VO2máx (prueba Course Navette), el estado nutricional mediante el índice de masa corporal (IMC) y la ingesta dietética de fuentes de hierro hem y no hem.

Resultados: Un atleta (0,79%) fue diagnosticado con anemia por deficiencia de hierro (ADH); el 23,02% (n = 29) presentó niveles de ferritina < 30 ng/mL y el 11,11% (n = 14) mostró signos de deficiencia de hierro (DH). Los valores de VO2máx indicaron un rendimiento adecuado para la edad: M1 = 69,17 ml/kg/min y M2 = 76,90 ml/kg/min. Se registró una alta ingesta de alimentos ricos en hierro Hem, con un 96,90% de consumo de carne y un 96,03% de consumo de aves. Se observó una correlación positiva entre el VO2máx y la Hb (r = 0,430; p = 0,01) en el grupo M2.

Discusión: A pesar de la baja prevalencia de anemia ferropénica, una proporción considerable de deportistas mostraron niveles reducidos de ferritina, indicador de un riesgo subclínico de deficiencia de hierro.

Conclusiones: Esta población presentó deficiencias de almacenamiento de hierro a pesar de niveles de rendimiento adecuados y un peso promedio para la edad.

Palabras clave

Adolescentes; anemia ferropénica; deportistas; estado nutricional; rendimiento físico.



Introduction

Iron deficiency (ID) consists of low serum iron and ferritin (Fer) levels without affecting hematopoiesis (Garcia-Casal et al., 2021; Leung et al., 2024; Tarancon-Diez et al., 2022). Iron deficiency anemia (IDA) prevalence in adolescents has been reported around 20-30% (Adetola et al., 2023; GBD 2019 Diabetes in the Americas Collaborators, 2022). IDA arises as a clinical manifestation of reduced red blood cells, where hemoglobin (Hb) and serum iron (sFe) levels drop to fulfill physiological demands (GBD 2019 Diabetes in the Americas Collaborators, 2022; Leung et al., 2024). ID has long been recognized as a concern in athletic populations (Coates et al., 2017). Some studies link ID and hematological parameters to performance outcomes, with significant findings among elite athletes showing associations with reduced performance (Nabeyama et al., 2020).

Athletes, particularly those undergoing intensive training, are vulnerable to IDA due to insufficient dietary iron intake, exercise-induced gastrointestinal bleeding, hematuria, sweating, and compromised intestinal iron absorption, often attributed to subclinical, exercise-induced chronic inflammation (Grosso et al., 2022; Sim et al., 2019; Soares et al., 2017; Xhufi & Bozo, 2025). IDA, in turn, is associated with increased free radical production, lipid peroxidation of cellular membranes, hemolysis, and gastrointestinal bleeding, further lowering sFe concentrations (Clénin et al., 2015). Some athletes are at risk of relative deficiencies in sports arising from a mismatch between nutrient intake and exercise utilization (Burke, 2015). Among professional and adolescent soccer players, IDA has been observed as an adaptive response to exercise, often manifesting as hemodilution (Damian et al., 2021; Kuwabara et al., 2022; Parks et al., 2017). Hence, exercise physiology research frequently considers these blood biomarkers to evaluate health, performance, and recovery during training (Pedlar et al., 2019).

In aerobic sports, physical performance can be measured by maximum oxygen consumption speed (VO₂max) (Vázquez-López et al., 2019). Reduced physical performance has been linked with lower concentrations of erythrocytes, Hb, sFe, Fer, and soluble transferrin receptors in young and adult athletes (Heffernan et al., 2019). In adolescent and adult soccer players, IDA has been linked to physical performance, though some studies report contradictory findings, including a lack of association between Hb and physical performance among adolescent athletes in the United States (Hurwitz, 1974).

Simultaneously, evidence highlights a double burden of malnutrition among adolescents (ages 12 to 15), particularly in low- and middle-income countries in the Americas (Poveda-Loor et al., 2023; Zambrano-Villacres et al., 2024). In these regions, 7% of adolescents experience stunting, 2.9% are classified as thin, and 7% are considered overnourished (Caleyachetty et al., 2018). The Ecuadorian Health and Nutrition National Survey (ENSANUT-ECU), reported that 15% of Ecuadorian children show low height-for-age, indicative of chronic malnutrition (Freire, 2014). Moreover, among school-aged children (5 to 11 years) in Guayaquil, 9.1% were malnourished, with rates rising to 17.9% among adolescents aged 12 to 14 years (Freire et al., 2014). According to the same survey, the prevalence of IDA due to undernutrition was 3.5% in school children and 4.1% in adolescents.

Given that both ID and nutritional status can influence physical performance, this study aimed to analyze the relationship between ID, nutritional status, and physical performance in an adolescent male athletic population.

Method

Participants

This study was conducted in Guayaquil, Ecuador, located at sea level, with a dry season from June to December (average 20°C) and wet season from January to May (average 35°C, 64% humidity). The research was carried out during the 2017 training season with adolescents from two top-ranked male soccer clubs in Ecuador: Club Sport Emelec and Guayaquil City Club.

Study participants were male soccer players aged 11 to 13 years, registered and trained at these institutions.

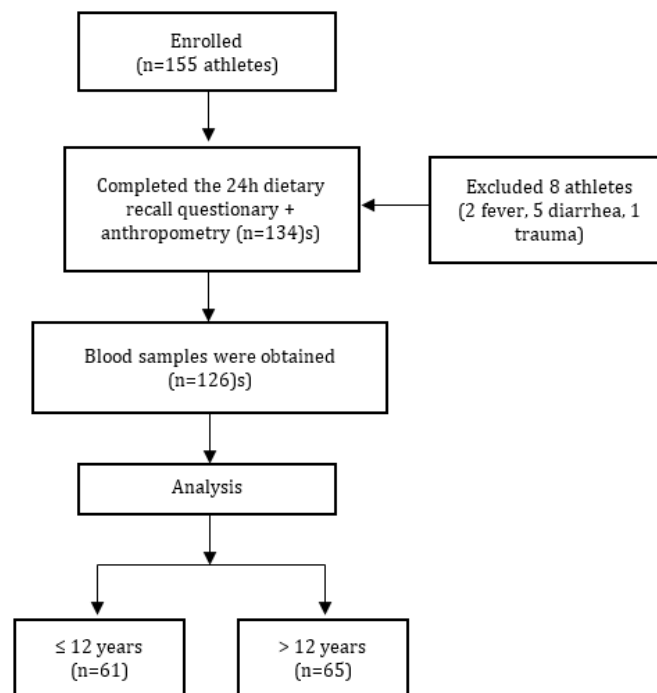
Procedure



This cross-sectional study involved three phases: anthropometric and dietary assessment, hematological analysis, and physical performance evaluation. In the first phase, 134 athletes completed a food intake questionnaire and anthropometric measurements. In the second phase, hematological parameters were assessed in 126 athletes, excluding eight due to fever, diarrhea, or injury. The third phase involved physical performance testing. Athletes were categorized into two age groups: M1 (≤ 12 years, $n=61$) and M2 (>12 years, $n=65$). To control the effect of different types of training on aerobic capacity, we included athletes with 12 hours of aerobic football training per week (6 days) in the pre-season with a duration of 2 months. Pre-season training focused on endurance and velocity with 25 % of anaerobic work once a week considering the athlete age. In addition, individual variations in fitness levels or positional demands were considered. The team used a partially tailored training: goalkeeper and the midfielder have done aerobic together and different tactic training. Also, we included adolescent with the following inclusion criteria: b) absence of acute or chronic illness, and c) signed informed consent provided at the time of assessments.

Participants living above 2,000 meters were excluded. The sample size was calculated a priori to include 70 athletes, with an effect size of 0.8, a statistical power of 95%, a 5% margin of error, and a ratio of 0.85 for comparing groups M1 and M2. Figure 1 displays the flowchart for the selection of the population.

Figure 1. Study population flowchart



Blood samples and Laboratory Analyses

Blood samples were collected after a 12-hour fast via venipuncture from the right antecubital vein. Hb was measured using flow cytometry (Sysmex Xe 2000; Illinois, USA), sFe by spectrophotometry (Architect; Abbott, Illinois, USA), and Fer by chemiluminescence (Centaur Siemens; Munich, Germany). Reference cut-off values for Hb in athletes ≤ 12 years were 11.0–13.8 g/dL and >12 years 11.1–14.7 g/dL; sFe ranged from 60 to 170 $\mu\text{g/dL}$, and Fer <30 ng/mL was used to indicate iron deficiency (Bonilla et al., 2005; Clénin et al., 2015; Parks et al., 2017; Urdampilleta et al., 2013) (Table 1).

Table 1. Study variables and references values for adolescent athletes

	Variable	Age group	
		≤ 12	> 12
Anthropometry*	BMI (kg/m ²), P50/Age	13.5 - 20.3	14.4 - 22.3
Anemia**	Hemoglobin (g/dL)	11.0 - 13.8	11.1 - 14.7
	Serum Iron (µg/dL)		60 - 170
	Ferritin (ng/dL)		30 - 300
Physical Performance***	VO2max (mL/kg/min)	64.28	63.69

BMI, body mass index.

*World Health Organization. 2004. "WHO | Assessing the Iron Status of Populations." WHO. 2004. http://www.who.int/nutrition/publications/micronutrients/anaemia_iron_deficiency/9789241596107/en/. 2007. "Growth Reference 5- 19 Years - BMI-for-Age (5-19 Years)." World Health Organization References. 2007. <https://www.who.int/tools/growth-reference-data-for-5to19-years/indicators/bmi-for-age>.

** Coates, Alexandra, Margo Mountjoy, and Jamie Burr. 2017. "Incidence of Iron Deficiency and Iron Deficient Anemia in Elite Runners and Triathletes." *Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine*. September 2017. <https://pubmed.ncbi.nlm.nih.gov/27606953/>.

*** Flores Abad, Elizabeth, Claudia Arancibia Cid, and Santiago Calero Morales. 2014. "Análisis y Medición Antropométrica En La Detección de Posibles Talentos Deportivos, En Niños/as y Adolescentes Ecuatorianos." *Parámetros Antropométricos y de Aptitud Física de Población Ecuatoriana Para Selección de Deportistas*, May. <http://repositorio.ug.edu.ec/handle/redug/22405>

Blood samples with EDTA were used for Hb determination, while samples in polymer gel tubes (PET tubes) were used for biochemical analysis. Samples were transported at -70°C and processed the same day, with serum extracted following 3000-rpm centrifugation. Physical assessments were conducted post-breakfast two days after blood collection.

Physical Performance

Physical performance was assessed using the Course Navette test, an incremental effort test conducted on an open soccer field (García & Secchi, 2014; Tomkinson et al., 2017). The test was conducted under controlled conditions: in morning (20-20°C), at a market field, with physiotherapist and trainers supervision to identified fatigue because their age.

Athletes ran in one-minute intervals (peliers) following the validated protocol proposed by the EUROFIT battery and the Australian Sports Commission (Agata & Monyeki, 2018). The test began at an initial speed of 8.5 km/h, with speed increments of 0.5 km/h at each interval. Pre-recorded audio cues, previously validated, set the pace for the athletes. The test concluded when the athletes could no longer maintain the pace. Physical activity was measured by the total distance covered, the highest level achieved (Levels 1-20), and the duration of the test, which were used to calculate Maximum Aerobic Capacity or "Maximum oxygen consumption" (VO2max).

VO2max was estimated using the Leger et al. equation (30), proposed for children aged 6 to 17.9 years:

$$VO2max = 31,025 + (3,238 \times VFA) - (3248 \times E) + (0.1536 \times VFA \times E)$$

The outcomes were compared with national VO2max standards from the MINDE-UG Project document (Determination of basic parameters of physical fitness of Ecuadorian population), which aims to identify athletic talent by sex and age. The reference VO2max value for adolescents aged 11-12 was 64.28 ml/kg/min, while for adolescents aged 13-14, it was 63.69 ml/kg/min (Table 1) (Abad et al., 2014).

Anthropometry

The athletes were weighed and measured barefoot, wearing only sports shorts. Measurements were taken using a mechanical scale (SECA 762, Hamburg, DE), calibrated from 0 to 150 kg, and a mechanical stadiometer (SECA 206, Hamburg, DE), with a scale range from 20 to 205 cm. Anthropometric variables were assessed using World Health Organization (WHO) reference charts for weight, height, and body mass index (BMI) (World Health Organization, 2007). Nutritional status was determined by BMI and



categorized as average weight (50th percentile), overweight (≥ 75 th percentile), and low weight (≤ 25 th percentile) according to age and sex (Table 1).

Food intake

All participants completed a 24-hour dietary recall and a validated food frequency questionnaire (FFQ) adapted from the PREDIMED study (Estruch et al., 2013). For this study, only iron-rich foods were included, classified into two groups: Hem (animal sources such as meat, fish, poultry, dairy, eggs, and sausages) and Non-Hem (plant sources such as lentils, beans, and peas) (Young et al., 2018). Frequency of intake was recorded as daily (d), biweekly/monthly (m), or never/occasionally (n).

Data analysis

Statistical analyses were conducted using SPSS v.22.0 (IBM, Inc., Chicago, Illinois). Before inferential analyses, all quantitative variables were evaluated for compliance with the assumption of normality. Data distribution was assessed using the Kolmogorov-Smirnov test. Variables that met normality assumptions were analyzed using parametric tests, whereas non-normally distributed variables were analyzed using non-parametric methods. Descriptive statistics are presented as mean \pm SD or range. Comparisons of mean values for Hb, sFe, Fer, VO₂max, BMI, and Hem vs. Non-Hem food intake between age groups were performed. Independent samples were evaluated using Student's t-tests. Associations between categorical variables were analyzed using Pearson's chi-square test. Correlations between continuous variables were assessed using Spearman's rank correlation coefficient after verifying non-normal data distribution. Statistical significance was set at $p < 0.05$.

Results

The sample of 126 subjects was divided into two age groups: M1 (children ≤ 12 years, $n=61$) and M2 (children > 12 years, $n=65$). The variables analyzed included Hb, sFe, Fer, VO₂max (determined in km/h), BMI, and Hem/NoHem food intake. No significant differences were found between the groups in terms of BMI or Hem/NoHem food intake. Outlier values were observed for Fer and sFe, while Hb and VO₂max showed no outliers. Most outliers were mild ($\pm 1.5 \times$ IQR), with two extreme outliers in Fer ($\pm 3 \times$ IQR), which were adjusted to the mean value based on age and sex. The descriptive characteristics are displayed in Table 2.

Table 2. Descriptive Data for Anthropometric and Blood Variables in Adolescent Athletes.

	Ferritin (ng/mL)		Serum Iron (μ g/dL)		Hemoglobin (g/dL)		BMI (kg/m ²)		
	M1 ≤ 12	M2 > 12	M1 ≤ 12	M2 > 12	M1 ≤ 12	M2 > 12	M1 ≤ 12	M2 > 12	
Sample Size	(n=61)	(n=65)	(n=61)	(n=65)	(n=61)	(n=65)	(n=61)	(n=65)	
Mean	54.73	46.23	88.29	102.33	13.15	13.53	17.58	17.76	
Median	51.61	41.36	81.53	91.11	13.1	13.3	17.31	17.86	
Standard Deviation	31.37	24.419	28.61	38.97	0.84	1.078	2.09	2.47	
Range	195.59	106.72	140.06	174.97	4.3	4.3	8.71	10.37	
Minimum	16.71	12.58	31.3	35.97	10.9	11.8	13.61	12.68	
Maximum	212.3	119.3	171.36	210.94	15.2	16.1	22.32	23.05	
Percentiles	25	35.79	26.92	71.1	77.96	12.6	12.7	15.81	16.27
	50	51.61	41.36	81.53	91.11	13.1	13.3	17.31	17.86
	75	66.79	57.22	107.75	119.63	13.7	14.55	19.27	19.54

Blood results

In group M1, 0.79% (one subject) was diagnosed with IDA, showing Hb values below 11 g/dL. The majority of subjects had Hb values within the normal range: 95.1% (58/61) in M1 and 84.5% (55/65) in M2. Elevated Hb values (> 13.8 g/dL) were observed in 3.30% (2/61) of M1 and 15.4% (10/65) of M2. Regarding sFe levels, 82.54% of participants were within the normal range (60–170 μ g/dL), with M1 at 85.25% (52/61) and M2 at 80.00% (52/65). Low sFe (< 60 μ g/dL) was observed in 11.11% of athletes (M1: 11.48% (7/61), M2: 10.77% (7/65)), while 6.35% had elevated levels (> 170 μ g/dL), with M1 at 3.28% (2/61) and M2 at 9.23% (6/65). Iron values and their distribution by quartiles are detailed in



Table 2. Of the athletes, 11.11% (n=14) with sFe <60 µg/dL were classified as having ID. Fer levels indicated that 76.98% (n=97) of participants had adequate body iron stores (Fer >30 ng/mL), with M1 at 81.97% (50/61) and M2 at 72.31% (47/65). ID was observed in 23.02% (n=29) of the sample (Fer <30 ng/mL), distributed as M1 at 18.03% (11/61) and M2 at 27.63% (18/65).

Physical Performance

The 126 athletes were assessed. The average speed was 0.75 km/h (SD 0.31) for M1 and 1.11 km/h (SD 0.33) for M2. The mean distance covered was lower in M1 than in M2, with M1 achieving levels 2–5 and M2 reaching levels 5–9. The average VO₂max in M1 levels was 2-5, while M2 levels was 5-9. The average VO₂max was 69.17 ml/kg/min (SD 2.37) for M1 and 76.90 ml/kg/min (SD 2.60) for M2, showing higher values for athletes over 12 years old.

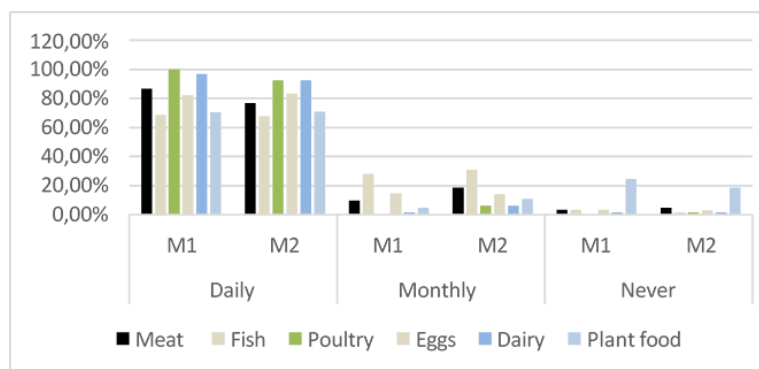
Anthropometry

The BMI average in M1 was 17.58 kg/m² (SD 2.09, Z score -0.39), and in M2, 17.76 kg/m² (SD 2.47, Z score 0.37) (Table 2). Nutritional status was normal in 79.35% of athletes, with M1 at 80.33% (49/61) and M2 at 78.46% (51/65). The remaining 20.65% included 1 case of low weight and 11 cases of overweight in M1, and 11 cases of low weight and 3 cases of overweight in M2. IDA cases were different from low-weight cases.

Food intake

Daily hem food intake was high at 98.4% (124/126), with lower daily non-Hem intake at (55/126). Meat, poultry, and dairy consumption were 97.6% (123/126 athletes), 96.03% (121/126 athletes) and 94.44% (119/126 athletes), respectively. Daily egg and fish consumption was moderate at 74.60% (94/126) and 68.9% (86/126). Younger athletes (M1) showed higher daily meat intake at 100% (61 athletes) compared to M2 at 96.9% (63/65). Daily poultry and dairy intake were also high across both groups (96.03% and 94.44%, respectively). Moderate daily intake levels were observed for eggs (74.60%, 94/126) and fish (68.25%, 86/126). Lower non-Hem (plant-based) food intake was noted at 43.7% across both groups. Details of food intake by group are shown in Figure 2.

Figure 2. Frequency of Intake of Heme and Non-Heme Foods Among Adolescent Athletes



Associations

No statistically significant relationship was found between anemia and BMI for either M1 (p=0.522) or M2 (p=0.590) (Figure 3).

Figure 3. Association between Anemia and Nutritional Status among Adolescent Athletes

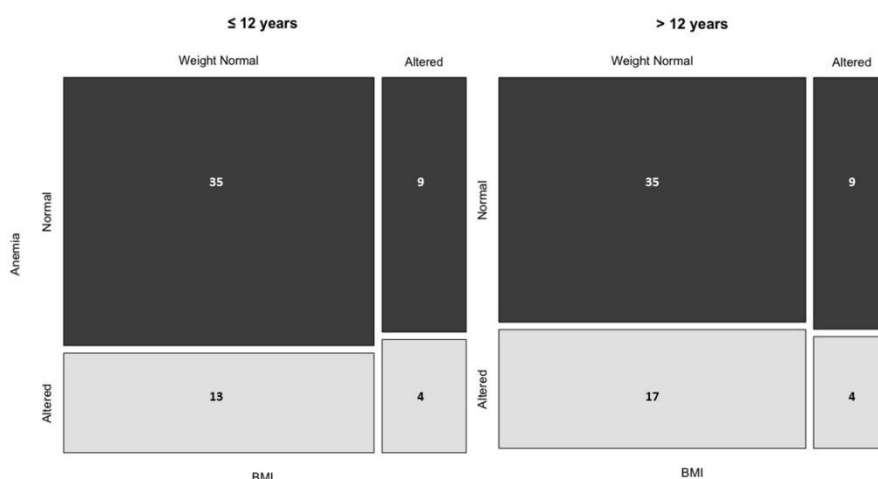


Table 3. Spearman's correlation coefficient between anemia, nutritional and performance variables

	Age (years)									
	M2 ≤12					M2 >12				
	Hb (g/dl)	Ferritin (ng/ml)	Iron (µg/100ml)	VO ₂ max (ml/kg/min)	BMI (Kg/m)	Hb (g/dl)	Ferritin (ng/ml)	Iron (µg/100ml)	VO ₂ max (ml/kg/min)	BMI (Kg/m)
Hemoglobin (g/dl)	1 (.)	0.272* (0.034)	0.325* (0.011)	-0.043548	0.066 (0.612)	1 (.)	0.091 (0.469)	0.579** (0)	0.430** (0)	0.112 (0.373)
Ferritin (ng/ml)	0.272* (0.034)	1 (.)	0.119 (0.362)	0.211 (0.102)	-0.219 (0.09)	0.091 (0.469)	1 (.)	0.241 (0.053)	-0.017 (0.893)	0.069 (0.587)
Iron (ug/100 ml)	0.325* (0.011)	0.119 (0.362)	1 (.)	-0.054 (0.682)	-0.014 (0.917)	0.579** (0)	0.241 (0.053)	1 (.)	0.2 (0.11)	0.208 (0.096)
VO ₂ max (ml/kg/ min)	-0.114 (0.382)	0.211 (0.102)	-0.054 (0.682)	1 (.)	-0.055 (0.672)	0.430** (0)	-0.017 (0.893)	0.2 (0.11)	1 (.)	-0.296* (0.017)
BMI (Kg/m ²)	0.066 (0.612)	-0.219 (0.09)	-0.014 (0.917)	-0.055 (0.672)	1 (.)	0.112 (0.373)	0.069 (0.587)	0.208 (0.096)	-0.296* (0.017)	1 (.)

BMI, body mass index.

Hb, hemoglobin; BMI, body mass index

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed). p-value is in parentheses (.)

No significant association was observed between anemia and physical performance (M1: $p=0.403$; M2: $p=0.504$). Additionally, no association was found between IDA and Hem/NoHem food intake (M1: $p=0.057$; M2: $p=0.321$). Spearman's correlation revealed a weak but significant positive correlation in M1 between Fer and Hb ($r=0.272$; $p=0.05$), and between sFe and Hb ($r=0.325$; $p=0.05$). In M2, a strong positive correlation was found between sFe and Hb ($r=0.579$; $p=0.01$) and between VO₂max and Hb ($r=0.430$, $p=0.01$). Additionally, an inverse correlation was noted between BMI and VO₂max ($r=-0.269$), highlighting the relationship between age, Hb concentration, and VO₂max (Table 3).

Discussion

This study found a low prevalence of IDA and ID, along with normal nutritional and physical status in a population of young male athletes. This is noteworthy as anemia, ID, and malnutrition are typically expected in low- and middle-income countries (Safiri et al., 2021).

The prevalence of anemia and reduced physical performance among athletes has been previously documented (Keller et al., 2024). However, the prevalence of anemia in our athlete sample was low (0.79%),



compared to the 7% reported by the National Health and Nutrition Survey (ENSANUT-ECU-2012) for non-athletes of similar age and sex (Freire, 2014). Our results are consistent with Sales et al., who reported an anemia prevalence of 0,8% in urban Brazilian male adolescents aged 12 and 19 (Sales et al., 2021), while Vázquez-López reported a prevalence of 1,4% with low Hb concentration in Spanish non-athlete male adolescents aged 12-16 (Vázquez-López et al., 2019).

SFe is a valuable biomarker for ID as physical activity-induced inflammatory responses can lead to decreased sFe and Fer levels during active training (Kardasis et al., 2023). Iron stores may deplete before Hb levels drop to those needed for an anemia diagnosis. In our study, 11.11% of the participants exhibited low sFe levels compared to the 4.4% reported by Winocur et al. among low-income, urban Argentinian non-athletes aged 3 to 12 years living in a children's home (Winocur et al., 2004). The Consensus Statement from the Swiss Society of Sports Medicine reported a 21% prevalence of ID among British adolescent athletes (Clénin et al., 2015), while Capanema et al. found a 16,4% anemia rate among Brazilian athletes aged 10 and 17 (Naimo et al., 2021).

In this study, 23.02% of adolescents showed low Fer values, compared to the 10.4% reported by Vázquez-López (Vázquez-López et al., 2019). No cases of Fer values at or below 12 ng/mL, indicative of severe iron depletion, were observed. The adequate Hb values, despite abnormal sFe and Fer concentrations, may result from factors such as age-specific cutoffs, inflammation due to intense training, maturity, sex (influence of testosterone), and the type of sport, all of which influence the incidence and prevalence of ID and IDA (Berthou et al., 2021).

IDA is associated with both the physiological and psychological stress induced by strength training and the onset of sexual maturity (Berthou et al., 2021). IDA biomarkers have demonstrated sex-specific relationships with anaerobic exercise performance in youth athletes (Jastrzebska et al., 2017; Lee et al., 2017; Shoemaker et al., 2019), 12,43). Regarding physical performance, the athletes' mean VO₂max values (M1 = 69.17 ml/kg/min; M2 = 76.90 ml/kg/min) exceeded those recorded in the MINDE-UG Project, which included 861 age- and sex-matched athletes nationwide (Barbry et al., 2022), placing both groups in the 95th percentile. These values also surpassed the range reported in meta-analyses by Slimani et al. (48–62 ml/kg/min) for outfield players, irrespective of performance level (Slimani et al., 2019).

Additionally, our values align with those reported in a systematic review by Tomkinson et al. and a study by Ghouili on Tunisian soccer players of similar age and sex (García & Secchi, 2014; Slimani et al., 2019), further supporting the consistency of our results with existing research. The high VO₂max values observed may be attributable to increased lean body mass, as noted by Welde et al. (Welde et al., 2020), as well as factors such as optimal Hb concentration, training stage (Clénin et al., 2015; Ghouili et al., 2023), playing position (Gulías González, 2014), hormonal activity (Lee et al., 2017), and genetic predisposition (Semenova et al., 2020). Further explanation of these factors will be crucial to fully understand our results.

Adolescence is a critical period characterized by significant physiological changes that increase nutritional needs (Sandström et al., 2012). These developmental demands, combined with intense training, lead to higher energy and protein requirements (Cohen & Powers, 2024). In low-income countries, these conditions can elevate the risks of malnutrition and low Hb levels in both sexes (Monyeki et al., 2024). According to the ENSANUT-ECU-2012, the nutritional status of non-athletes of the same age and sex showed BMI levels indicative of "Chronic Malnutrition" in 38% of individuals aged ≤12 years and 34.4% of those over 12 years (Freire, 2014). In contrast, our study found no cases of malnutrition among the athletes; 79.4% had an adjusted BMI for age and sex, and only 9.52% (12/126) were classified as underweight according to WHO standards (World Health Organization, 2007). These differences may be attributed to the nutritional support provided by soccer clubs, including dietary assessments and snack provisions tailored to the athletes' developmental and high-performance needs.

The dietary patterns observed in these adolescents showed a predominant intake of heme (animal) protein, with culturally limited consumption of non-heme (plant-based) foods. Our findings reveal a significant disparity in nutritional status between these adolescent athletes and their non-athletic peers, underscoring the importance of targeted nutritional interventions during this crucial developmental stage.

No statistically significant associations were found between IDA and BMI, physical performance, or Hem/NoHem food intake in this population. However, we observed strong correlations between IDA variables (sFe/Hb), IDA and performance (Hb/VO₂max), and nutritional status and performance



(BMI/VO₂max) in the older M2 group. Similar results were described by Schoemaker, who suggested that aerobic metabolism becomes more prominent in adolescence, with higher oxidative enzyme levels potentially linked to maturity and sex (Schoemaker et al., 2019).

The lack of correlations in the younger M1 group may indicate reliance on myoglobin-rich oxidative fibers (Bonilla et al., 2005). This study contributes to the field by emphasizing that findings in adult athletes may not be generalizable to preadolescent and adolescent populations due to differences in energy use.

A limitation of this study was the absence of a non-athlete comparison group. Additionally, reliance on a single 24-hour dietary recall may introduce bias, as a single day's food intake may not accurately reflect usual dietary habits. Future research could expand on this by studying this age group in academic settings, providing a broader context for discussions on the prevalence of IDA in the Ecuadorian population.

Recommendations include implementing hematological and iron screenings, including ferritin testing, in other soccer teams across Ecuador to better understand iron status in this population.

Conclusions

This study found that while IDA was rare among young athletes, a significant proportion displayed low Fer levels and ID. Despite these deficiencies, VO₂max values were within the expected range for age, indicating adequate physical performance. A high intake of heme iron from sources like meat and poultry was observed. Although no significant associations were found between IDA, performance, and nutritional status, a positive correlation between sFe and Hb, as well as VO₂max and Hb in athletes over 12 years of age, suggests that iron status may subtly influence aerobic capacity in this age group. These findings highlight the importance of monitoring iron levels to optimize athletic performance and overall health in adolescent athletes.

Acknowledgements

We want to thank Gary Hirsh and Carlos Poveda-Loor for his translation supervision of the manuscript.

Financing

This research was entirely supported by Sistema de Investigación y Desarrollo (SINDE) - (Grant No. CBICS-2017-015); Universidad Católica de Santiago de Guayaquil, Ecuador.

References

- Abad, E., Cid, C., & Calero Morales, S. (2014). Análisis y medición antropométrica en la detección de posibles talentos deportivos, en niños/as y adolescentes ecuatorianos/ Anthropometric analysis and physical aptitude for possible sports talents detection in Ecuadorian children and adolescents.
- Adetola, O. Y., Taylor, J. R. N., & Duodu, K. G. (2023). Can consumption of local micronutrient- and absorption enhancer-rich plant foods together with starchy staples improve bioavailable iron and zinc in diets of at-risk African populations? *International Journal of Food Sciences and Nutrition*, 74(2), 188-208. <https://doi.org/10.1080/09637486.2023.2182740>
- Agata, K., & Monyeki, M. (2018). Association Between Sport Participation, Body Composition, Physical Fitness, and Social Correlates Among Adolescents: The PAHL Study. *PubMed*, 15(12). <https://pubmed.ncbi.nlm.nih.gov/30544884/>
- Barbry, A., Carton, A., Ovigneur, H., & Coquart, J. (2022). Relationships Between Sports Club Participation and Health Determinants in Adolescents and Young Adults. *Frontiers in Sports and Active Living*, 4. <https://doi.org/10.3389/fspor.2022.918716>



- Berthou, C., Iliou, J. P., & Barba, D. (2021). Iron, neuro-bioavailability and depression. *EJHaem*, 3(1), 263. <https://doi.org/10.1002/jha2.321>
- Bonilla, J. F., Narváez, R., & Chuairé, L. (2005). El deporte como causa de estrés oxidativo y hemólisis. *Colombia Médica*, 36(4), 275-280. http://www.scielo.org.co/scielo.php?script=sci_abstract&pid=S1657-95342005000400009&lng=en&nrm=iso&tlng=es
- Burke, L. M. (2015). Dietary assessment methods for the athlete: Pros and Cons of different methods. *Sports Science Exchange*, 28(150), 1-6.
- Caleyachetty, R., Thomas, G. N., Kengne, A. P., Echouffo-Tcheugui, J. B., Schilsky, S., Khodabocus, J., & Uauy, R. (2018). The double burden of malnutrition among adolescents: Analysis of data from the Global School-Based Student Health and Health Behavior in School-Aged Children surveys in 57 low- and middle-income countries. *The American Journal of Clinical Nutrition*, 108(2), 414-424. <https://doi.org/10.1093/ajcn/nqy105>
- Clénin, G., Cordes, M., Huber, A., Schumacher, Y. O., Noack, P., Scales, J., & Kriemler, S. (2015). Iron deficiency in sports—Definition, influence on performance and therapy. *Swiss Medical Weekly*, 145, w14196. <https://doi.org/10.4414/smw.2015.14196>
- Coates, A., Mountjoy, M., & Burr, J. (2017). Incidence of Iron Deficiency and Iron Deficient Anemia in Elite Runners and Triathletes. *Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine*, 27(5), 493-498. <https://doi.org/10.1097/JSM.0000000000000390>
- Cohen, C. T., & Powers, J. M. (2024). Nutritional Strategies for Managing Iron Deficiency in Adolescents: Approaches to a Challenging but Common Problem. *Advances in Nutrition*, 15(5), 100215. <https://doi.org/10.1016/j.advnut.2024.100215>
- Damian, M.-T., Vulturar, R., Login, C. C., Damian, L., Chis, A., & Bojan, A. (2021). Anemia in Sports: A Narrative Review. *Life*, 11(9), 987. <https://doi.org/10.3390/life11090987>
- Estruch, R., Ros, E., Salas-Salvadó, J., Covas, M.-I., Corella, D., Arós, F., Gómez-Gracia, E., Ruiz-Gutiérrez, V., Fiol, M., Lapetra, J., Lamuela-Raventós, R. M., Serra-Majem, L., Pintó, X., Basora, J., Muñoz, M. A., Sorlí, J. V., Martínez, J. A., & Martínez-González, M. A. (2013). Primary Prevention of Cardiovascular Disease with a Mediterranean Diet. *New England Journal of Medicine*, 368(14), 1279-1290. <https://doi.org/10.1056/NEJMoa1200303>
- Freire, W. (with Ministerio de Salud Pública). (2014). Encuesta Nacional de Salud y Nutrición: ENSANUT-ECU 2012. INEC.
- Freire, W. B., Silva-Jaramillo, K. M., Ramírez-Luzuriaga, M. J., Belmont, P., & Waters, W. F. (2014). The double burden of undernutrition and excess body weight in Ecuador. *The American Journal of Clinical Nutrition*, 100(6), 1636S-1643S. <https://doi.org/10.3945/ajcn.114.083766>
- García, G. C., & Secchi, J. D. (2014). Test course navette de 20 metros con etapas de un minuto. Una idea original que perdura hace 30 años. *Apunts Sports Medicine*, 49(183), 93-103. <https://doi.org/10.1016/j.apunts.2014.06.001>
- García-Casal, M. N., Pasricha, S.-R., Martínez, R. X., López-Pérez, L., & Peña-Rosas, J. P. (2021). Serum or plasma ferritin concentration as an index of iron deficiency and overload. *The Cochrane Database of Systematic Reviews*, 5(5), CD011817. <https://doi.org/10.1002/14651858.CD011817.pub2>
- GBD 2019 Diabetes in the Americas Collaborators. (2022). Burden of diabetes and hyperglycaemia in adults in the Americas, 1990-2019: A systematic analysis for the Global Burden of Disease Study 2019. *The Lancet. Diabetes & Endocrinology*, 10(9), 655-667. [https://doi.org/10.1016/S2213-8587\(22\)00186-3](https://doi.org/10.1016/S2213-8587(22)00186-3)
- Ghouili, H., Dridi, A., Ouerghi, N., Ben Aissa, M., Bouassida, A., Guelmami, N., Sortwell, A., Branquinho, L., Forte, P., & Dergaa, I. (2023). Normative reference and cut-offs values of maximal aerobic speed-20 m shuttle run test and maximal oxygen uptake for Tunisian adolescent (elite) soccer players. *Heliyon*, 9(10), e20842. <https://doi.org/10.1016/j.heliyon.2023.e20842>
- Grosso, G., Laudisio, D., Frias-Toral, E., Barrea, L., Muscogiuri, G., Savastano, S., & Colao, A. (2022). Anti-Inflammatory Nutrients and Obesity-Associated Metabolic-Inflammation: State of the Art and Future Direction. *Nutrients*, 14(6), 1137. <https://doi.org/10.3390/nu14061137>
- Gulías González, R. (2014). Condición Física y Estado Ponderal de niños y adolescentes de Castilla-La Mancha. <https://hdl.handle.net/10578/4117>
- Heffernan, S. M., Horner, K., De Vito, G., & Conway, G. E. (2019). The Role of Mineral and Trace Element Supplementation in Exercise and Athletic Performance: A Systematic Review. *Nutrients*, 11(3), 696. <https://doi.org/10.3390/nu11030696>



- Hurwitz, S. (1974). Medical aspects of adolescents participating in sports. *Western Journal of Medicine*, 121(5), 443-447. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1129637/>
- Jastrzebska, M., Kaczmarczyk, M., Suárez, A. D., Sánchez, G. F. L., Jastrzebska, J., Radziminski, L., & Jastrzebski, Z. (2017). Iron, Hematological Parameters and Blood Plasma Lipid Profile in Vitamin D Supplemented and Non-Supplemented Young Soccer Players Subjected to High-Intensity Interval Training. *Journal of Nutritional Science and Vitaminology*, 63(6), 357-364. <https://doi.org/10.3177/jnsv.63.357>
- Kardasis, W., Naquin, E. R., Garg, R., Arun, T., Gopianand, J. S., Karmakar, E., & Gnana-Prakasam, J. P. (2023). The IRONY in Athletic Performance. *Nutrients*, 15(23), 4945. <https://doi.org/10.3390/nu15234945>
- Keller, K., Friedrich, O., Treiber, J., Quermann, A., & Friedmann-Bette, B. (2024). Iron deficiency in athletes: Prevalence and impact on VO₂ peak. *Nutrition (Burbank, Los Angeles County, Calif.)*, 126, 112516. <https://doi.org/10.1016/j.nut.2024.112516>
- Kuwabara, A. M., Tenforde, A. S., Finnoff, J. T., & Fredericson, M. (2022). Iron deficiency in athletes: A narrative review. *PM & R: The Journal of Injury, Function, and Rehabilitation*, 14(5), 620-642. <https://doi.org/10.1002/pmrj.12779>
- Lee, E. C., Fragala, M. S., Kavouras, S. A., Queen, R. M., Pryor, J. L., & Casa, D. J. (2017). Biomarkers in Sports and Exercise: Tracking Health, Performance, and Recovery in Athletes. *Journal of Strength and Conditioning Research*, 31(10), 2920-2937. <https://doi.org/10.1519/JSC.0000000000002122>
- Leung, A. K. C., Lam, J. M., Wong, A. H. C., Hon, K. L., & Li, X. (2024). Iron Deficiency Anemia: An Updated Review. *Current Pediatric Reviews*, 20(3), 339-356. <https://doi.org/10.2174/1573396320666230727102042>
- Monyeki, M. A., Veldsman, T., Coetzee, B., Sparks, M., Moss, S. J., Pienaar, C., Swanepoel, M., Malan, L., & Kruger, H. S. (2024). Relationships between Iron Status and Selected Physical Fitness Components of South African Adolescents: The PAHL-Study. *Children*, 11(6), 659. <https://doi.org/10.3390/children11060659>
- Nabeyama, T., Suzuki, Y., Yamamoto, K., Sakane, M., Sasaki, Y., Shindo, H., Takita, M., & Kami, M. (2020). Prevalence of iron deficiency among university kendo practitioners in Japan: An observational cohort study. *Journal of the International Society of Sports Nutrition*, 17, 62. <https://doi.org/10.1186/s12970-020-00393-2>
- Naimo, M. A., Varanoske, A. N., Hughes, J. M., & Pasiakos, S. M. (2021). Skeletal Muscle Quality: A Biomarker for Assessing Physical Performance Capabilities in Young Populations. *Frontiers in Physiology*, 12, 706699. <https://doi.org/10.3389/fphys.2021.706699>
- Parks, R. B., Hetzel, S. J., & Brooks, M. A. (2017). Iron Deficiency and Anemia among Collegiate Athletes: A Retrospective Chart Review. *Medicine and Science in Sports and Exercise*, 49(8), 1711-1715. <https://doi.org/10.1249/MSS.0000000000001259>
- Pedlar, C. R., Newell, J., & Lewis, N. A. (2019). Blood Biomarker Profiling and Monitoring for High-Performance Physiology and Nutrition: Current Perspectives, Limitations and Recommendations. *Sports Medicine (Auckland, N.Z.)*, 49(Suppl 2), 185-198. <https://doi.org/10.1007/s40279-019-01158-x>
- Poveda-Loor, C., Yaguachi-Alarcón, R., Espinoza-Burgos, Á., Frias-Toral, E., & Suárez, R. (2023). Dietary intake, anthropometric profile and somatotype in university athletes: Differences between gender and sports practiced. *Mediterranean Journal of Nutrition and Metabolism*, 16(4), 335-352. <https://doi.org/10.3233/MNM-230065>
- Safiri, S., Kolahi, A.-A., Noori, M., Nejadghaderi, S. A., Karamzad, N., Bragazzi, N. L., Sullman, M. J. M., Abdollahi, M., Collins, G. S., Kaufman, J. S., & Grieger, J. A. (2021). Burden of anemia and its underlying causes in 204 countries and territories, 1990–2019: Results from the Global Burden of Disease Study 2019. *Journal of Hematology & Oncology*, 14(1), 185. <https://doi.org/10.1186/s13045-021-01202-2>
- Sales, C. H., Rogero, M. M., Sarti, F. M., & Fisberg, R. M. (2021). Prevalence and Factors Associated with Iron Deficiency and Anemia among Residents of Urban Areas of São Paulo, Brazil. *Nutrients*, 13(6), 1888. <https://doi.org/10.3390/nu13061888>
- Sandström, G., Börjesson, M., & Rödger, S. (2012). Iron deficiency in adolescent female athletes—Is iron status affected by regular sporting activity? *Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine*, 22(6), 495-500. <https://doi.org/10.1097/JSM.0b013e3182639522>



- Semenova, E. A., Miyamoto-Mikami, E., Akimov, E. B., Al-Khelaifi, F., Murakami, H., Zempo, H., Kostryukova, E. S., Kulemin, N. A., Larin, A. K., Borisov, O. V., Miyachi, M., Popov, D. V., Boulygina, E. A., Takaragawa, M., Kumagai, H., Naito, H., Pushkarev, V. P., Dyatlov, D. A., Lekontsev, E. V., ... Ahmetov, I. I. (2020). The association of HFE gene H63D polymorphism with endurance athlete status and aerobic capacity: Novel findings and a meta-analysis. *European Journal of Applied Physiology*, 120(3), 665-673. <https://doi.org/10.1007/s00421-020-04306-8>
- Shoemaker, M. E., Gillen, Z. M., McKay, B. D., Bohannon, N. A., Gibson, S. M., Koehler, K., & Cramer, J. T. (2019). Sex-specific relationships among iron status biomarkers, athletic performance, maturity, and dietary intakes in pre-adolescent and adolescent athletes. *Journal of the International Society of Sports Nutrition*, 16, 42. <https://doi.org/10.1186/s12970-019-0306-7>
- Sim, M., Garvican-Lewis, L. A., Cox, G. R., Govus, A., McKay, A. K. A., Stellingwerff, T., & Peeling, P. (2019). Iron considerations for the athlete: A narrative review. *European Journal of Applied Physiology*, 119(7), 1463-1478. <https://doi.org/10.1007/s00421-019-04157-y>
- Slimani, M., Znazen, H., Miarka, B., & Bragazzi, N. L. (2019). Maximum Oxygen Uptake of Male Soccer Players According to their Competitive Level, Playing Position and Age Group: Implication from a Network Meta-Analysis. *Journal of Human Kinetics*, 66, 233-245. <https://doi.org/10.2478/hukin-2018-0060>
- Soares, A. V., Marcelino, E., Maia, K. C., & Borges, N. G. (2017). Relation between functional mobility and dynapenia in institutionalized frail elderly. *Einstein (Sao Paulo, Brazil)*, 15(3), 278-282. <https://doi.org/10.1590/S1679-45082017AO3932>
- Tarancon-Diez, L., Genebat, M., Roman-Enry, M., Vázquez-Alejo, E., Espinar-Buitrago, M. de la S., Leal, M., & Muñoz-Fernandez, M. Á. (2022). Threshold Ferritin Concentrations Reflecting Early Iron Deficiency Based on Hepcidin and Soluble Transferrin Receptor Serum Levels in Patients with Absolute Iron Deficiency. *Nutrients*, 14(22), 4739. <https://doi.org/10.3390/nu14224739>
- Tomkinson, G. R., Lang, J. J., Tremblay, M. S., Dale, M., LeBlanc, A. G., Belanger, K., Ortega, F. B., & Léger, L. (2017). International normative 20 m shuttle run values from 1 142 026 children and youth representing 50 countries. *British Journal of Sports Medicine*, 51(21), 1545-1554. <https://doi.org/10.1136/bjsports-2016-095987>
- Urdampilleta, A., Martínez-Sanz, J. M., & Mielgo-Ayuso, J. (2013). Anemia ferropénica en el deporte e intervenciones dietético-nutricionales preventivas. *Revista Española de Nutrición Humana y Dietética*, 17(4), Article 4. <https://doi.org/10.14306/renhyd.17.4.16>
- Vázquez-López, M. A., López-Ruzafa, E., Ibáñez-Alcalde, M., Martín-González, M., Bonillo-Perales, A., & Lendínez-Molinos, F. (2019). The usefulness of reticulocyte haemoglobin content, serum transferrin receptor and the sTfR-ferritin index to identify iron deficiency in healthy children aged 1-16 years. *European Journal of Pediatrics*, 178(1), 41-49. <https://doi.org/10.1007/s00431-018-3257-0>
- Welde, B., Morseth, B., Handegård, B. H., & Lagstad, P. (2020). Effect of Sex, Body Mass Index and Physical Activity Level on Peak Oxygen Uptake Among 14–19 Years Old Adolescents. *Frontiers in Sports and Active Living*, 2, 78. <https://doi.org/10.3389/fspor.2020.00078>
- Winocur, D., Ceriani Cernadas, J. M., Imach, E., Otasso, J. C., Morales, P., & Gards, A. (2004). Prevalencia de anemia ferropénica en niños pre-escolares y escolares con necesidades básicas insatisfechas. *Medicina (Buenos Aires)*, 64(6), 481-486. https://www.scielo.org.ar/scielo.php?script=sci_abstract&pid=S0025-76802004000600001&lng=es&nrm=iso&tlng=es
- World Health Organization. (2007). Growth reference 5-19 years—BMI-for-age (5-19 years). <https://www.who.int/tools/growth-reference-data-for-5to19-years/indicators/bmi-for-age>
- Khufi, S., & Bozo, D. (2025). Hematological and iron status in female elite athlete players in Albania. *Retos*, 71, 693-702. <https://doi.org/10.47197/retos.v71.116034>
- Young, I., Parker, H. M., Rangan, A., Prvan, T., Cook, R. L., Donges, C. E., Steinbeck, K. S., O'Dwyer, N. J., Cheng, H. L., Franklin, J. L., & O'Connor, H. T. (2018). Association between Haem and Non-Haem Iron Intake and Serum Ferritin in Healthy Young Women. *Nutrients*, 10(1), 81. <https://doi.org/10.3390/nu10010081>
- Zambrano-Villacres, R., Frias-Toral, E., Maldonado-Ponce, E., Poveda-Loor, C., Leal, P., Velarde-Sotres, A., Leonardi, A., Trovato, B., Roggio, F., Castorina, A., Wenxin, X., & Musumeci, G. (2024). Exploring body composition and somatotype profiles among youth professional soccer players. *Mediterr J Nutr Metab*, 17(3), 241-254. <https://doi.org/10.3233/MNM-240038>

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