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The Role of Protein Intake: Benefits, Risks, and Metabolic Effects – A Literature Review

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ABSTRACT

Introduction. The aim of this systematic review is to assess the impact of dietary protein intake on muscle strength, metabolic health, hormonal balance, and gastrointestinal function in healthy adults, including athletes. Particular attention was given to the effects of protein intake level, protein sources, interactions with carbohydrates, and age- and training-related differences in physiological response.

Materials and Methods. A systematic review of randomized controlled trials (RCTs) and population-based studies available in PubMed was conducted, focusing on the effects of moderate and high protein intake in healthy adults, including individuals engaged in resistance training. Eligible studies included both protein supplementation and increased dietary protein intake, with variation in intervention duration, protein quantity, and protein source.

Summary. Increased dietary protein intake promotes moderate gains in lean body mass and lower-body strength in resistance-trained individuals, with more pronounced effects in older adults and those consuming ≥1.6 g/kg/day of protein. Evidence also indicates that individuals aiming to reduce body weight may prevent excessive muscle loss and maintain physical

performance when following a high-protein diet combined with exercise. However, very high protein intake (>3.4 g/kg/day) may lower total testosterone levels in men, although typical athlete diets rarely exceed this threshold. Protein source affects metabolic outcomes: animal and seafood proteins are associated with higher risk of hyperuricemia, while plant proteins—particularly soy—may have protective effects. The impact of protein intake on gut function depends on carbohydrate availability; low carbohydrate intake combined with high protein consumption increases constipation risk. Historical and contemporary data show considerable variability in protein intake among athletes, underscoring the need for individualized nutrition strategies.

Conclusions. Optimal protein intake to support muscle mass, strength, and metabolic health depends on physical activity type, age, overall dietary composition, and protein source. Although high-protein diets generally benefit muscle health, very high intake may carry metabolic and hormonal risks. Protein source selection is important for preventing hyperuricemia. Future research should focus on the long-term effects of very high protein intake, interactions with other macronutrients, and individualized strategies to optimize health and athletic performance.

Keywords: dietary protein, lean body mass, muscle strength, hyperuricemia, testosterone, resistance training, protein intake levels

Introduction

Protein intake plays a key role in regulating metabolic processes, supporting tissue regeneration, and maintaining overall health. As a macronutrient, protein influences muscle protein synthesis, body composition, energy metabolism, gut function, and may modulate hormone levels, including testosterone. In recent years, numerous studies have evaluated the effects of increased protein intake in both physically active individuals and the general population. Findings indicate that high-protein diets may offer measurable benefits for physical performance, body composition, and metabolic regulation, while also highlighting the importance of assessing long-term safety—particularly regarding kidney function and cardiovascular health. Given the diversity of results and heterogeneity of study populations, a structured review of the literature is essential to present the current state of knowledge on the metabolic effects of protein intake, associated health benefits, and potential risks.

Study Aim

The aim of this work is to systematically review scientific studies on the metabolic effects of protein intake and to identify the benefits and potential risks associated with high-protein diets. The analysis includes studies investigating the effects of high protein intake on physical performance, body composition, kidney function, metabolic processes, gut health, and testosterone levels. The goal is to provide a concise summary of current knowledge and to identify areas requiring further research.

Materials and Methods

This review is based on scientific literature from PubMed published between 1997 and 2024.

Inclusion criteria: studies conducted in healthy adults (including physically active individuals/athletes) reporting dietary protein intake or protein supplementation, analyzing metabolic outcomes, body composition, muscle strength, kidney function, hormonal regulation, or gastrointestinal function.

Exclusion criteria: studies involving minors, individuals with chronic disease, pharmacological interventions, or without a clearly defined protein intake level.

Literature Review

Benefits of High-Protein Diets

Physical performance and protein intake

Protein is an essential macronutrient required for normal physiological functioning. In the context of competitive sports, its role is particularly important due to its involvement in recovery processes, muscle growth, and maintenance. High-intensity physical activity increases muscle protein breakdown and elevates the need for amino acids required for new protein synthesis and tissue repair. Adequate dietary protein intake is therefore crucial not only for optimizing athletic performance, but also for maintaining health, minimizing injury risk, and preventing chronic fatigue and overtraining [1].

Recommendations vary depending on sport type, training intensity, and individual characteristics such as body mass and age. Furthermore, not only total protein intake but also its distribution throughout the day and the quality of protein sources influence amino acid bioavailability and the efficiency of protein utilization [2].

The role of protein-carbohydrate ratios in athletic performance

Poor dietary balance with excessive protein intake may result in energy deficits, which are particularly dangerous for competitive athletes who must maintain adequate energy levels. A meta-analysis of studies on carbohydrate–protein supplementation showed that combined CHO-PRO intake significantly improves physical performance, including time-to-exhaustion and endurance test results, especially during longer recovery periods (>8 hours) [3].

These findings suggest that not only the amount of protein, but also its ratio to carbohydrates, is essential for training adaptation and recovery, which is important when planning high-protein diets aimed at improving performance and muscle recovery.

Effects of high protein intake on body composition and metabolic function in athletes — muscle gain under caloric surplus

Increased dietary protein intake in elite athletes is a key factor supporting muscular adaptations, strength, and favorable body composition. In a year-long study involving resistance-trained men, higher caloric intake associated with high protein consumption did not lead to increases in fat mass, suggesting that a high-protein diet may support maintenance or growth of lean body mass (LBM) without negative effects on energy metabolism [4].

A meta-analysis of 74 RCTs confirmed that protein supplementation in resistance-trained individuals produces moderate increases in LBM. This effect is particularly prominent in older adults (>65 years) consuming 1.2–1.59 g/kg/day and younger adults (<65 years) consuming ≥1.6 g/kg/day. Increased protein intake also slightly improves lower-body strength and bench press performance, although effects on grip strength and physical function are limited or inconsistent [5].

These findings indicate that the anabolic effects of high protein intake are moderate and depend on age, training level, and total dietary protein intake. The quality of protein and macronutrient ratios also play an important role, as interactions between nutrients may modulate anabolic responses and influence digestion and training adaptation [4,5].

4. Increased protein intake in weight reduction — preservation of muscle mass

A review of 47 RCTs (3,218 participants) found that increased protein intake significantly protects against loss of lean body mass in overweight or obese adults undergoing caloric restriction. In 28 of these studies (1,989 participants), the effect was statistically significant (SMD = 0.75, 95% CI 0.41–1.10; $p < 0.001$), indicating that additional protein substantially reduces LBM loss during weight loss. Subgroup analyses showed that intake above ~1.3 g/kg/day is associated with muscle preservation, while intake below ~1.0 g/kg/day is linked with greater risk of LBM loss [6].

Overall, high protein intake in elite athletes as well as individuals with obesity aiming for weight loss can support muscle preservation and strength with minimal metabolic risk. However, the effect is moderate, and optimal protein intake must be individualized according to age, training type, and overall diet.

Risks Associated With Excessive Protein Intake

Despite many benefits of high-protein diets, interest in their potential negative long-term effects is increasing [7].

Exceeding optimal protein intake levels may overload kidney function, disrupt acid-base balance, and affect metabolism of other nutrients. Excessive protein intake may also reduce the efficient use of carbohydrates and fats, potentially influencing athletic performance and recovery [8,9].

1. Effects of high-protein diets on kidney function

According to available reviews, high-protein diets—especially those exceeding 1.5–2.0 g/kg/day—may increase intraglomerular pressure, causing glomerular hyperfiltration. Hyperfiltration increases nephron workload, potentially leading to glomerular injury and proteinuria. Long-term exposure to elevated filtration pressure may increase the risk of developing chronic kidney disease (CKD). Healthy individuals typically tolerate protein intake up to 2.8 g/kg/day without adverse effects, but long-term intake above this level may pose risks, particularly for individuals with pre-existing kidney issues [10].

2. Effects of high protein intake on testosterone levels

Studies indicate that the effect of high protein intake on testosterone levels in men depends on the amount consumed. An analysis of three studies found that very high protein intake exceeding 3.4 g/kg/day may lower total testosterone concentration. However, moderate protein intake in the range of 1.25–3.4 g/kg/day does not appear to produce such effects, suggesting that typical athlete diets do not pose a risk of testosterone suppression, as most do not exceed this threshold [11].

3. Protein source as a determinant of metabolic risk

Protein quality is an important factor influencing metabolic risk. Epidemiological studies show that consumption of animal protein and seafood is associated with a higher risk of hyperuricemia, whereas plant protein—especially soy—may have protective effects. No significant correlation was found between total protein intake and hyperuricemia risk, indicating that the type of protein consumed is key in regulating uric acid levels and preventing metabolic diseases [12].

4. Gastrointestinal function and dietary patterns of athletes

Protein intake can influence gastrointestinal function, including stool consistency and bowel movement frequency. An analysis of NHANES data from 13,941 adults found no clear association between higher protein intake and constipation when assessed by bowel movement frequency and stool consistency. The effect was modulated by carbohydrate intake: higher protein intake increased constipation risk only in individuals with low carbohydrate intake; with moderate carbohydrate consumption the effect was neutral or mildly beneficial [13].

These findings highlight the importance of macronutrient interactions and suggest that proper balance between protein and carbohydrates is crucial for maintaining gut function and preventing digestive issues.

Historical and modern analyses of athlete diets show significant variation in energy and macronutrient intake, including protein and carbohydrates. Studies of athletes participating in the 1952 Helsinki Olympic Games showed that protein accounted for ~20% of energy intake and fat for 40%. Modern studies indicate a broader range of protein intake among athletes (1.0–4.3 g/kg/day) and carbohydrate intake (3.5–6.9 g/kg/day) [14].

These trends suggest a more balanced carbohydrate intake in modern sports nutrition compared to earlier periods, while protein intake remains variable and strongly dependent on sport discipline, training type, and individual dietary strategies.

Both the impact of protein on gastrointestinal function and the variability of athlete diets underscore the need for individualized nutritional recommendations. Considering protein–carbohydrate ratios and training characteristics is essential for optimizing metabolic and digestive function and improving athletic performance.

Summary

Protein is a key macronutrient necessary for maintaining muscle mass, strength, and proper metabolic function in physically active adults under both caloric surplus and deficit conditions. Increased protein intake promotes gains in lean body mass and strength, especially when combined with resistance training and in older adults.

Very high intake (>3.4 g/kg/day) may lower testosterone levels in men, while moderate intake does not cause hormonal disturbances.

Protein source has important metabolic implications: animal and seafood proteins increase the risk of hyperuricemia, while plant proteins—especially soy—have protective effects. Gastrointestinal function is influenced by the relationship between protein and carbohydrate intake; high protein intake combined with low carbohydrate intake may increase constipation risk.

Analyses of athlete diets reveal large variability in protein intake driven by training demands and energy needs, with modern intake generally ranging from 1.0 to 4.3 g/kg/day. Optimizing protein intake requires considering total amount, protein quality, macronutrient balance, age, training type, and athletic goals. Moderate-to-high protein intake is safe and beneficial, although the long-term effects of very high intake—especially from animal sources—require further research.

Disclosure

Author's contribution

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