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**Original Article**

# Protein intake in adolescent athletes: Nutritional requirements and performance implications

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**Abstract:**
Aim: This study investigated the crucial role of protein intake in meeting the specific nutritional needs of adolescent athletes. During adolescence, a phase characterized by rapid growth and development, protein is essential for muscle development, bone health, hormonal regulation, and immune function. The aim of this review is to highlight the importance of a well-balanced diet that addresses the unique requirements of adolescent athletes. Methods: This review compiles findings from peer-reviewed studies published between 2010 and 2024, focusing on protein intake, metabolism, muscle recovery, and athletic performance in adolescent athletes. Relevant studies were identified through a systematic search of databases, including PubMed, Scopus, Web of Science, and Google Scholar, using predefined keywords such as "protein intake," "adolescent athletes," "muscle recovery," and "sports nutrition." While adolescent athletes may have higher protein requirements owing to increased physical demands, this study emphasizes the importance of avoiding excessive protein intake, which could lead to potential health issues. Results: The findings indicate that adolescent athletes require 1.2–2.0 g/kg/day of protein, depending on the type of sport and training intensity. Research suggests that consuming 20–25 g of protein within 30 min after exercise can enhance muscle recovery. However, excessive intake exceeding 3.0 g/kg/day may lead to increased nitrogen excretion without providing any additional performance benefits. This study advocates for educational initiatives aimed at athletes, coaches, and parents to raise awareness about the crucial role of proper nutrition, including protein, in optimizing athletic performance and preventing injuries. In identifying research gaps, the study outlines areas for future investigation, such as optimal protein timing, the types of proteins, and their effects on performance and recovery in adolescent athletes. A thorough understanding of the protein needs of this demographic is essential for promoting both athletic success and long-term health. Conclusions: In summary, this study adds to the growing body of knowledge regarding protein intake among adolescent athletes, providing valuable insights that can inform nutrition planning, enhance performance, and support overall well-being during this crucial developmental stage. Future research should prioritize protein timing, plant-based protein alternatives, and metabolic differences across various sports.
**Keywords: Muscle Protein Synthesis; Sports Nutrition Guidelines; Growth and Development; Exercise-Induced Adaptations; Nutrient Timing**

## Introduction

Adolescence is a crucial stage of life characterized by considerable physical, hormonal, and psychological changes. During this period, ensuring sufficient protein intake is vital for optimal growth and development. However, there are still relatively few studies in the literature that address protein requirements in adolescents, considering variables such as age, sex, level of physical activity, pubertal stage, and overall health status. The hormones involved in puberty have a profound impact on metabolism and body growth, making it essential to focus on this age group (Demir et al., 2025; Mancini et al., 2024; Moroșanu et al., 2024). While protein intake in elite athletes has been extensively studied, there is still a lack of research specifically targeting


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adolescent populations. There is limited understanding of how protein sources, timing, and dietary strategies specifically affect adolescent athletes. Moreover, most existing guidelines are derived from adult populations, creating a gap in knowledge regarding age-specific metabolic responses and protein requirements for younger athletes. Many participants in sports are children and adolescents, and the scarcity of scientific data on protein metabolism complicates efforts to assess the recommended daily protein intake for this group.

To accurately determine the protein requirements of young athletes, it is essential to consider their unique needs for optimal performance and recovery. Several factors, including age, gender, type of sport, training intensity, and duration, influence these protein requirements. Research by Aerenhouts et al. (2013) suggests that these factors significantly impact the protein needs of adolescent athletes. The age range of 12–18 is chosen because it represents a critical period of muscle growth, hormonal changes, and increased energy demands, all of which make protein metabolism essential. The rapid growth experienced during adolescence may require increased protein intake to support ongoing muscle and skeletal development.

Similarly, the energy expenditure related to physical activity and training influences the protein requirements for muscle recovery and repair. Furthermore, the dietary habits of adolescent athletes can differ and may not always align with recommended nutritional guidelines. Research reveals that adolescent athletes frequently do not meet optimal dietary standards, underscoring the need for nutritional education. However, it is important to recognize that ongoing counseling and nutrition education can result in moderate improvements in the eating habits of these athletes (Aerenhouts et al., 2013; Akarsu et al., 2009).

This underscores the need for continuous education and support to help adolescent athletes meet their nutritional needs—especially protein—for optimal growth, development, and performance.

Moreover, the prevalence of dietary supplement use among athletes should be considered because it may influence their overall nutritional intake (Knapik et al., 2016; Mario et al., 2022; Nafiiah & Rahardjo, 2024). Identifying adequate energy and protein needs is essential to support the growth, development, and performance of young athletes (Garcia-Iborra et al., 2023; O. C. Witard et al., 2022).

Research suggests that the daily protein requirement of the fetus is inversely related to gestational age, emphasizing the importance of protein as an energy source during this critical developmental phase (Knapik et al., 2016). Additionally, it is important to acknowledge the occurrence of sports-related injuries, such as anterior cruciate ligament (ACL) tears, which can considerably impact young athletes.

These injuries often require targeted nutritional support to facilitate recovery and rehabilitation (Hurst et al., 2023a). Additionally, the use of sports foods as convenient alternatives to conventional performance-enhancing options should be assessed because they can enhance the overall nutritional intake of young athletes (Cadili et al., 2023). When evaluating protein intake, the quality and sources of protein are important factors.

For instance, the extraction methods and quality of proteins from commercial sources, such as algae, can provide valuable insights into alternative protein options for young athletes (Forsyth & Mantzioris, 2023). Furthermore, age-related declines in muscle mass and function emphasize the importance of sufficient protein intake to maintain muscle health and support physical performance in young individuals (Charlier et al., 2016).

Given the potential benefits of incorporating prebiotic ingredients into high-protein beverages for athletes, it is essential to investigate innovative nutritional strategies tailored to the specific needs of young athletes (Forsyth & Mantzioris, 2023b). Additionally, effectively managing nutrient intake for adolescents participating in sports federations is vital for supporting their growth, development, and athletic performance (Garcia-Iborra et al., 2023).

To clearly define the objectives of this review, the following research questions are explored:

- ✓ What are the general protein requirements for adolescent athletes, and how do age and levels of physical activity affect these needs?
- ✓ How do dietary habits and nutritional education influence protein consumption and overall nutritional adequacy in adolescent athletes?
- ✓ What role do dietary supplements play in meeting protein requirements for adolescent athletes, and what potential risks are associated with their use?
- ✓ How does protein intake aid in muscle recovery for young athletes, particularly after sports-related injuries?
- ✓ What are the main alternative protein sources and innovative nutritional strategies accessible to adolescent athletes?

In summary, a thorough understanding of the protein requirements for young athletes requires a comprehensive evaluation of their nutritional needs, which includes energy, protein, and specific micronutrients. It is essential to take into account factors such as nutritional supplement usage, sports-related injuries, alternative protein sources, and innovative nutritional strategies to enhance the overall health and performance of young athletes.

This study aims to provide a literature-based review of protein needs in adolescent athletes, considering a range of influential factors while addressing these research questions.

**Selection Criteria for Studies**

To ensure the relevance and reliability of the findings, studies included in this review were chosen based on clearly defined inclusion and exclusion criteria. The review emphasized peer-reviewed publications from the past 15 years (2010–2024), a timeframe selected to encompass both recent advancements and established research in the fields of sports nutrition and adolescent physiology.

Studies were identified through an extensive literature search across major scientific databases. The selection process was iterative, ensuring the inclusion of the most relevant peer-reviewed articles based on their contributions to the topic. Additional studies were obtained by reviewing references from key publications to provide a comprehensive overview of existing knowledge. To ensure a comprehensive review, specialized journals in sports nutrition and exercise science were also examined. Studies were assessed based on the relevance of their titles, abstracts, and full texts to ensure alignment with the review objectives. Particular emphasis was placed on research involving adolescent athletes (ages 12–18) engaged in structured training, specifically focusing on protein intake, metabolism, muscle recovery, and their effects on athletic performance.

Priority was given to studies using rigorous methodologies, transparent data presentation, and clearly defined research objectives. Special emphasis was placed on research, including systematic reviews, meta-analyses, clinical trials, and observational studies related to sports nutrition.

Conversely, studies focusing only on adult or elderly populations that had no direct relevance to adolescent athletes were excluded. Additionally, research involving clinical populations, such as individuals with metabolic disorders, was omitted unless it had clear implications for adolescent sports performance. Studies lacking quantitative data on protein intake or its effects were also excluded from consideration.

Studies were chosen for their relevance, methodological clarity, and alignment with the review's objectives. Priority was given to research with well-documented methodologies and strong study designs, ensuring the inclusion of reliable and informative findings. Although formal risk-of-bias assessment tools were not used, studies were selected based on the transparency of their methodology, statistical rigor, and relevance to adolescent sports nutrition.

Limitations

This review focused solely on peer-reviewed studies published in English, which may introduce a language bias. Additionally, unpublished studies and gray literature were excluded, potentially narrowing the scope of available findings. Despite these limitations, the selection process prioritized methodologically sound and relevant studies to offer meaningful insights into protein intake and adolescent athletic performance.

**Energy Requirements**

Ensuring that children receive the right nutrients from their food is essential for optimizing their growth and development. Extra attention may be needed to prevent excessive calorie intake in children who are obese. Estimating the energy needs of obese children who engage in sports can be challenging owing to variations in energy expenditure related to growth and physical activity levels (Chu & Timmons, 2019). When calculating metabolic equivalents for different activities, it is important to account for body weight using a mass-specific resting metabolic rate (Ridley et al., 2008).

However, summaries of youth energy expenditure may underestimate the energy costs associated with certain activities for heavier youth. Thus, caution is needed when applying these energy costs, regardless of body weight. To our knowledge, a substantial proportion of obese children has not been included in existing energy expenditure databases for children and adolescents (Clevenger et al., 2016; McMurray et al., 2015). As a result, the accuracy of these compendiums in estimating energy expenditures in obese children remains uncertain.

Given these challenges, it is recommended that obese children track their average calorie intake and expenditure during their training regimen with the support of coaches, parents, and/or clinicians. A minimum one-week diet and exercise log is necessary to estimate typical energy intake and expenditure. The child's specific goals should then be established. To facilitate monitoring progress, any dietary adjustments should be made under the guidance of a specialist during a period when the child's weight remains stable.

This review focuses on optimizing muscle responses to exercise, as previously discussed. Knowledge of the macronutrient composition of meals and their effects on health and training adaptations can help optimize muscle growth and strength, which are often beneficial for athletic performance. These recommendations are based on the evidence available to date; unfortunately, there remains a lack of research on children (Chu & Timmons, 2019).

**Food Supplements**

Caregivers have different opinions on the use of dietary supplements. Some believe that taking supplements is a practical way to ensure adequate vitamin intake, while others prefer children to get their nutrition from a balanced diet. Additionally, the fact that dietary supplements are not regulated in the same way as medications raises concerns for some (Barretto et al., 2024).

Studies on dietary supplement use among children in North America, aged 1–10 years, found that 52% of parents provided some form of supplement, with the most common types being multivitamins, probiotics, minerals, and omega-3. Only 43% of respondents reported seeking medical advice, and higher-income

households were more likely to use supplements (Barretto et al., 2024). The primary reasons for supplement use were inadequate consumption of fruits and vegetables and unhealthy snacking habits.

Teenagers' views on dietary supplements are influenced by marketing that portrays these products as nutrient-rich, capable of enhancing sports performance, and helping achieve the "ideal body." Friends, gym buddies, and celebrity endorsements on social media also serve as key sources of information. Often, teenagers overuse these products owing to a lack of guidance from nutritionists or doctors, believing that they will improve their health. The most popular supplements among teenagers, especially those who work out to build muscle mass, are proteins and amino acids. However, unless they are adolescent athletes or vegetarians who struggle to meet their protein needs through a regular diet, it is recommended to obtain high-quality protein from dietary sources (Burke et al., 2019a).

Whey protein, the most valuable protein component of milk, is used in various food products, including dietary supplements for both adults and children, in amounts suitable for their respective age ranges, as well as in infant formulas that comply with regulations for foods intended for infants. Among adults and teenagers who work out at the gym, whey protein is the most popular protein supplement (Barretto et al., 2024).

Whey protein is available in three forms: hydrolyzed, concentrated, and isolated. The concentrated form undergoes less processing, resulting in lower nutrient extraction, and has a higher calorie content with a protein concentration ranging from 34% to 89%. The isolated form, which contains approximately 90% protein, undergoes more extensive filtration to remove or reduce lipids and carbohydrates (Lin et al., 2021).

The product that undergoes hydrolysis, producing rapidly absorbed oligopeptides, is known as the hydrolyzed form. Whey proteins are recognized as beneficial for various purposes, including appetite management, exercise recovery, and promoting satiety. Teenagers involved in physical activity should consult a specialized dietary plan for training or sports before using whey protein. When dietary protein intake is insufficient to support muscle growth during training, the available protein is primarily used for essential bodily functions instead (Figure 1).

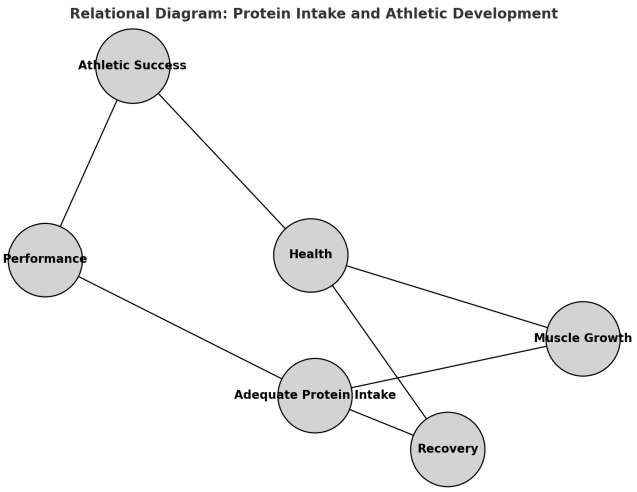


Figure 1. Adequate protein intake promotes muscle growth, aids recovery, and enhances performance in young athletes, contributing to overall health and athletic success

While nutrition is important both before and after exercise, the "window of opportunity" between 16 and 48 h after resistance training is when protein synthesis peaks. As a result, consuming whole foods throughout the day—particularly after a full day of exercise—is more beneficial for protein synthesis and muscle repair (Burke et al., 2019).

Adolescent athletes aiming to build or maintain muscle mass should have their whey protein recommendations and prescriptions tailored to their specific needs and training objectives (Jäger et al., 2017).

This guideline recommends a protein intake ranging from 1.3 to 1.7 g/kg/day for adults. Unlike whey protein, albumin has a lower leucine content and is absorbed more slowly. It is a high-quality biological protein derived from dried egg whites. Its use has been exaggerated by bodybuilders and teenagers who work out at the gym, with some consuming up to thirty egg whites per day, which exceeds the daily requirements for muscle development and could lead to kidney strain (Woźniak et al., 2022). To reduce fatigue and promote muscle growth, branched-chain amino acids (BCAAs) are often taken with carbohydrate solutions after exercise. Although they are administered to reduce the risk of infections, there is limited evidence supporting their effectiveness (Barretto et al., 2024).

Creatine is composed of three amino acids: methionine, glycine, and arginine. Supplementing with creatine increases the amount of phosphocreatine in muscles, enhancing muscular explosiveness and providing

energy for intense, repetitive workouts. It also helps buffer lactic acid produced during exercise, delaying the onset of discomfort and muscle fatigue (Jagim & Kerksick, 2021). Creatine may benefit both competitive athletes and individuals with neuromuscular conditions, traumatic brain injuries, or other conditions that require improved muscle strength and reduced fatigue.

The recommended dosage involves a saturation phase lasting five to seven days, with 0.3 g/kg/day of creatine monohydrate, followed by a maintenance phase of 3–5 g/day. The timing of intake—whether before or after exercise—does not matter; it can be taken at any time during the day (Kaufman et al., 2022).

**Protein Intake Trends**

Available data show that most people in Western Europe and the United States consume more protein than the recommended amounts in their diets ("Scientific Opinion on Dietary Reference Values for Protein," 2012; Trumbo et al., 2002). Protein intake recommendations for the pediatric population (under 18 years old) vary slightly depending on the health authority. The most frequently cited guidelines are the Dietary Reference Intakes (DRIs) from the US Institute of Medicine (IoM) (*Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*, 2005) and the Dietary Reference Values (DRVs) released by the EFSA.

The Recommended Dietary Allowance (RDA) and the Population Reference Intake (PRI), which represent the average daily intake levels sufficient to meet nutrient requirements and prevent deficiencies in nearly all (97.5%) healthy individuals in a population, are the most frequently cited guidelines, despite covering various terms (O. C. Witard et al., 2022a). However, there are no specific recommendations for "optimal" protein consumption in pediatric patients to support healthy growth and development, aside from dietary measures to prevent deficiencies.

In industrialized nations, protein intake among children and adolescents is often two to three times higher than recommended, with the majority of these proteins coming from animal sources. According to data from the National Diet and Nutrition Survey (NDNS) (Nüse et al., 2023) ($n \approx 1000$; 500 adults and 500 children), performed in the United Kingdom (UK) between 2016 and 2017, the average protein intake was 52.9 g/d for children aged 4–10 years and 64.5 g/d for those aged 11–18 years.

Protein consumption for these age groups was 1.40 and 2.39 times higher than the PRI. Protein intake is even greater in other European countries. According to data from 1,862 individuals in the National Dietary Survey on the Child and Adolescent Population in Spain (ENALIA) (López-Sobaler et al., 2019), average intakes ranged from 74.45 g/d for children aged 4–8 years to 93.6 g/d for those aged 14–17 years, representing 3.88–1.88 times the PRI, respectively.

It is worth noting that protein accounted for up to 17.8% of the total energy consumed by children aged 4–17. Similar findings have been reported in the US. According to the National Health and Nutrition Examination Survey 2001–2014 (NHANES) (Berryman et al., 2018) ($n = 15,829$; ages 2–80 years), average protein intakes ranged from 59.7 g/d in children aged 4–8 years to 79.75 g/d in those aged 14–18 years.

It is noteworthy that among Spanish children aged 1–3, protein accounted for 12.1% of total energy intake, while 0.96% of 2–3-year-olds exceeded the Acceptable Macronutrient Distribution Range (AMDR) for protein (10%–30% E). Although the upper limit of the AMDR (35% E) in adults has been associated with an increased risk for prediabetes and type 2 diabetes, the AMDR reflects a range of protein intakes in the context of a balanced diet (Mittendorfer et al., 2020). Therefore, the AMDR should be used with caution.

Finally, original research from cohort studies, such as the Generation R (Larsen et al., 2018) and Dortmund Nutritional and Anthropometric Longitudinal Design (DONALD) study (Günther et al., 2007), has shown similar and even higher protein consumption, aligning with the findings of these national dietary surveys.

In summary, while observational research consistently shows that children's average protein intake is two to three times higher than the levels recommended to prevent deficiencies in 97.5% of the population, there are currently no established guidelines for an "optimal" protein intake that exceeds these recommendations to support healthy growth and development (Bilsborough & Mann, 2006; Schoenfeld & Aragon, 2018a; Tsagari, 2020).

**Protein Intake Guideline**

According to guidelines from major international agencies, such as the World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO), and the National Research Council Food and Nutrition Board, the recommended daily protein intake for adolescents ranges from 0.8 to 1.0 g/kg body weight. The revised timing of protein and amino acid requirements, discussed by the FAO and WHO, has led to new parameters in Dietary Reference Intakes (DRIs), particularly in the United States. Some researchers have explored the implications of these values in the metabolic framework to assess the nutritional adequacy of protein intake in children and adolescents in both developed and developing countries (Millward & Jackson, 2004).

However, it is important to note that this value may vary depending on individual factors such as physical activity levels and pubertal stage (Deer & Volpi, 2015; Jäger et al., 2017; Kitada et al., 2019; Morton et al., 2018). A key consideration with these recommended values is that they apply to "ideal" adolescents, not those who engage in regular sports or intensive training. Therefore, daily protein requirements and allowances

are not established for children or adolescents with high levels of physical activity (at least 50% higher than the general population) (Boisseau et al., 2007; Soriano-Moreno et al., 2022).

In a study, several authors (Berryman et al., 2018; *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*, 2005; "Scientific Opinion on Dietary Reference Values for Protein," 2012) concluded that an average protein intake of approximately 1.5 g/kg/day was sufficient to maintain a positive nitrogen balance, even during periods of peak growth. Therefore, protein intake does not need to be increased during periods of peak linear or muscle growth.

The prevalence of eating disorders is higher among adolescent elite athletes, particularly females. This underscores the importance of understanding the relationship between protein intake and overall nutritional patterns in adolescent athletes. Additionally, studies on the energy intake and macronutrient composition of adolescent athletes' diets indicate that their dietary habits may differ from those of non-athletic adolescents (Kowalsky et al., 2022). Moreover, the physical activity levels of adolescent athletes are crucial in estimating their energy needs, with observed activity levels often lower than those reported for vigorously active adolescents (Ray et al., 2023). Additionally, studies have examined the influence of coaches' perceptions of adolescent athletes' food intake, appetite, and nutrition, emphasizing the importance of considering external factors in shaping young athletes' eating habits (Alzahrani et al., 2022; Boisseau et al., 2007; Kowalsky et al., 2022; Ray et al., 2023).

This is essential for understanding the various factors that influence the protein requirements of adolescent athletes. In summary, the protein needs of adolescent athletes are influenced by various factors, including growth rate, energy expenditure, dietary habits, and external influences such as coach perceptions. Understanding these factors is crucial to ensuring that adolescent athletes receive adequate protein to support their growth, development, and athletic performance.

**Establishing Consensus on Protein Recommendations**

One of the key challenges in reviewing literature on protein intake for adolescent athletes is the variability in recommendations. The reviewed studies showed inconsistencies in protein intake levels, often influenced by sport type, training volume, and individual metabolic differences.

This review recognizes the varying viewpoints on protein timing and supplementation, with some studies highlighting its benefits, while others caution against excessive intake. Additionally, potential biases in industry-funded studies promoting high protein supplementation were critically assessed to ensure objectivity in the findings.

To provide a clear and structured comparison of the research findings, a summary table was created, highlighting key details from each study, including the author, year, sample population, protein intake levels, and key findings related to athletic performance and recovery. This approach aids in contextualizing the results and facilitates efficient cross-study comparisons.

To provide a clearer perspective on protein requirements for adolescent athletes, a summary table comparing the guidelines from key authorities is presented below (Table 1). This table consolidates recommendations from the World Health Organization (WHO), the American College of Sports Medicine (ACSM), and the International Society of Sports Nutrition (ISSN) (Table 1) (Burke et al., 2019; Jäger et al., 2017, 2017d; Thomas et al., 2016).

Table 1 highlights the differences in protein recommendations, with the WHO focusing on general health, while the ACSM and ISSN emphasize the increased needs of athletes. By offering a structured comparison, the review provides clearer insights into protein intake guidelines, helping athletes, coaches, and sports nutritionists make informed dietary choices.

Table 1. Summary of Protein Intake Recommendations from WHO, ACSM, and ISSN for Adolescents

| Organization | Recommended Protein Intake (g/kg/day) | Population | Key Notes |
|---|---|---|---|
| **World Health Organization** (WHO) | 0.85–1.0 | General adolescent population | Recommended for normal growth and development, not specific to athletes |
| **American College of Sports Medicine** (ACSM) | 1.2–2.0 | Adolescent athletes | Considers training intensity, with increased needs for strength-based sports |
| **International Society of Sports Nutrition** (ISSN) | 1.4–2.2 | Adolescent athletes | Recommends a higher intake for optimal muscle recovery and performance |

**Critical Perspectives and Research Gaps in Protein Intake for Adolescent Athletes**

Despite the growing emphasis on sports nutrition and the recognized importance of protein intake for adolescent athletes, several critical gaps in the literature remain. Current research offers a wide range of recommendations regarding protein needs, yet a clear consensus on the optimal daily intake and distribution for young athletes, considering various sports and training intensities, is still lacking. While it is widely recognized that adolescent athletes require more protein than their non-athletic counterparts, there is no standardized framework to guide personalized recommendations based on the type of sport. Training frequency and metabolic needs are key factors to consider. Some studies highlight the beneficial effects of higher protein intake on muscle synthesis, recovery, and injury prevention, while others caution against the potential risks of excessive protein consumption, such as kidney strain, altered calcium metabolism, and increased nitrogen excretion. Further research is required to establish safe upper limits for protein intake in this population and to determine whether individualized protein recommendations should vary based on biological age, training load, and sport-specific demands (O. C. Witard et al., 2022).

One of the most debated topics in sports nutrition is protein timing—the strategic consumption of protein in relation to exercise. In adult athletes, consuming protein immediately after exercise has been shown to enhance muscle protein synthesis and recovery. However, it remains unclear whether these findings apply to adolescent athletes, given the ongoing metabolic and hormonal changes during growth. While some studies support evenly distributing protein intake throughout the day, others suggest that a targeted post-workout protein window may offer particular benefits. Future research should explore how different timing strategies affect muscle repair, adaptation, and athletic performance in young athletes, while also considering how carbohydrate and fat intake interact to optimize recovery (Morton et al., 2018).

Current evidence suggests that post-exercise protein intake (20–25 g within 30 min) enhances muscle protein synthesis, while evenly distributing protein intake across meals (0.4 g/kg per meal) further optimizes recovery (Burke et al., 2019). However, the long-term effects of these strategies on adolescent athletes, particularly in terms of muscle growth and metabolic efficiency, remain understudied. Additional studies are needed to compare different protein distribution models and establish clear recommendations for young athletes. Given the growing adoption of plant-based diets among young athletes, future research should also investigate the long-term effectiveness of plant-based protein sources on muscle adaptation and recovery. Emphasizing dietary diversity and combining various protein sources may provide a practical solution to ensure optimal amino acid intake, particularly for athletes with dietary restrictions. With the growing popularity of vegetarian and vegan diets among young athletes, there is an urgent need to investigate whether plant-based protein intake can sufficiently support muscle development and athletic performance in this group. Future studies should evaluate the digestibility, absorption rates, and muscle-building effectiveness of plant-based alternatives compared to animal proteins, while also examining the long-term effects on bone health, metabolic function, and endurance capacity (Jäger et al., 2017).

In addition to dietary preferences, socioeconomic disparities can impact protein intake among adolescent athletes. Athletes from lower socioeconomic backgrounds may face challenges in meeting their protein needs owing to financial constraints and limited access to high-quality protein sources. This highlights the need for cost-effective dietary solutions, such as plant-based protein combinations (e.g., legumes and grains) that offer complete amino acid profiles. Future research should explore economic and policy-driven interventions to ensure equitable access to adequate nutrition for young athletes, regardless of their financial circumstances.

Furthermore, nutritional education and awareness continue to be considerable challenges in adolescent sports nutrition. Studies indicate that many young athletes and their caregivers lack adequate knowledge about protein requirements, dietary planning, and the potential risks of excessive supplementation. This knowledge gap often results in suboptimal dietary choices, with some athletes failing to meet their protein needs through whole foods and others over-relying on protein supplements, which may contain contaminants, banned substances, or unnecessary additives. Educational initiatives aimed at athletes, coaches, and parents should emphasize the importance of a food-first approach, promoting a balanced diet over excessive dependence on commercial supplements (Woźniak et al., 2022).

In addition to general concerns about protein intake, there is a gap in research on protein consumption during injury recovery in adolescent athletes. Given the prevalence of injuries such as ACL tears, stress fractures, and muscle strains in this population, optimizing protein intake during rehabilitation may be crucial for promoting tissue repair, preserving muscle mass, and preventing re-injury. Future studies should investigate whether increased protein intake during periods of immobilization or reduced training can help reduce muscle atrophy and enhance recovery outcomes (Hurst et al., 2023; Jagim & Kerksick, 2021).

Finally, existing research often overlooks the sociocultural and economic factors that influence protein consumption among adolescent athletes. Variations in access to high-quality protein sources, driven by factors such as geographic location, socioeconomic status, and food availability, may result in disparities in nutritional adequacy. Future studies should examine how dietary habits, food accessibility, and cultural beliefs shape

protein intake in young athletes, with an emphasis on developing practical and affordable dietary strategies tailored to diverse populations (Hurst et al., 2023; Kowalsky et al., 2022).

Future Research Directions

To address these gaps, future research should focus on:

- Developing sport-specific protein intake guidelines that consider training intensity, sport type, and individual metabolic responses.
- Investigating the long-term effects of protein supplementation on adolescent athletes, with particular focus on kidney function, metabolic health, and hormonal balance.
- Identifying the optimal timing and distribution of protein intake throughout the day to maximize performance and recovery.
- Comparing the effectiveness of plant-based versus animal-based proteins in promoting muscle growth, endurance, and overall performance in adolescent athletes.
- Exploring nutritional interventions that educate young athletes on proper dietary choices, aiming to prevent misinformation and unnecessary supplement reliance.
- Examining the role of protein intake in sports injury prevention and rehabilitation, especially in athletes recovering from muscle tears, fractures, or ligament damage.
- Analyzing socioeconomic and cultural disparities in protein consumption and their potential effects on athletic development and performance.

By addressing these unresolved questions, future research can refine scientific recommendations for adolescent athletes, ensuring their nutritional needs are met to optimize performance, support growth, and protect long-term health. A multidisciplinary approach, integrating sports science, endocrinology, dietetics, and behavioral nutrition, will be essential in bridging the gap between scientific findings and their practical application in sports training and dietary planning.

**Practical Implications for Athletes and Coaches**

Proper nutrition is crucial for adolescent athletes because it directly affects their performance, recovery, and long-term health. Although scientific research provides guidelines on protein intake, effectively applying these recommendations remains a challenge for many young athletes, their coaches, and parents. This section outlines key recommendations for optimizing protein consumption in real-world training and competition environments.

***1. Tailoring Protein Intake to Sport-Specific Needs***

The protein requirements of adolescent athletes vary based on the type of sport they participate in. Endurance sports, such as running, cycling, and swimming, require moderate protein intake (1.2–1.6 g/kg/day) to support muscle repair and prevent fatigue. Strength and power athletes, including weightlifters, sprinters, and football players, need higher protein intake (1.6–2.0 g/kg/day) to promote muscle growth and recovery (Table 2).

Sports that combine endurance and strength, such as basketball, tennis, or martial arts, benefit from an intermediate protein intake (1.4–1.8 g/kg/day), balancing protein consumption with adequate carbohydrate intake to maintain sustained energy levels.

Table 2. Recommended protein intake for adolescent athletes by sport type, timing, and food sources

| Sport Type | Recommended Protein Intake (g/kg/day) | Optimal Timing | Example Food |
|---|---|---|---|
| Strength sports | 1.6–2.0 | 20–25 g post-exercise | Chicken, eggs, tofu |
| Endurance sports | 1.2–1.6 | Evenly distributed throughout the day | Fish, dairy, quinoa |

Understanding these sport-specific differences allows for more effective nutritional planning, ensuring athletes receive the appropriate amount of protein without overconsumption, which could result in digestive issues, kidney strain, or imbalanced macronutrient intake (Thomas et al., 2016; O. Witard et al., 2016).

***2. Timing of Protein Intake for Maximum Benefits***

Timing of protein consumption, in addition to total daily intake, plays a crucial role in muscle synthesis, recovery, and performance. Young athletes should focus on distributing their protein intake throughout the day instead of consuming large amounts in one meal (Morton et al., 2018; Schoenfeld & Aragon, 2018).

- Pre-workout meals should include a small amount of protein (10–15 g) and complex carbohydrates to provide sustained energy and minimize muscle breakdown during exercise.
- Post-workout nutrition is essential for muscle repair and growth. The period immediately following exercise, often called the "anabolic window," is when muscles are most responsive to protein. Consuming 20–25 g of fast-digesting protein (such as whey, eggs, or lean meat) within 2 h of training can enhance recovery and adaptation.
- Bedtime protein intake is also beneficial, especially for athletes undergoing intense training. Slow-digesting proteins such as casein (found in Greek yogurt or cottage cheese) provide a gradual release of

amino acids overnight, helping to prevent muscle breakdown and promote long-term muscle development.

By implementing well-timed protein consumption, adolescent athletes can enhance muscle recovery, build endurance and strength, and minimize unnecessary protein waste.

***3. Choosing High-Quality Protein Sources***

Protein quality is just as important as quantity. A food-first approach should always take precedence over supplements, ensuring young athletes obtain a well-balanced intake of essential nutrients (Lin et al., 2021).

- Animal-based proteins, such as eggs, dairy, lean meats, poultry, and fish, provide a complete amino acid profile, making them particularly effective for muscle synthesis and recovery.
- Plant-based proteins, including legumes, tofu, quinoa, and nuts, can also be beneficial, as long as they are properly combined to ensure adequate amino acid intake. Pairing grains with legumes (such as rice and beans) enhances protein quality, making it a viable choice for vegetarian and vegan athletes.

By prioritizing natural, nutrient-dense protein sources, young athletes can reduce the risks associated with processed protein supplements, including exposure to artificial additives, high sugar content, and potential contamination with banned substances.

***4. The Role of Supplements: When Are They Necessary?***

Although protein supplements are widely available and often marketed to young athletes, they are not always necessary. In most cases, a well-balanced diet provides enough protein to meet athletic needs. However, supplementation may be beneficial in certain situations, such as when an athlete faces challenges meeting protein requirements owing to dietary restrictions, limited meal availability, or intense training schedules. If supplementation is needed, whey protein isolate or casein is recommended owing to their high digestibility and complete amino acid profile. It is essential that athletes, coaches, and parents are educated about safe supplementation practices, ensuring that products are tested for contaminants and comply with anti-doping regulations (Burke et al., 2019; Jagim & Kerksick, 2021).

***5. Education as the Key to Proper Nutrition***

One of the most often overlooked aspects of sports nutrition is education and awareness. Many adolescent athletes, as well as their parents and coaches, lack adequate knowledge about protein needs, proper meal planning, and the potential risks of excessive supplementation.

- Athletes should be informed about their actual protein requirements and how to distribute intake effectively throughout the day.
- Coaches and parents should promote whole-food-based nutrition and discourage dependence on unverified supplements.
- Schools and sports organizations should offer basic nutrition workshops to empower young athletes to make informed dietary choices.

By promoting better nutritional education, young athletes can develop lifelong healthy eating habits, leading to improved sports performance and long-term well-being (Alzahrani et al., 2022; Woźniak et al., 2022). In conclusion, optimizing protein intake for adolescent athletes requires a personalized approach that takes into account sport-specific demands, dietary preferences, and practical limitations. Ensuring proper protein distribution, selecting high-quality sources, and promoting nutritional education among young athletes and coaches are essential strategies for enhancing both performance and long-term health.

**Conclusions**

This review underscores the importance of a well-balanced diet that provides adequate protein from a variety of sources. Owing to their increased physical demands, athletes may need higher protein intake compared to their non-athletic peers. However, maintaining a balance is crucial to avoid excessive protein consumption, which could pose potential health risks.

The study emphasizes the need for individualized nutrition plans tailored to the type of sport, training intensity, duration, and specific athletic goals. Educating athletes, coaches, and parents about the significance of proper nutrition, including protein intake, is vital for optimizing athletic performance, preventing injuries, and ensuring long-term health. Identified research gaps highlight the need for future studies on the optimal protein requirements for adolescent athletes, the timing of protein intake, and the effects of different protein sources on performance and recovery.

A comprehensive understanding of adolescent athletes' protein needs will support both their athletic performance and overall well-being during this vital stage of development.

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