Review Article

Micronutrient Deficiencies in Female Football Players - A Narrative Review

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Abstract

Female football players experience substantial physiological and metabolic demands, making adequate micronutrient status essential for energy metabolism, oxygen transport, musculoskeletal health, and immune function. Iron and vitamin D deficiencies are particularly important nutritional concerns among female athletes. This narrative review synthesized evidence on micronutrient deficiencies among female football players and their implications for health and athletic performance. Literature published from January 2010 to June 2025 was searched in PubMed/MEDLINE, , Scopus, and Google Scholar using terms related to female football players, micronutrient deficiencies, iron, vitamin D, and sports nutrition. Relevant observational studies, clinical trials, systematic reviews, and narrative reviews were analyzed narratively. Iron deficiency was the most frequently reported nutritional concern, while vitamin D deficiency was also commonly reported. Factors associated with micronutrient inadequacy included menstrual blood loss, high training loads, inadequate dietary intake, restrictive diets, limited sunlight exposure, and low energy availability associated with Relative Energy Deficiency in Sport (RED-S). Deficiencies may adversely affect endurance, muscle function, recovery, bone health, and injury risk. Regular nutritional assessment, targeted screening, and appropriate dietary strategies may help improve health and athletic performance. Further research, particularly in low- and middle-income countries, is needed.

Key words: *Female football players, Micronutrient deficiency, Iron deficiency, Vitamin D, Sports nutrition.*

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Introduction

Over the last 20 years, women's football has seen exceptional growth worldwide in participation at amateur, university and professional levels. In competitive women's football match play (MP) characterized by frequent bursts of high-intensity actions such as sprinting, accelerations, decelerations and multidirectional movements, exert substantial physiological and metabolic demands on players. Recent analysis of elite female team-sport competition has established that female athletes are expected to achieve significant external loads with multiple high-speed running and sprinting efforts throughout match play.[1] Therefore, optimal nutritional status is a crucial factor in maintaining athletic performance as well as recovery and decreasing injury risk among female football players.

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Adequate consumption of micronutrients is particularly important for athletes, as these nutrients play vital roles in energy metabolism, oxygen transport, immune function, and musculoskeletal health.[2] Notably, iron and vitamin D have received significant attention in sports medicine due to their strong association with endurance capacity, muscle function, and bone health.[3] However, despite increased awareness of sports nutrition, micronutrient deficiencies remain common among female athletes worldwide.[4]

Iron deficiency is widely recognized as the most prevalent nutritional deficiency in athletes, particularly among females.[5] Iron plays a central role in hemoglobin synthesis and oxygen transport, making it essential for aerobic performance. Athletes may experience increased iron loss due to factors such as menstruation, sweating, gastrointestinal bleeding, and exercise-induced hemolysis.[6] Studies suggest that iron deficiency may affect between 15% and 50% of female athletes, depending on the type of sports and training intensity.6 Even in the absence of anemia, reduced iron stores can impair aerobic capacity, increase fatigue, and negatively affect athletic performance.[7]

Vitamin D deficiency has also emerged as a major concern in athletes. Calcium homeostasis, bone mineralization, and muscular function all depend on vitamin D.[8] Insufficient vitamin D levels have been linked to reduced muscle strength, diminished neuromuscular coordination, and an increased risk of stress fractures.[9] Many athletes have poor vitamin D levels despite engaging in regular physical exercise; this is frequently caused by insufficient dietary intake, indoor training conditions, seasonal variations, and restricted sunshine exposure.[10]

A combination of physiological and environmental variables may make female football players more susceptible to micronutrient deficits. Hormonal variations, menstrual blood loss, and the need to maintain a lean body all have an impact on nutritional intake and energy availability.[11] The link between these determinants, micronutrient deficiencies, and their potential consequences for athletic performance are illustrated in Figure 1. Furthermore, the syndrome known as Relative Energy Deficiency in Sport (RED-S) may contribute to micronutrient imbalances and poor physiological function.[12]

Research on sports nutrition has grown significantly, but there are still few studies that primarily address the micronutrient status of female football players, especially in low- and middle-income nations like Bangladesh. Understanding micronutrient deficits in this population is critical for improving performance, avoiding injuries, and promoting long-term athlete health. The purpose of this narrative review is to outline existing global evidence on micronutrient deficiencies among female football players, with a focus on iron and vitamin D, and to examine the implications for athletic performance and health

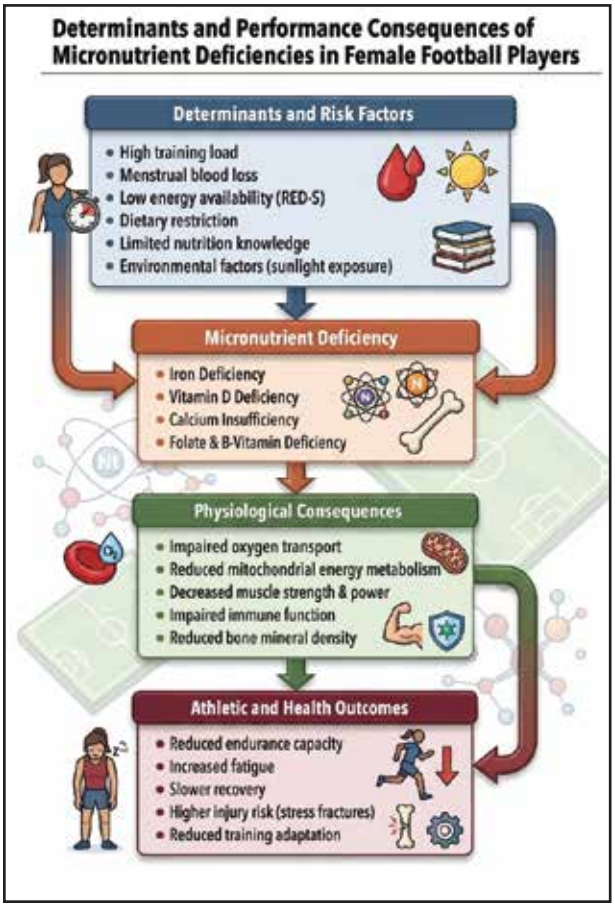

Figure 1: Conceptual framework illustrating determinants and consequences of micronutrient deficiencies in female football players.

Materials and Methods

Study Design

This article was conducted as a narrative review to synthesize existing evidence on micronutrient deficiencies among female football players and their potential implications for athletic performance and health. A narrative review approach was selected to provide a comprehensive overview of the available literature, integrate findings from diverse study designs, and identify emerging themes in sports nutrition research related to female football athletes.[13]

Literature Search Strategy

A structured literature search was performed using the electronic databases PubMed/MEDLINE, Scopus, and Google Scholar to identify relevant study published between January 2010 and June 2025. Keywords and Medical Subject Headings (MeSH) terms related to female athletes, football/soccer, micronutrient deficiencies, sports nutrition, and energy availability were combined using Boolean operators (AND/OR) to identify relevant literature.[14]

An example search strategy used in PubMed included
("female athletes" OR "women athletes" OR "female football players" OR "women's soccer") AND ("micronutrient deficiency" OR "iron deficiency" OR "vitamin D deficiency" OR "sports nutrition" OR "energy availability")

Reference lists of relevant articles were also manually screened to identify additional studies that were not captured through database searches.

Study Selection
Articles were screened based on relevance to the review topic. The following inclusion criteria were applied:
• Peer-reviewed articles published in English
• Studies involving female athletes, particularly football players
• Studies investigating micronutrient status, iron deficiency, vitamin D deficiency, or related nutritional factors
• Observational studies, clinical trials, systematic reviews, and narrative reviews related to sports nutrition and athlete health

Studies focusing exclusively on male athletes, non-athletic populations, or unrelated nutritional topics were excluded unless they provided important physiological insights relevant to female athletes.

Data Extraction and Synthesis
Relevant information from the selected studies was extracted and summarized, including:
• Study population and sport discipline
• Type of micronutrient deficiency investigated
• Reported prevalence of deficiencies
• Physiological mechanisms and risk factors
• Effects on athletic performance and health outcomes

Because of heterogeneity in study designs, populations, and outcome measures, a quantitative meta-analysis was not performed. Instead, findings were synthesized narratively, emphasizing common themes, areas of agreement, and knowledge gaps in literature.

Ethical Considerations
As this study was based exclusively on previously published literature, ethical approval and informed consent were not required.

Results

Iron Deficiency in Female Athletes
Iron deficiency is commonly reported as one of the most common nutritional deficiencies among female athletes.[15,16] Iron plays a pivotal role in athletic performance by supporting hemoglobin synthesis, oxygen transport, and mitochondrial oxidative metabolism; therefore, insufficient iron availability may impair aerobic capacity and limit training adaptation in athletes.[17] Therefore, maintaining optimal iron stores is considered a key component of sports nutrition and athlete health management.

Female athletes are mostly susceptible to iron deficiency due to a combination of physiological and sport-related factors. Exercise-induced iron losses may occur through mechanisms such as hemolysis associated with repetitive foot-strike during running, iron loss through sweat, gastrointestinal bleeding, and inflammation-related alterations in iron metabolism.[18] Physiological factors like menstrual blood loss, combined with the metabolic demands of intensive training, can contribute to depleted iron stores. As a result, many female athletes display reduced iron status, even though prevalence estimates vary across sports, training loads, and diagnostic criteria.[19]

In Sports Medicine, iron deficiency without anemia is recognized as a condition that can spoil aerobic performance and increase fatigue despite normal hemoglobin levels.[6] Additionally, low iron status may influence mitochondrial function and metabolic efficiency, thereby affecting endurance performance and recovery.[20]

Athletes are particularly vulnerable to iron depletion who participate in sports that involve high training loads and repetitive running activities, such as football, distance running, and other endurance-based disciplines. Dietary habit may also contribute to inadequate iron intake, especially in athletes following energy-restricted diets or dietary patterns with limited heme-iron sources.[21] Exercise-induced inflammation and increased hepcidin activity may further reduce iron absorption and availability in athletes undergoing intensive training.[22] In light of these risks, regular monitoring of iron status including serum ferritin, hemoglobin, and transferrin saturation has been recommended in female athletes to allow early detection and appropriate nutritional intervention.[23] Targeted nutritional interventions and iron supplementation protocols may help restore iron balance and support optimal athletic performance in iron-deficient athletes.[24]

Taken together, the frequent occurrence of iron deficiency and its potential impact on endurance capacity, fatigue, and training adaptation underscore the need for adequate iron intake and routine screening in female athletes.

Vitamin D Deficiency in Athletes
Vitamin D deficiency has emerged as an important concern in athletic populations due to its critical role in musculoskeletal health, immune function, and athletic performance. Vitamin D is essential for calcium homeostasis, bone mineralization, and skeletal muscle function, making it particularly relevant for athletes engaged in high-impact and endurance sports.[25] Adequate vitamin D status contributes to optimal muscle contraction, neuromuscular coordination, and bone strength, all of which are necessary for maintaining athletic performance and reducing injury risk.

Suboptimal vitamin D status is frequently observed among athletes despite regular physical activity. Research across both elite and recreational athletic populations has demonstrated a considerable prevalence of vitamin D insufficiency. Contributing factors include limited sunlight exposure, seasonal fluctuations in ultraviolet radiation, geographic latitude, predominantly indoor training environments, and inadequate dietary intake of vitamin D–rich foods.[10,26] Athletes who predominantly train indoors or live at higher latitudes may be particularly vulnera

ble to vitamin D deficiency because limited exposure to ultraviolet-B (UVB) radiation restricts endogenous vitamin D synthesis in the skin.[27] Low vitamin D status has been associated with outcomes relevant to athletic performance, including reduced muscle strength, impaired neuromuscular function, and diminished power output, which may negatively influence performance during high-intensity activities.[3,9] In addition, vitamin D deficiency has been linked to an increased risk of bone stress injuries and stress fractures, particularly in athletes participating in repetitive weight-bearing sports. These injuries may significantly disrupt training schedules and competitive performance. In addition to its well-established role in musculoskeletal health, vitamin D is also involved in immune modulation and regulation of inflammatory responses, processes that may influence recovery and vulnerability to illness in athletes exposed to intensive training loads.[28] Emerging evidence indicates that maintaining sufficient vitamin D status may contribute to overall athlete health and potentially reduce the risk of infections, particularly during periods of heavy training or competitive stress. Female athletes may be particularly vulnerable to vitamin D insufficiency due to factors such as dietary restriction, low energy availability, and inadequate intake of vitamin-D rich foods. Monitoring vitamin D status using serum 25-hydroxyvitamin D concentrations is therefore recommended in at-risk athletes. Strategies such as safe sunlight exposure, dietary optimization, and supplementation, when necessary, can help maintain adequate vitamin D levels, supporting bone health, muscle function, and reducing injury risk in athletic populations.[29]

Micronutrient Status in Female Football Players

Female football (soccer) involves intermittent high-intensity activity characterized by repeated sprinting, rapid accelerations, and frequent changes of direction, placing considerable physiological and metabolic demands on players.[30] Adequate nutritional status including sufficient micronutrient intake is therefore essential to sustain performance, support recovery, and reduce injury risk.[31] However, emerging evidence suggests that female football players may frequently exhibit suboptimal micronutrient status.[32] Studies evaluating dietary intake in football players have reported inadequate consumption of several key micronutrients, including iron, vitamin D, calcium, and folate.[33] Female athletes may be particularly vulnerable due to high training loads, increased physiological demands, and dietary practices aimed at maintaining a lean body composition. When energy intake does not sufficiently match the metabolic demands of training and competition, the availability of essential micronutrients may be compromised.[34]

Among these nutrients, iron and vitamin D as discussed earlier appear to be among the most commonly reported deficiencies in female football players. These deficiencies may adversely affect physiological function, recovery, and performance. Additional factors may further influence micronutrient status in female football players. Dietary restriction, limited nutrition education, and restricted access to sports nutrition support may contribute to inadequate micronutrient intake in some athletic populations.[35]

Furthermore, low energy availability associated with Relative Energy Deficiency in Sport (RED-S) may exacerbate micronutrient deficiencies by reducing dietary intake and impairing physiological adaptation to training.[12]

Therefore, monitoring micronutrient status particularly iron and vitamin D has become an important component of athlete health management. Regular nutritional assessment and targeted screening may help identify at-risk athletes and facilitate early intervention. Nutritional strategies such as dietary counseling, optimized meal planning, and supplementation, when necessary, may help maintain adequate micronutrient status and support performance, recovery, and long-term athlete health.[36] Table I summarizes key micronutrients relevant to physiological function and athletic performance in female football players.

Table I: Key micronutrients relevant to physiological function and athletic performance in female football players

Micronutrient	Primary Physiological Role	Causes of Deficiency in Athletes	Potential Performance Effects
Iron	Hemoglobin synthesis, oxygen transport, mitochondrial energy metabolism	Menstrual blood loss, exercise -induced hemolysis, sweat loss, inadequate dietary intake	Reduced aerobic capacity, fatigue, impaired endurance performance
Vitamin D	Calcium regulation, bone mineralization, skeletal muscle function	Limited sunlight exposure, indoor training, inadequate dietary intake	Reduced muscle strength, increased risk of stress fractures
Calcium	Bone health, neuromuscular function, muscle contraction	Low dietary intake, low energy availability	Increased risk of bone injury, impaired muscle function
Folate / Vitamin B12	Red blood cell production, DNA synthesis	Inadequate intake, restrictive diets	Anemia, reduced endurance capacity
Magnesium	Muscle contraction, energy metabolism, neuromuscular transmission	High sweat loss, insufficient intake	Muscle cramps, fatigue, impaired recovery

Physiological and Environmental Determinants

Micronutrient status in athletes is influenced by a complex interaction of physiological, environmental, and lifestyle factors. In female athletes, these determinants may be particularly important because sex-specific biological characteristics and intensive training demands can influence nutrient metabolism and availability. Hormonal fluctuations associated with the menstrual cycle, increased metabolic demands during training, and variations in energy availability may affect micronutrient balance in female athletes. For example, menstrual-related hormonal changes may influence nutrient requirements and iron metabolism, potentially increasing the risk of micronutrient insufficiency.[37]

Low energy availability is another important determinant of micronutrient status in athletes. When energy intake does not meet the metabolic demands of training and normal physiological function, athletes may develop Relative Energy Deficiency in Sport (RED-S). This condition has been associated with hormonal disturbances, impaired bone health, and nutritional deficiencies. Reduced dietary intake and altered metabolism under conditions of low energy availability may increase the risk of deficiencies in micronutrients such as iron, calcium, and vitamin D.[38,39]

Environmental factors can also influence micronutrient status. Geographic location, seasonal variation, and training environment affect exposure to ultraviolet B radiation required for endogenous vitamin D synthesis. Athletes who train indoors or live in higher latitudes may therefore have limited sunlight exposure and reduced vitamin D production. Vitamin D insufficiency has been reported even among outdoor athletes, suggesting that inadequate intake or increased physiological utilization may contribute to suboptimal levels.[40,41]

Training intensity and exercise-related physiological stress may further influence micronutrient balance. High training volumes can increase nutrient turnover and losses through sweat, hemolysis, and inflammatory responses, which may contribute to reductions in iron stores and other micronutrients important for energy metabolism and muscle function. Consequently, athletes participating in high-intensity sports such as football may have greater micronutrient requirements than the general population.[18]

Dietary practices and nutrition knowledge also influence micronutrient status. Athletes attempting to maintain a lean body composition or following restrictive diets may inadvertently reduce intake of micronutrient-rich foods. Limited access to sports nutrition education or professional dietary guidance may further contribute to inadequate nutrient intake. Understanding these determinants is therefore essential for identifying at-risk athletes and developing nutritional strategies that support performance and long-term athlete health.[42]

Discussion

Performance and Health Implications

Micronutrient deficiencies can adversely affect both athletic performance and overall health in female athletes. Adequate availability of vitamins and minerals is essential for physiological processes including energy metabolism, oxygen transport, musculoskeletal integrity, and immune function. When micronutrient status is inadequate, these systems may be compromised, potentially impairing training adaptation, recovery, and competitive performance.[43,44]

Iron deficiency is among the most clinically relevant micronutrient concerns in athletes. As iron is required for hemoglobin synthesis and oxygen transport, reduced iron stores can limit oxygen delivery to working muscles, thereby decreasing aerobic capacity, endurance performance, and fatigue resistance. Even without anemia, low iron availability may impair mitochondrial enzyme activity and oxidative metabolism, contributing to reduced exercise tolerance and increased perceived fatigue during intense or prolonged activity.[6,18]

Vitamin D deficiency may also negatively influence musculoskeletal health and injury risk. Vitamin D plays an important role in calcium regulation, bone mineralization, and skeletal muscle function. Inadequate vitamin D status has been associated with reduced muscle strength, impaired neuromuscular function, and a higher risk of bone stress injuries such as stress fractures, which may disrupt training and competition.[9,29,45]

Micronutrient inadequacies may further affect broader aspects of athlete health. Suboptimal micronutrient intake can impair immune function and increase susceptibility to illness during periods of heavy training or competition. In addition, deficiencies in key nutrients may compromise recovery by limiting tissue repair and metabolic adaptation following exercise.[46,47]

In female athletes, these consequences may be amplified when micronutrient deficiencies coexist with low energy availability. Relative Energy Deficiency in Sport (RED-S) has been linked to endocrine disturbances, reduced bone mineral density, metabolic alterations, and impaired immune function, all of which may negatively affect both performance and long-term health.[48,49] The relationship between low energy availability, RED-S, micronutrient deficiencies, and their impact on athlete health and performance is illustrated in Figure 2.

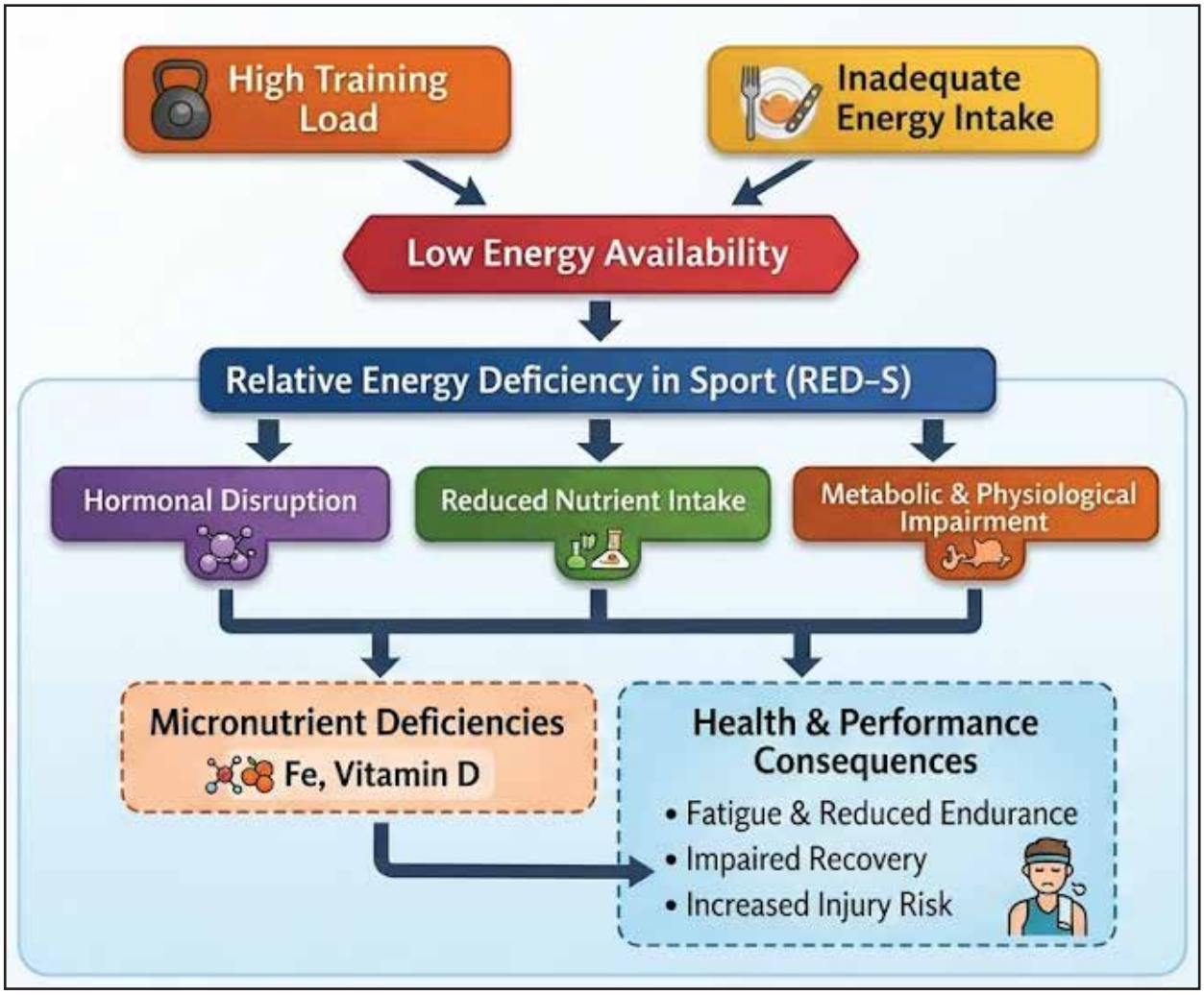

Figure 2: Conceptual pathway linking low energy availability, Relative Energy Deficiency in Sport (RED-S), and micronutrient deficiencies in female football players

Overall, maintaining adequate micronutrient status is essential for optimizing performance, reducing injury risk, and preserving long-term athlete health. Regular nutritional assessment and targeted dietary strategies may therefore play an important role in supporting athlete health and performance.

Implications for Sports Medicine Practice

The growing recognition of micronutrient deficiencies among female athletes highlights the importance of integrating nutritional assessment into routine sports medicine practice. Sports physicians, physiotherapists, and other healthcare professionals play an important role in identifying nutritional factors that may influence performance, recovery, and risk of injury. Given the high prevalence of deficiencies such as iron and vitamin D in female athletes, proactive screening and early intervention may help prevent adverse health and performance outcomes. Regular monitoring of micronutrient status is particularly important for athletes at increased risk of deficiency. Female athletes participating in endurance or high-intensity intermittent sports such as football may experience elevated physiological demands that increase micronutrient requirements. Screening may include laboratory assessments such as serum ferritin, hemoglobin, and transferrin saturation for iron status, and serum 25-hydroxyvitamin D for vitamin D status. Table II summarizes recommended screening strategies for detecting micronutrient deficiencies and guiding nutritional management in female football players. Early detection enables timely nutritional interventions, including dietary modification and supplementation when clinically indicated.[2,19,36]

Table II: Suggested screening approaches for identifying micronutrient deficiencies in female football players.

Nutrient	Screening Test	Risk Indicators	Recommended Management
Iron	Serum ferritin, hemoglobin, transferrin saturation	Fatigue, reduced endurance, low ferritin, heavy menstrual loss	Dietary counseling, iron -rich foods, oral iron supplementation if required
Vitamin D	Serum 25 - hydroxyvitamin D	Bone pain, muscle weakness, stress fractures	Sunlight exposure, vitamin D supplementation
Calcium	Dietary intake assessment, serum calcium if needed	Bone stress injuries, low bone mineral density	Increased dietary intake, supplementation if necessary
Folate / Vitamin B12	Serum folate and vitamin B12	Macrocytic anemia, fatigue	Dietary modification or supplementation
Magnesium	Serum magnesium (limited sensitivity)	Muscle cramps, fatigue	Dietary optimization or supplementation

Comprehensive nutritional evaluation should also be incorporated into athlete health assessments. Factors such as dietary habits, energy availability, menstrual history, and training load can influence micronutrient status in female athletes. Collaboration between sports medicine practitioners and sports dietitians is therefore important to provide individualized nutritional guidance that supports both health and performance.[50,51]

Nutrition education programs may further help prevent deficiencies, as athletes may have limited knowledge regarding optimal dietary practices during intensive training. In addition, the recognition of Relative Energy Deficiency in Sport (RED-S) highlights the need for multidisciplinary management involving physicians, dietitians, coaches, and sports scientists to restore energy balance and correct associated nutritional deficiencies.[12,52]

Overall, integrating nutrition-focused assessment and management into sports medicine practice may improve athlete health, reduce injury risk, and support long-term athletic performance in female football players.

Research Gaps and Future Directions

Despite growing awareness of the importance of micronutrients in athletic performance, important gaps remain in the literature regarding micronutrient deficiencies among female football players. Much of the available research has focused on general athletic populations or endurance athletes, while sport-specific evidence in female football players remains limited. Given the unique physiological and performance demands of football, further targeted investigations are needed to better understand the nutritional requirements of this population.[53]

One key gap concerns the prevalence and determinants of micronutrient deficiencies across different competitive levels and geographic regions. Although deficiencies such as iron and vitamin D have frequently been reported in athletes, findings remain heterogeneous because of differences in study design, diagnostic criteria, and assessment methods.[4,10] Standardized biochemical markers and diagnostic thresholds are therefore needed to improve comparability between studies and better estimate the true prevalence of deficiencies among female football players.[10,19]

Another important research priority is understanding the interaction between micronutrient status, energy availability, and athletic performance. Evidence suggests that micronutrient deficiencies may coexist with low energy availability and Relative Energy Deficiency in Sport (RED-S), which can negatively affect metabolic function, bone health, and endocrine regulation.[12,54] Longitudinal and interventional studies are required to clarify how these factors influence training adaptation, injury risk, and recovery in female football players.

There is also limited evidence from low- and middle-income countries. Although women's football has expanded considerably in Bangladesh in recent years, scientific data regarding dietary practices and micronutrient status among Bangladeshi female football players remain scarce.[55] Socioeconomic constraints, cultural dietary patterns, and limited access to sports nutrition expertise may influence nutritional intake in this population. Future research should also examine the effectiveness of nutritional interventions such as dietary education, supplementation strategies, and routine screening programs for micronutrient deficiencies. Implementing well-designed prospective and interventional studies could provide stronger evidence to guide nutritional strategies aimed at improving athlete health and performance.[56]

Addressing these research gaps will help improve understanding of the role of micronutrients in athlete health and may support the development of evidence-based nutritional guidelines for female football players worldwide.

Conclusion

Micronutrient status is crucial for maintaining physiological function, athletic performance, and long-term health in female football players. Iron and vitamin D stand out particularly important due to their key roles in oxygen transport, energy metabolism, bone health, and muscle function. Research indicated that deficiencies in these nutrients are fairly common among female athletes and may undesirably affect endurance capacity, recovery, and injury risk. Female football players may face heightened risk due to intense training demands, menstrual blood loss, and potential low energy availability associated with Relative Energy Deficiency in Sport (RED-S). More research particularly in low- and middle-income countries like Bangladesh is needed to better understand micronutrient status and guide evidence-based nutritional strategies.

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