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Effects and Implementation Pathway of a High-Protein Diet Combined with Exercise Intervention in Adolescent Obesity

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Abstract: With the continuous improvement in living standards, the incidence of adolescent obesity has shown an increasing trend. Adolescent obesity not only affects growth, development, and mental health but also increases the risk of future chronic diseases. Existing intervention methods primarily include exercise, dietary modification, and pharmacotherapy, each with inherent limitations. Research suggests that a combined exercise and nutritional strategy can effectively improve body composition and overcome the negative effects of single-modality interventions. Therefore, this paper aims to provide a narrative review of the mechanisms and implementation pathways of a high-protein diet combined with exercise intervention in adolescent obesity, to enhance understanding of its effects on adolescents' physical and mental health, and to offer a reference for theoretical development and clinical practice in related fields.

Keywords: Adolescent obesity; High-protein diet; Exercise intervention

Introduction

Current status of adolescent obesity

Adolescent obesity has become a major global public health challenge. According to the MSD Manuals 2024 Global Report, approximately one-fifth of children and adolescents worldwide are overweight or obese. Data from 2022 also indicate a rapidly increasing prevalence of obesity among children and adolescents in China. [1] Obesity adversely affects mental health, motor skills, and social integration, and it significantly increases the risk of developing metabolic diseases such as type 2 diabetes, hypertension, and non-alcoholic fatty liver disease in adulthood. [2] Unlike adults, adolescents are in a critical phase of growth and development, with unique energy and nutrient requirements. [3] Therefore, any obesity treatment plan for this population must aim to reduce body fat while simultaneously ensuring normal growth, sexual development, and healthy brain development.

Limitations of existing intervention models

Dietary intervention alone

Dietary intervention alone, typically a low-calorie balanced diet, can induce short-term weight loss but is often followed by a significant loss of lean body mass (LBM). LBM is a primary determinant of resting metabolic rate (RMR); its reduction lowers RMR, thereby increasing the likelihood of weight regain. This creates a detrimental cycle of "weight loss → metabolic decline → weight regain." [4] Furthermore, very low-calorie diets may lead to insufficient nutrient intake, compromising adolescent growth and development. Such restrictive diets are also difficult to sustain long-term, increasing the risk of weight rebound. [5]

Exercise intervention alone

When exercise is not accompanied by dietary adjustments, the energy deficit created can be easily offset by increased food intake, resulting in minimal fat loss. [6] Moreover, if the exercise regimen consists primarily of aerobic activities without resistance training, it is challenging to stimulate muscle protein synthesis under a negative energy balance. The consequent loss of muscle mass, coupled with a reduced metabolic rate, is also detrimental to long-term weight management. [7]

Value of combined intervention

Given these limitations, a combination of a high-protein diet and exercise—particularly when resistance training is

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included—has emerged as a promising strategy for adolescent obesity. Adequate protein intake provides the essential amino acids for muscle repair and growth following exercise, while also promoting satiety, which improves dietary adherence. [8] Regular exercise, especially resistance training, directly stimulates muscle protein synthesis and increases total energy expenditure. This combined approach shifts the goal from mere "weight loss" to "improving body composition"—reducing fat mass while preserving or even increasing LBM, thereby enhancing metabolic health. [9] This study is designed as a narrative review to systematically (though not exhaustively) synthesize the proposed mechanisms and practical effects of a high-protein diet combined with exercise on adolescent obesity, and to propose a scientific implementation pathway, offering a reference for both theory and clinical practice.

Definition of Core Concepts

Adolescent obesity

Adolescent obesity is defined as a chronic metabolic state in individuals aged 10–19 years, characterized by excessive body fat accumulation that impairs current or future health. Diagnosis is primarily based on the Chinese standard, "Screening for Overweight and Obesity in School-Age Children and Adolescents," which uses age- and sex-specific body mass index (BMI) percentiles. Obesity is typically defined as a BMI at or above the 95th percentile for the corresponding age and sex. [10] Waist circumference and waist-to-height ratio are also recommended as adjunctive measures to assess abdominal obesity and associated metabolic risks. [11]

High-protein diet

A high-protein diet is a dietary pattern in which the proportion of energy derived from protein is increased to 20%–30% of total daily caloric intake (compared to 10%–15% in a normal balanced diet), or protein intake reaches 1.5–2.0 g per kilogram of body weight per day. [12] In practice, this is often calculated based on ideal body weight or fat-free mass to avoid overestimation in individuals with high body fat. The total energy intake is maintained at an appropriate level, and the overall diet remains balanced. The core principle is to select high-quality, low-fat protein sources, such as lean meats, poultry, fish, eggs, low-fat or skim dairy products, and soy products, integrating these within a holistic healthy eating pattern rather than simply increasing protein intake. [13]

Exercise intervention

In this paper, exercise intervention refers to a planned, structured, and purposeful physical activity program based on exercise science, aimed at improving body composition and metabolic health in obese adolescents. It is primarily divided into two types: aerobic exercise and resistance training. A comprehensive and effective exercise program typically integrates both modalities and clearly prescribes the frequency, intensity, time, and type (FITT principle). For adolescent obesity, the program must be carefully tailored to the physiological characteristics of their developmental stage, as well as individual interests and adherence levels. [14]

Mechanisms of Intervention

Effects on body composition

The combined intervention facilitates fat loss while preserving or increasing muscle mass. Caloric restriction alone often leads to LBM loss, reducing RMR and increasing the risk of weight regain. In the combined approach, regular exercise provides mechanical loading, directly activating muscle protein synthesis pathways. Concurrently, adequate high-quality protein intake supplies the necessary amino acid precursors, effectively counteracting muscle breakdown under a negative energy balance. This establishes an efficient "stimulation + supply" cycle, enabling the body to utilize fat for energy while preserving metabolically active muscle tissue. The result is a lower body fat percentage and increased or maintained fat-free mass, thereby breaking the detrimental cycle of weight loss, metabolic slowdown, and weight regain.

Improvement of metabolic profile

Following the improvement in body composition, the combined approach addresses obesity-related metabolic disturbances through multiple pathways. The preservation or increase of muscle mass significantly enhances insulin sensitivity and glycemic control. [16] The reduction in body fat, particularly visceral adipose tissue, directly lowers the levels of pro-inflammatory adipokines, improves the lipid profile, and reduces triglycerides and low-density lipoprotein cholesterol. [17] Additionally, a high-protein diet can modulate appetite-regulating hormones, increasing levels of satiety hormones (e.g., peptide YY, GLP-1) and decreasing the hunger hormone ghrelin. This appetite-regulating effect, combined with the increased energy expenditure from exercise, facilitates the establishment of a stable and sustainable energy balance. [8]

Effects on exercise performance and physiological metabolism

The combined intervention creates a positive feedback loop that enhances exercise performance and physiological metabolism. Adequate protein supports muscle energy metabolism during exercise and facilitates the timely repair of muscle fibers afterward, which helps delay fatigue, increase muscle strength and endurance, and accelerate post-exercise recovery. [18] Weight loss and improved muscle function reduce the cardiovascular load during daily activities and exercise, alleviate joint stress, and make physical activity feel less strenuous. Aerobic exercise directly improves cardiorespiratory fitness. These physical improvements act

as positive feedback, further motivating adolescents to adhere to the intervention program. [19]

Psychological and behavioral effects

The benefits of the combined intervention extend to psychological and behavioral domains. Achieving tangible changes in body shape, physical fitness, and health markers through personal effort can significantly improve obese adolescents' self-efficacy, body image, and self-esteem, helping to alleviate negative emotions such as anxiety and low self-worth associated with obesity. [20] When a scientific diet and regular exercise together produce positive personal experiences—such as increased energy and a feeling of lightness—this healthy behavior pattern is more likely to be internalized as a personal habit. The resulting improvement in overall physical and mental health, combined with a sense of control over weight management, reinforces the intrinsic motivation for long-term healthy behaviors, which is crucial for the sustainability of obesity intervention effects.

Existing Controversies Regarding Combined Intervention

Despite the promise of a high-protein diet combined with exercise for adolescent obesity, its long-term safety and potential risks—particularly the effects of a high-protein diet on adolescents in a critical developmental stage—remain topics of debate. These controversies primarily focus on the metabolic load on organs, the maintenance of a balanced diet, and the potential for interfering with growth and development.

Organ burden

A primary concern is the increased metabolic load a high-protein diet may place on the liver and kidneys of adolescents. The breakdown of protein produces nitrogenous wastes, such as urea and uric acid, which are primarily excreted by the kidneys. In theory, chronically consuming protein significantly above the recommended intake could increase the glomerular filtration rate and workload on the kidneys, particularly in adolescents whose renal function is not yet fully mature or who have underlying renal conditions. While short-term studies in healthy individuals generally suggest that moderate high-protein intake does not impair renal function, [21] there is insufficient long-term evidence, especially in obese adolescents who may already have subclinical metabolic issues. Furthermore, a high protein load may also increase the liver's gluconeogenic and detoxification workload. Therefore, in practice, it is crucial to screen for pre-existing renal conditions, conduct regular monitoring of renal function, and ensure adequate hydration. [22]

Nutritional imbalance

An overemphasis on high protein can inadvertently lead to an imbalanced diet and deficiencies in other essential nutrients. If adolescents and their families focus excessively on "high protein," they may neglect vegetables, fruits, and whole grains, which are rich in dietary fiber, vitamins, and minerals. This can lead to insufficient intake of these vital nutrients. For example, inadequate fiber intake can impair gut health and satiety, while insufficient calcium, potassium, or magnesium can negatively affect bone health and blood pressure regulation. [23] More concerning, if protein is sourced primarily from poor-quality sources, such as large amounts of red and processed meats, this could also mean excessive intake of saturated fat and cholesterol, which is detrimental to cardiovascular and metabolic health. [24] Therefore, "high protein" must be understood within the context of a balanced diet; the key is to optimize protein quality and quantity, not to overemphasize a single nutrient.

Interference with growth, development, and endocrine function

As adolescents are in a critical period of rapid growth and development, a high-protein diet carries a theoretical risk of interfering with normal hormonal axes and developmental milestones. It has been hypothesized that a long-term low-carbohydrate, high-protein diet could affect the hypothalamic-pituitary-gonadal axis, potentially delaying or altering the normal onset and progression of puberty. [25] However, studies on balanced high-protein diets have not confirmed this, and such concerns are often extrapolated from extreme dietary patterns. [26] Also, a very high protein intake often comes with a significant phosphate load. If calcium intake is insufficient, the calcium-phosphate balance could be disrupted, theoretically posing a long-term risk to achieving peak bone mass. [27] Ensuring adequate calcium and vitamin D intake during the intervention and avoiding extremely low-carbohydrate diets are key strategies to mitigate these risks. It is important to distinguish between these theoretical risks and established findings; the available evidence does not confirm that a well-formulated high-protein diet within recommended ranges harms growth or endocrine function in healthy adolescents.

Implementation Pathway

A practical and safe implementation pathway requires a multi-component, staged approach (**Table 1**).

Conclusion

This narrative review has focused on the proposed mechanisms and scientific implementation pathways of a high-protein diet combined with exercise for adolescent obesity. The available evidence suggests that this combined strategy is a viable approach to improve body composition by reducing fat mass while preserving or increasing lean mass. It may also address metabolic disturbances such as insulin resistance and dyslipidemia, while potentially enhancing exercise performance and psychological well-being. However, the in-

Table 1 | Summary of Implementation Pathway for Combined High-Protein Diet and Exercise Intervention

Component	Key Elements	Details and Considerations
Individualized Assessment	Physical Exam	Height, weight, BMI, waist circumference, body composition (e.g., BIA, DEXA). Blood tests (renal function, lipid profile, glucose, insulin) to rule out secondary obesity and set baselines.
	Dietary Assessment	24-hour diet recalls or food diaries to assess daily energy, macronutrient (especially current protein) and fiber intake, and eating patterns.
	Exercise Capacity	Physical fitness tests or questionnaires to evaluate current activity levels, interests, skills, and sedentary time.
	Psychological Check	Assess motivation for weight loss, self-efficacy, emotional eating, and family support structure.
Intervention Prescription	Dietary Targets	Protein: 1.5–2.0 g/kg of ideal body weight or fat-free mass (not actual weight), or 20-25% of total energy.Distribution: Spread evenly across 3-4 meals, with a focus on post-exercise intake (20-40g).Sources: Prioritize lean meats, poultry, fish, eggs, low-fat dairy, soy, and legumes. Ensure adequate fiber, calcium, and vitamin D.
	Exercise Prescription (FITT)	Aerobic Exercise:- Frequency: 3–5 sessions/week.- Intensity: Moderate (e.g., 40-60% HRR, RPE 12-14).- Time: 30–60 minutes/session.- Type: Walking, jogging, swimming, cycling.Resistance Training:- Frequency: 2–3 non-consecutive sessions/week.- Intensity: 60-80% of 1RM.- Time: 30–45 minutes/session.- Type: Bodyweight exercises, resistance bands, or machine-based exercises for major muscle groups.
Multi-Dimensional Support	Family	Provide education to parents on intervention principles, assist in improving family meals, and offer emotional support.
	School	Integrate resistance training into PE classes. Provide nutrition/health education focusing on protein and exercise. Involve school dietitians for guidance.
	Digital Tools	Use apps for food logging and exercise tracking to facilitate monitoring and feedback. Establish peer support groups for interaction and motivation.
Monitoring & Adjustment	Core Indicators	Re-assess body composition, anthropometrics, and blood markers at regular intervals (e.g., monthly, quarterly). Review diet and exercise logs for adherence.
	Safety Checks	Monitor renal function (creatinine, BUN), hydration, and any gastrointestinal discomfort. Watch for signs of nutrient deficiencies.
	Feedback Loop	Professionals review monitoring data with the adolescent and family, translating positive changes into reinforcement. Adjust the plan based on progress (e.g., fine-tune protein intake, modify exercise intensity, or set new behavior goals).

tervention must be carefully implemented to mitigate the theoretical risks of a high-protein intake on renal function and nutritional balance in adolescents. Future research should prioritize long-term follow-up studies with rigorous safety monitoring, individualized assessments, and the development of collaborative support systems involving families, schools, and communities to ensure the safety, efficacy, and sustainability of this combined intervention. It is crucial to emphasize that "high-protein" should always be understood within the context of a balanced diet tailored to the individual needs of the growing adolescent.

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