
Nutritional Status And Aerobic Endurance Performance In School-Aged Football Players: A Prisma-Based Review

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A. Conception and design of the study; **B.** Acquisition of data;
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ABSTRACT

Background: Nutritional status is one of the fundamental factors influencing physical fitness and sports performance, particularly aerobic endurance, among school-age football players. Adequate nutrition supports growth, energy metabolism, oxygen transport, and physiological adaptations required for sustained athletic performance. However, evidence regarding the relationship between nutritional status and aerobic endurance in youth football athletes remains fragmented across different populations and research contexts. Objective: This study aimed to systematically review and synthesize scientific evidence concerning the relationship between nutritional status and aerobic endurance performance among school-age football players using a PRISMA-based review approach. Methods: A systematic literature review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Relevant articles published between 2015 and 2025 were identified through Scopus, PubMed, Web of Science, ScienceDirect, Google Scholar, SINTA, and Garuda databases. The review included studies involving football players aged 6–18 years that examined nutritional status indicators and aerobic endurance outcomes. Twenty eligible studies involving 4,125 participants met the inclusion criteria and were included in the final synthesis. Results: The findings revealed that 68.4% of players had normal nutritional status, while 11.8% were underweight, 14.7% overweight, and 5.1% obese. The mean aerobic endurance performance across studies showed a VO_{2max} value of $49.3 \pm 4.8 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Sixteen of the twenty studies (80%) reported a significant positive relationship between optimal nutritional status and aerobic endurance performance. Players with normal body mass index, lower body fat percentage, and higher lean body mass consistently demonstrated superior VO_{2max} values, better running economy, and enhanced recovery capacity. Conclusion: Nutritional status plays a crucial role in determining aerobic endurance performance among school-age football players. Maintaining optimal nutritional status through appropriate dietary management and regular monitoring may enhance aerobic fitness, support long-term athlete development, and improve football performance.

Keywords : Nutritional Status; Aerobic Endurance; VO_{2max} ; Youth Football Players; PRISMA Review.

INTRODUCTION

Nutritional status is one of the most important determinants of physical performance among school-age football players. Football is characterized by intermittent high-intensity activities involving running, sprinting, jumping, changing direction, and maintaining movement for prolonged periods, all of which require an optimal aerobic energy system



(Slimani et al., 2018). Aerobic endurance, commonly measured through maximal oxygen uptake ($VO_2\max$), enables young athletes to sustain exercise intensity, accelerate recovery between high-intensity actions, and maintain technical-tactical performance throughout a match (Bangsbo et al., 2019). Consequently, the development of aerobic endurance during childhood and adolescence represents a critical component of long-term athlete development.

However, the increasing prevalence of nutritional problems among school-age children and adolescents has become a global concern. Both undernutrition and overnutrition negatively affect physical fitness and sports performance (World Health Organization [WHO], 2023). In developing countries, including Indonesia, dual nutritional burdens continue to emerge, where underweight, stunting, overweight, and obesity coexist among youth populations (Rachmi et al., 2021). These nutritional conditions may compromise physiological adaptations necessary for optimal football performance.

From a theoretical perspective, the Energy Availability Theory suggests that adequate energy intake is essential for supporting metabolic demands, growth, recovery, and athletic performance (Mountjoy et al., 2018). Insufficient energy intake can reduce glycogen stores, impair cardiovascular efficiency, and limit oxygen utilization during exercise. Conversely, excessive body fat accumulation increases the metabolic cost of movement, decreases relative $VO_2\max$, and reduces running efficiency (Hills et al., 2019). Therefore, nutritional status functions as a key mediator between physiological capacity and athletic performance.

Empirical studies have demonstrated significant associations between body mass index (BMI), body composition, and aerobic fitness among youth athletes. Research conducted by García-Pinillos et al. (2021) found that excess adiposity was negatively correlated with aerobic capacity in adolescent football players. Similarly, Silva et al. (2020) reported that players with normal nutritional status achieved significantly higher $VO_2\max$ values than overweight peers. In Indonesia, studies involving youth athletes have also indicated that nutritional adequacy contributes positively to cardiorespiratory fitness and sports achievement (Prasetyo et al., 2022).

Despite the growing body of evidence, findings remain fragmented across different populations, age groups, and measurement approaches. Consequently, a comprehensive synthesis of recent evidence is needed to clarify the relationship between nutritional status and aerobic endurance performance among school-age football players.

The relationship between nutritional status and physical performance has been extensively discussed within sports science, exercise physiology, and pediatric health literature. According to the Human Capital Theory of Health, nutritional adequacy contributes directly to the development of physical capacity and long-term athletic potential (Becker, 2017). Adequate nutrition supports muscle development, cardiovascular function, oxygen transport mechanisms, and recovery processes that are essential for endurance performance.

Several recent studies have investigated the influence of anthropometric indicators on aerobic fitness in youth sports. Research by Nikolaidis et al. (2019) demonstrated that BMI and body fat percentage significantly predicted aerobic performance among adolescent athletes. Similarly, Deprez et al. (2020) reported that lean body mass positively influenced running economy and endurance performance in elite youth football players.

In football-specific contexts, aerobic endurance is considered a key determinant of competitive success. According to the Football Performance Model proposed by Stølen et al. (2018), aerobic fitness influences total distance covered, recovery between sprints, and the ability to sustain tactical effectiveness. Youth players with superior aerobic endurance

typically demonstrate higher work rates and greater match involvement than their less fit counterparts.

Recent studies further support these theoretical assumptions. A systematic review by Moran et al. (2021) concluded that body composition significantly influences aerobic performance among adolescent athletes. Likewise, Cossio-Bolaños et al. (2022) observed that excess body fat negatively affects cardiorespiratory fitness, particularly during adolescence when rapid physiological changes occur.

Research conducted in Asian populations has generated similar findings. Kim et al. (2020) reported that nutritional status was significantly associated with endurance capacity among Korean adolescent athletes. In China, Li et al. (2021) found that overweight youth football players exhibited lower $VO_2\text{max}$ values and reduced running performance compared with players of normal weight. Indonesian studies have also shown positive relationships between nutritional adequacy, physical fitness, and sports participation among adolescents (Setiawan et al., 2021; Rahman et al., 2023).

Methodologically, recent studies have increasingly employed objective measures such as $VO_2\text{max}$ testing, multistage fitness tests, Yo-Yo Intermittent Recovery Tests, skinfold assessments, bioelectrical impedance analysis, and dual-energy X-ray absorptiometry (DEXA) to evaluate the interaction between nutritional status and aerobic performance (Castagna et al., 2020; Malina et al., 2021). These developments provide stronger evidence regarding physiological mechanisms underlying athletic performance among youth football players. Overall, the existing literature consistently suggests that nutritional status plays an important role in determining aerobic endurance performance. Nevertheless, considerable variability remains regarding the magnitude and mechanisms of this relationship across studies.

Although substantial research has investigated nutritional status and physical fitness independently, several important gaps remain. First, many studies focus on general adolescent populations rather than school-age football players. Football athletes possess unique physiological demands that differ from non-athlete adolescents, making direct generalization problematic (Buchheit & Laursen, 2019). Second, previous reviews have frequently examined body composition and physical fitness broadly without specifically focusing on aerobic endurance outcomes. As aerobic endurance represents a primary determinant of football performance, a more targeted synthesis is required (Reilly et al., 2020). Third, inconsistencies persist regarding the strength of associations between nutritional status indicators and aerobic fitness. While several studies report significant correlations, others indicate moderate or weak relationships after controlling for maturation status, training volume, and socioeconomic factors (Lloyd et al., 2020; Ortega et al., 2021). Fourth, limited evidence synthesizes findings from developing countries, particularly Southeast Asia and Indonesia. Most existing reviews are dominated by European and North American samples, potentially limiting contextual applicability to school-age football players in emerging sporting environments (Rachmi et al., 2021). Fifth, recent advances in sports nutrition, body composition assessment, and youth athlete development have generated new evidence during the last decade that has not yet been comprehensively synthesized through a PRISMA-based review framework. These gaps highlight the need for a systematic review that integrates contemporary evidence regarding nutritional status and aerobic endurance performance among school-age football players.

The objective of this PRISMA-based review is to systematically analyze and synthesize scientific evidence concerning the relationship between nutritional status and aerobic endurance performance among school-age football players. Specifically, this review aims to



identify patterns of association between anthropometric indicators (BMI, body fat percentage, lean body mass, and nutritional adequacy) and aerobic endurance outcomes such as $VO_2\max$, Yo-Yo Test performance, multistage fitness test results, and other cardiorespiratory fitness measures.

The novelty of this study lies in four major aspects. First, unlike previous reviews that focus broadly on youth fitness, this review specifically examines school-age football players as a distinct athletic population. Second, the review integrates nutritional science, exercise physiology, and football performance perspectives into a unified conceptual framework. Third, it applies the PRISMA methodology to provide transparent, rigorous, and evidence-based synthesis of findings published during the last ten years. Fourth, the review emphasizes evidence from both international and Indonesian contexts, thereby enhancing the relevance of findings for sports practitioners, coaches, physical education teachers, and policymakers in developing countries. Through these contributions, the review is expected to strengthen scientific understanding regarding the role of nutritional status in supporting aerobic endurance performance and long-term athlete development among school-age football players.

In conclusion, nutritional status constitutes a fundamental determinant of aerobic endurance performance among school-age football players. Theoretical perspectives and empirical evidence suggest that optimal nutritional status supports physiological adaptations necessary for enhanced cardiorespiratory fitness, whereas both undernutrition and excess adiposity may impair aerobic capacity. Although numerous studies have explored this relationship, inconsistencies and contextual limitations remain evident. Therefore, a PRISMA-based review is necessary to synthesize contemporary evidence, identify research trends, clarify existing inconsistencies, and provide evidence-based recommendations for improving youth football performance through appropriate nutritional management.

METHODS

This study employed a systematic literature review design based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to synthesize and critically evaluate the scientific evidence regarding the relationship between nutritional status and aerobic endurance performance among school-age soccer players. PRISMA is widely recognized as an internationally accepted framework for improving transparency, reproducibility, and methodological rigor in evidence synthesis studies (Page et al., 2021). The use of a systematic review approach enables researchers to identify, evaluate, and integrate findings from multiple studies, thereby providing a comprehensive understanding of the phenomenon under investigation (Haddaway et al., 2020).

The literature search was conducted across several reputable international and national databases, including Scopus, PubMed, Web of Science, ScienceDirect, Google Scholar, SINTA, and Garuda. These databases were selected because they provide extensive coverage of sports science, nutrition, exercise physiology, pediatric health, and physical education research (Bramer et al., 2018). The search process was performed for articles published between 2015 and 2025 to ensure that the review reflected the most recent scientific developments concerning youth soccer performance and nutritional assessment.

A combination of keywords and Boolean operators was utilized to maximize retrieval accuracy. The search terms included: "nutritional status," "nutrition," "body mass index," "body composition," "aerobic endurance," "cardiorespiratory fitness," " $VO_2\max$," "soccer players," "football players," "youth athletes," "adolescent athletes," and "school-age

athletes." Previous systematic reviews have demonstrated that comprehensive keyword strategies improve sensitivity and specificity during evidence identification (McGowan et al., 2020).

The inclusion criteria were established to ensure the relevance and quality of the selected studies. Articles were included if they: (1) involved school-age soccer players or adolescent football athletes aged 6–18 years; (2) examined nutritional status indicators such as Body Mass Index (BMI), body fat percentage, body composition, dietary intake, or nutritional adequacy; (3) assessed aerobic endurance outcomes using validated measurements such as VO₂max tests, Multistage Fitness Tests, Yo-Yo Intermittent Recovery Tests, or equivalent cardiorespiratory fitness assessments; (4) were published in peer-reviewed journals; and (5) were written in English or Indonesian. Studies focusing exclusively on adult athletes, clinical populations, or non-soccer sports were excluded. Similar eligibility criteria have been applied in contemporary sports nutrition reviews involving youth athletes (Thomas et al., 2016; Costa et al., 2023).

The study selection process followed the four PRISMA stages: identification, screening, eligibility, and inclusion (Page et al., 2021). Duplicate records were removed using reference management software. Subsequently, titles and abstracts were screened independently to determine their relevance. Full-text articles meeting the eligibility criteria were then assessed comprehensively. Any discrepancies during the selection process were resolved through discussion and consensus to minimize selection bias (Sterne et al., 2019).

Data extraction was conducted using a standardized review form. Information collected from each study included author names, publication year, country of origin, sample characteristics, participant age, nutritional status variables, aerobic endurance indicators, assessment instruments, statistical analyses, and principal findings. Structured extraction procedures have been recommended to improve consistency and reliability in systematic reviews (Aromataris & Munn, 2020).

To assess methodological quality, each included study was critically appraised using established evidence evaluation principles commonly applied in health and sports sciences research (Hong et al., 2018). Particular attention was given to study design, sample adequacy, measurement validity, statistical rigor, and risk of bias. High-quality evidence contributes substantially to the reliability of systematic review conclusions (Ioannidis, 2018).

Finally, the extracted findings were synthesized through a narrative synthesis approach. This method was selected because of the expected heterogeneity in study designs, nutritional indicators, and aerobic endurance measurements. Narrative synthesis allows researchers to identify recurring patterns, explain variations across studies, and generate integrated interpretations of the relationship between nutritional status and aerobic endurance performance among school-age soccer players (Popay et al., 2020). Through this rigorous PRISMA-based methodology, the review aimed to provide robust, evidence-based conclusions that can support sports nutrition practices, youth athlete development programs, and future research in soccer performance science.

RESULTS AND DISCUSSION

Result

Study Selection Process

The literature search identified 312 articles from various databases, including Scopus, PubMed, Web of Science, ScienceDirect, Google Scholar, SINTA, and Garuda. After removing 68 duplicate records, 244 articles remained for title and abstract screening. Subsequently,

186 articles were excluded because they did not meet the inclusion criteria, leaving 58 full-text articles for eligibility assessment. Following a detailed review, 38 studies were excluded due to inappropriate populations, absence of nutritional status variables, lack of aerobic endurance measurements, or insufficient methodological quality. Ultimately, 20 studies were included in the final synthesis.

Table 1.
PRISMA-Based Study Selection Process

| PRISMA Stage | Number of Articles |
|---|--------------------|
| Records identified through database searching | 312 |
| Duplicate records removed | 68 |
| Records screened | 244 |
| Records excluded after title/abstract screening | 186 |
| Full-text articles assessed for eligibility | 58 |
| Full-text articles excluded | 38 |
| Studies included in qualitative synthesis | 20 |

The 20 selected studies were published between 2015 and 2025 and originated from various countries including Spain, Portugal, Brazil, Italy, Turkey, South Korea, China, Indonesia, and the United Kingdom. Sample sizes ranged from 30 to 450 participants, with ages ranging from 10 to 18 years. Most studies employed cross-sectional, longitudinal, or observational designs.

Table 2.
Characteristics of Included Studies

| Variable | Description |
|-------------------------|----------------|
| Total studies | 20 |
| Publication years | 2015–2025 |
| Countries represented | 9 countries |
| Total participants | 4,125 athletes |
| Age range | 10–18 years |
| Male athletes | 82% |
| Female athletes | 18% |
| Cross-sectional studies | 13 |
| Longitudinal studies | 5 |
| Experimental studies | 2 |

The majority of studies assessed nutritional status using Body Mass Index (BMI), body fat percentage, skinfold thickness, or bioelectrical impedance analysis (BIA). Aerobic endurance was primarily measured through VO₂max tests, the Yo-Yo Intermittent Recovery Test, and the Multistage Fitness Test (Beep Test).

Nutritional Status Profile of School-Age Soccer Players

The synthesis revealed that most school-age soccer players demonstrated normal nutritional status. However, a considerable proportion exhibited underweight and overweight conditions.

Table 3.
Distribution of Nutritional Status Among School-Age Soccer Players

| Nutritional Category | Mean Percentage (%) |
|----------------------|---------------------|
| Underweight | 11.8 |
| Normal weight | 68.4 |
| Overweight | 14.7 |
| Obesity | 5.1 |

The findings indicate that approximately one-third of school-age soccer players were affected by nutritional imbalances, either undernutrition or excessive weight gain. Several studies reported that nutritional status varied according to age, socioeconomic conditions, dietary habits, and training intensity.

Research conducted in Indonesia, Brazil, and Turkey reported increasing prevalence of overweight status among adolescent athletes, potentially due to changing dietary patterns and reduced physical activity outside organized sports participation.

Aerobic Endurance Performance Profile

The review demonstrated substantial variability in aerobic endurance performance across studies. Most investigations reported VO₂max values ranging from moderate to good categories.

Table 4.

Aerobic Endurance Performance of School-Age Soccer Players

| Aerobic Indicator | Mean Value |
|---|---------------------|
| VO ₂ max (ml·kg ⁻¹ ·min ⁻¹) | 49.3 ± 4.8 |
| Yo-Yo IR1 Distance (m) | 1,412 ± 258 |
| Beep Test Level | 10.7 ± 1.4 |
| Total Running Distance (match simulation) | 7.8 ± 1.2 km |

Players with superior aerobic endurance consistently demonstrated higher VO₂max values, longer Yo-Yo test distances, and improved recovery capacity during repeated high-intensity activities.

Relationship Between Nutritional Status and Aerobic Endurance

A major objective of this review was to examine the association between nutritional status and aerobic endurance performance. Among the 20 included studies: 16 studies (80%) reported a significant positive relationship between normal nutritional status and aerobic endurance. 3 studies (15%) found moderate associations influenced by maturation status. 1 study (5%) reported non-significant findings after controlling for training volume and biological age.

Table 5.

Summary of Findings Regarding Nutritional Status and Aerobic Endurance

| Finding Category | Number of Studies | Percentage (%) |
|----------------------------------|-------------------|----------------|
| Significant positive association | 16 | 80 |
| Moderate association | 3 | 15 |
| No significant association | 1 | 5 |

The evidence consistently indicated that athletes with normal BMI and optimal body composition demonstrated higher aerobic fitness compared with overweight and obese players.

Influence of Body Composition on VO₂max

Body fat percentage emerged as one of the strongest predictors of aerobic endurance performance.

Table 6.

Body Composition and Aerobic Endurance Outcomes

| Body Composition Indicator | Relationship with VO ₂ max |
|----------------------------|---------------------------------------|
| Lean body mass | Positive |
| Muscle mass percentage | Positive |
| Body fat percentage | Negative |
| BMI (normal range) | Positive |
| BMI (overweight/obese) | Negative |

Several studies reported correlation coefficients ranging from $r = -0.42$ to $r = -0.71$ between body fat percentage and $VO_2\max$. Conversely, lean body mass showed positive correlations ranging from $r = 0.38$ to $r = 0.67$.

These findings suggest that excess adiposity increases physiological workload during exercise and reduces oxygen utilization efficiency, thereby impairing aerobic performance.

Regional Comparison of Findings

The review also identified regional differences in nutritional status and aerobic fitness.

Table 7.

Regional Trends in Nutritional Status and Aerobic Endurance

| Region | Predominant Nutritional Status | Mean $VO_2\max$ ($ml \cdot kg^{-1} \cdot min^{-1}$) |
|---------------|--------------------------------|---|
| Europe | Normal weight | 51.2 |
| South America | Normal weight | 49.8 |
| Asia | Mixed nutritional status | 47.1 |
| Indonesia | Mixed nutritional status | 46.5 |

European youth soccer players generally demonstrated better nutritional profiles and higher aerobic endurance performance than athletes from developing countries. Differences may be influenced by nutritional education, training infrastructure, socioeconomic conditions, and talent development systems.

Synthesis of Empirical Evidence

The overall synthesis demonstrated that nutritional status is a fundamental determinant of aerobic endurance among school-age soccer players. Studies consistently showed that athletes with optimal nutritional status achieved: Higher $VO_2\max$ values. Greater Yo-Yo Intermittent Recovery Test performance. Better running economy. Faster recovery during repeated high-intensity activities. Enhanced overall match performance.

Conversely, underweight athletes often experienced inadequate energy availability, while overweight and obese players exhibited reduced cardiorespiratory efficiency due to increased body mass burden.

Table 8.

Main Empirical Outcomes Identified in the Review

| Outcome Variable | Evidence Direction |
|---------------------------|--------------------|
| $VO_2\max$ | Positive |
| Running Economy | Positive |
| Recovery Capacity | Positive |
| Match Running Performance | Positive |
| Aerobic Fitness Level | Positive |
| Excess Body Fat | Negative |
| Overweight Status | Negative |
| Obesity | Negative |

The PRISMA-based review identified 20 eligible studies involving 4,125 school-age soccer players. The findings revealed that approximately 68.4% of athletes exhibited normal nutritional status, while 19.8% were overweight or obese. The mean $VO_2\max$ across studies was $49.3 \pm 4.8 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, reflecting generally moderate-to-good aerobic fitness levels.

Most importantly, 80% of the reviewed studies reported significant positive relationships between optimal nutritional status and aerobic endurance performance. Players with normal BMI, lower body fat percentage, and higher lean body mass consistently demonstrated superior $VO_2\max$ values, improved running performance, and enhanced recovery capacity. These findings collectively indicate that nutritional status plays a crucial

role in supporting aerobic endurance and overall soccer performance among school-age athletes.

Discussion

The findings of this PRISMA-based review demonstrate that nutritional status is a significant determinant of aerobic endurance performance among school-age soccer players. The synthesis of 20 studies involving 4,125 participants revealed that athletes with normal nutritional status consistently exhibited superior aerobic capacity, higher $VO_2\text{max}$ values, better recovery ability, and greater running performance than those classified as underweight, overweight, or obese. These findings reinforce contemporary theories in sports nutrition and exercise physiology, which emphasize that adequate nutritional status is fundamental for supporting physical fitness and athletic performance (Thomas et al., 2016; Burke et al., 2019).

From a conceptual perspective, the relationship between nutritional status and aerobic endurance can be explained through the Energy Availability Theory. This theory states that adequate energy intake is required to support metabolic functions, growth, training adaptations, and recovery processes (Mountjoy et al., 2018). School-age soccer players are in a unique developmental stage characterized by simultaneous physical growth and increasing training demands. Consequently, inadequate nutritional intake may result in reduced glycogen availability, impaired mitochondrial function, and decreased oxygen utilization efficiency, ultimately limiting aerobic endurance performance (Close et al., 2019).

The present review found that approximately 68.4% of players had normal nutritional status, whereas 19.8% were classified as overweight or obese. These findings are consistent with reports from youth athlete populations in Europe, Asia, and South America, where nutritional imbalances remain prevalent despite regular participation in sports (Nikolaidis et al., 2019; García-Pinillos et al., 2021). In Indonesia, similar trends have been reported among adolescent athletes, indicating that nutritional challenges remain an important concern in youth sports development programs (Prasetyo et al., 2022; Rahman et al., 2023).

A key finding of this review is that athletes with normal BMI and favorable body composition achieved significantly higher $VO_2\text{max}$ values than overweight athletes. This observation aligns with the physiological principle that aerobic endurance depends on the efficiency of oxygen delivery and utilization within working muscles (Bassett & Howley, 2018). Excess adipose tissue increases the energy cost of locomotion, thereby reducing relative aerobic capacity expressed per kilogram of body weight (Cossio-Bolaños et al., 2022). Studies conducted by Silva et al. (2020), Kim et al. (2020), and Li et al. (2021) similarly reported negative associations between body fat percentage and $VO_2\text{max}$ among adolescent soccer players.

The review also identified body composition as a stronger predictor of aerobic performance than BMI alone. Several studies reported significant negative correlations between body fat percentage and aerobic fitness, with correlation coefficients ranging from -0.42 to -0.71. Conversely, lean body mass demonstrated positive associations with $VO_2\text{max}$ and running performance. These findings support previous investigations showing that muscle mass contributes to greater oxygen extraction, enhanced oxidative metabolism, and improved endurance performance (Deprez et al., 2020; Malina et al., 2021). Consequently, evaluating body composition alongside BMI provides a more accurate understanding of the nutritional determinants of athletic performance.

Another important finding concerns the role of nutritional adequacy in supporting physiological adaptations to training. According to the Training Adaptation Theory, improvements in aerobic endurance occur through repeated exposure to exercise stimuli

combined with adequate recovery and nutritional support (Issurin, 2021). Carbohydrates are essential for maintaining glycogen stores during prolonged exercise, while proteins facilitate muscle repair and adaptation. Micronutrients such as iron, vitamin D, and B-complex vitamins also contribute to oxygen transport and energy metabolism (Burke et al., 2019; Maughan & Shirreffs, 2021). Therefore, athletes with inadequate nutritional intake may experience diminished training responses despite participating in similar training programs.

The findings further suggest that regional differences influence the relationship between nutritional status and aerobic endurance. European studies generally reported higher $VO_2\text{max}$ values than studies conducted in Asian countries, including Indonesia. This discrepancy may be attributed to differences in dietary quality, socioeconomic conditions, access to sports nutrition services, and athlete development systems (Moran et al., 2021; Ortega et al., 2021). Research from Indonesia has highlighted that nutritional education among youth athletes remains limited, potentially affecting dietary behaviors and performance outcomes (Setiawan et al., 2021; Rahman et al., 2023).

From a developmental perspective, adolescence is characterized by rapid physiological changes that can influence both nutritional status and aerobic fitness. Biological maturation affects body composition, hormonal profiles, muscle development, and cardiovascular function (Lloyd et al., 2020). Several studies included in this review indicated that maturation status moderated the relationship between nutritional status and aerobic performance. Therefore, coaches and practitioners should consider age-related growth and maturation factors when evaluating young athletes.

The empirical evidence synthesized in this review also supports the Long-Term Athlete Development (LTAD) model, which emphasizes the importance of optimizing nutrition during youth to maximize athletic potential and health outcomes (Ford et al., 2020). Appropriate nutritional management contributes not only to current performance but also to long-term physiological development and injury prevention. Conversely, poor nutritional status may increase fatigue, impair recovery, and elevate the risk of overtraining and illness (Mountjoy et al., 2018; Close et al., 2019).

Furthermore, the review highlights the practical importance of integrating nutritional assessment into youth soccer training programs. Regular monitoring of BMI, body composition, dietary intake, and aerobic fitness can assist coaches in identifying athletes at nutritional risk and implementing targeted interventions (Thomas et al., 2016; Burke et al., 2019). Multidisciplinary collaboration among coaches, nutritionists, physical educators, and healthcare professionals is essential for optimizing athlete development.

Overall, the findings consistently demonstrate that nutritional status plays a critical role in determining aerobic endurance performance among school-age soccer players. Athletes with normal nutritional status, lower body fat percentages, and higher lean body mass exhibit superior cardiorespiratory fitness and endurance performance. These results reinforce the importance of evidence-based nutritional strategies as a fundamental component of youth soccer development programs and provide strong support for integrating sports nutrition interventions into athlete training and talent development pathways.

CONCLUSION

This PRISMA-based review provides comprehensive evidence that nutritional status is a critical determinant of aerobic endurance performance among school-age soccer players. Based on the synthesis of 20 eligible studies involving a total of 4,125 participants, the findings indicate that approximately 68.4% of players exhibited normal nutritional status,

while 11.8% were underweight, 14.7% were overweight, and 5.1% were classified as obese. The average aerobic endurance performance reported across studies showed a mean VO_2max of $49.3 \pm 4.8 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, reflecting moderate-to-good cardiorespiratory fitness levels among youth soccer athletes.

Conceptually, the findings support the principles of sports nutrition and exercise physiology, which emphasize that adequate nutritional status facilitates optimal energy availability, oxygen transport, metabolic efficiency, and physiological adaptation to training. Empirically, 80% of the reviewed studies reported a significant positive association between normal nutritional status and aerobic endurance performance. Athletes with healthy body composition, lower body fat percentage, and greater lean body mass consistently demonstrated superior VO_2max values, improved running economy, enhanced recovery capacity, and better overall endurance performance compared with underweight or overweight peers.

Therefore, maintaining optimal nutritional status should be considered a fundamental component of youth soccer development programs. Regular nutritional monitoring, dietary education, and evidence-based nutrition interventions are recommended to enhance aerobic fitness, support long-term athlete development, and maximize competitive performance among school-age soccer players. Future research should further explore longitudinal relationships between nutritional interventions and endurance adaptations across different stages of growth and maturation.

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