

**DIETARY INTERVENTIONS IN YOUNG FEMALE GYMNASTS EFFECTS ON BODY COMPOSITION, HORMONAL HEALTH, AND PERFORMANCE**

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**Abstract:** Young female gymnasts are exposed to high training loads and strict aesthetic demands, placing them at increased risk of low energy availability (LEA), inadequate nutrition, and related physiological dysfunctions. Recent research has focused on dietary interventions to improve body composition, hormonal health, and athletic performance in this population.

Current evidence suggests that chronic energy deficiency is strongly associated with hypothalamic–pituitary–gonadal axis disruption, menstrual irregularities, and impaired bone health. Inappropriate dietary restriction may also reduce lean mass and impair metabolic efficiency. Interventions such as increased caloric intake, individualized macronutrient planning, and nutrition education have shown benefits in restoring hormonal balance and improving physiological outcomes. Adequate carbohydrate and protein intake are particularly important for recovery, training capacity, and performance adaptation.

However, longitudinal and adolescent-specific research remains limited. Future studies should emphasize individualized nutrition strategies and multidisciplinary approaches. Overall, evidence-based dietary interventions are essential for balancing athletic performance with long-term health in young female gymnasts.

**Key words:** Young female gymnasts; dietary interventions; energy availability; RED-S; body composition; hormonal health; athletic performance

## 1 Introduction

Artistic and rhythmic gymnastics are aesthetic sports that require high training volumes and maintenance of a lean physique. During adolescence, these demands coincide with rapid growth and endocrine maturation, increasing the risk of nutritional inadequacy in young female gymnasts [1].

Low energy availability (LEA), caused by insufficient dietary intake relative to exercise expenditure, is highly prevalent in this population [2,3]. Chronic LEA is associated with Relative Energy Deficiency in Sport (RED-S) and the female athlete triad, which includes menstrual dysfunction and impaired bone health [4,5]. Hormonal disturbances caused by LEA suppress the hypothalamic–pituitary–gonadal axis, leading to reduced estrogen levels and increased risk of stress fractures and long-term skeletal complications [8,9].

Body composition is closely linked to gymnastics performance because a high strength-to-weight ratio is essential for technical execution. However, excessive

dietary restriction may reduce lean mass, impair recovery, and negatively affect performance [7]. Adequate carbohydrate and protein intake are therefore critical for supporting energy metabolism, muscle adaptation, and training capacity [10].

Dietary interventions, including improved energy intake, optimized macronutrient distribution, and nutrition education, may help restore hormonal balance and enhance performance outcomes [11]. This review examines the effects of dietary interventions on body composition, hormonal health, and athletic performance in young female gymnasts.

## 2 Nutritional Challenges and Energy Availability in Young Female Gymnasts

### 2.1 Energy Demands and Low Energy Availability

Young female gymnasts train intensively during adolescence, a period of rapid growth and endocrine development, making sufficient energy intake essential for both performance and physiological maturation [13]. However, strong aesthetic and leanness pressures often promote restrictive eating, creating a mismatch between intake and expenditure [6].

Low energy availability (LEA) occurs when dietary energy is insufficient to support normal physiological function after exercise. Optimal levels are ~45 kcal/kg fat-free mass/day, while <30 kcal/kg indicates LEA [3]. Persistent LEA can reduce metabolic rate, impair recovery, and decrease training capacity [14].

Many gymnasts consume 20–30% less energy than recommended, with training load, aesthetic demands, and psychological factors further increasing risk [2,6,15].

### 2.2 Macronutrient and Micronutrient Imbalances

Young female gymnasts frequently exhibit inadequate macronutrient intake. Insufficient carbohydrate consumption reduces glycogen stores and contributes to fatigue and impaired training performance [10]. Inadequate protein intake may limit muscle protein synthesis and recovery, increasing the risk of lean mass loss during energy deficiency [16]. Dietary fat is also commonly restricted despite its importance in steroid hormone synthesis and fat-soluble vitamin absorption, potentially worsening hormonal dysfunction [8].

Micronutrient deficiencies are also common. Calcium and vitamin D insufficiency may impair bone mineralization during adolescence, increasing susceptibility to stress fractures [9]. Iron deficiency, particularly among menstruating athletes, can reduce oxygen transport and contribute to fatigue, impaired aerobic capacity, and decreased cognitive performance [17].

## 3 Effects of Dietary Interventions on Body Composition

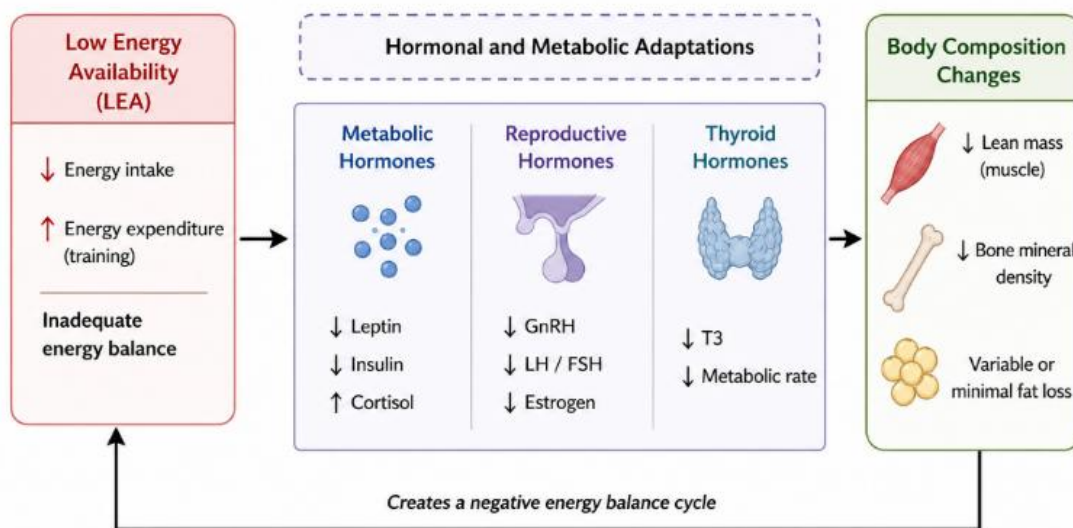
### 3.1 Energy Availability and Body Composition Regulation

Young female gymnasts generally exhibit lower body fat percentages than non-athletic peers, which may benefit performance by improving the strength-to-weight ratio [7]. However, chronic energy restriction can negatively alter normal developmental changes in body composition by reducing lean body mass and impairing recovery [16].

Low energy availability (LEA) induces several adaptive responses aimed at conserving energy, including reductions in resting metabolic rate and suppression of thyroid hormones, insulin, and leptin [14]. These hormonal alterations shift the body toward a catabolic state, promoting the breakdown of both fat and muscle tissue and ultimately compromising metabolic health and performance.

*Impact of Low Energy Availability on Body Composition Regulation*

Figure 1. Impact of Low Energy Availability on Body Composition Regulation



Note. Low energy availability (LEA) leads to hormonal and metabolic adaptations that negatively affect body composition, including reductions in lean mass and bone density, with minimal or variable fat loss.

3.2 Macronutrient Intake and Dietary Interventions

Macronutrient intake plays an essential role in body composition regulation. Carbohydrates are the primary fuel source for high-intensity gymnastics training, and inadequate intake reduces glycogen stores, leading to fatigue and impaired training quality [10]. Protein is critical for maintaining lean body mass and supporting muscle protein synthesis through activation of the mTOR pathway. Insufficient protein intake or poor nutrient timing may therefore impair recovery and muscle preservation during periods of energy deficiency [16].

Dietary fat, although frequently restricted, is necessary for steroid hormone synthesis and endocrine function. Extremely low fat intake may contribute to

reductions in estrogen levels and negatively affect body composition and overall health [8].

Dietary interventions aimed at restoring adequate energy availability are essential for optimizing body composition. Increasing total caloric intake, combined with sufficient protein consumption, supports lean mass maintenance and recovery. In addition, carbohydrate periodization based on training intensity may improve glycogen availability and overall training performance [10].

#### 4 Hormonal Health Mechanisms in Young Female Gymnasts

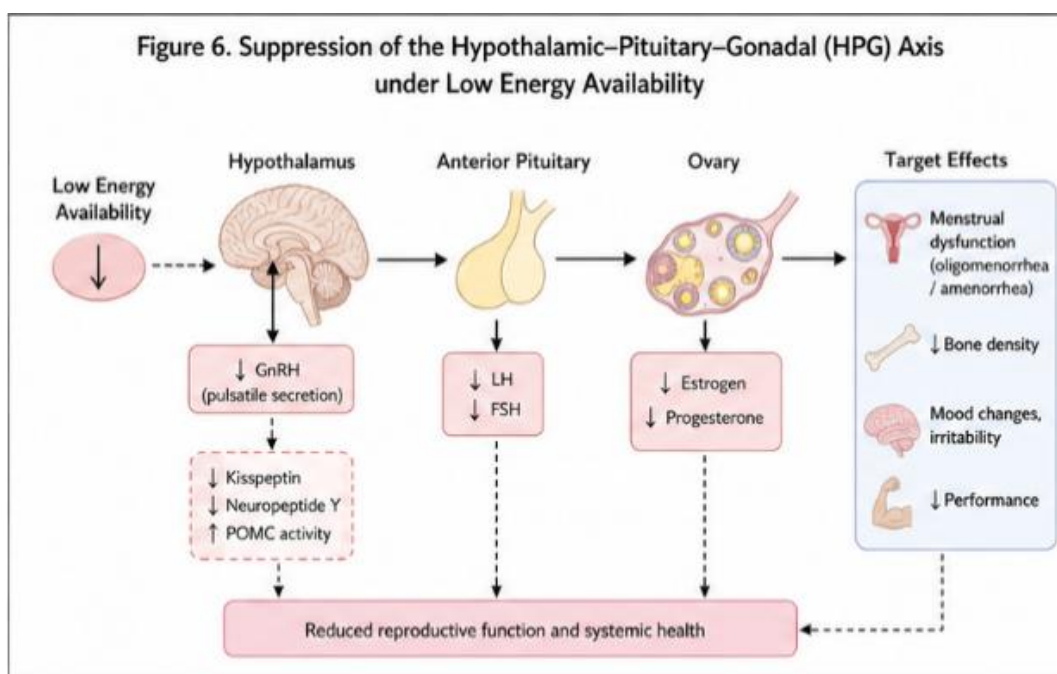
##### 4.1 Endocrine Function and Low Energy Availability

The hypothalamic–pituitary–gonadal (HPG) axis regulates reproductive function through hormonal signaling involving gonadotropin-releasing hormone (GnRH), luteinizing hormone (LH), follicle-stimulating hormone (FSH), and estrogen. Proper HPG axis function is essential for menstrual health, bone metabolism, and overall physiological stability [8]. However, under conditions of low energy availability (LEA), the body suppresses reproductive function in order to conserve energy, resulting in endocrine dysfunction.

##### 4.2 LEA-Induced Suppression of the HPG Axis

Reduced energy availability alters key metabolic hormones, particularly leptin and insulin, which signal energy status to the hypothalamus. Low leptin levels inhibit GnRH pulsatility, leading to reduced LH and FSH secretion and ultimately decreased estrogen production [4,8]. These hormonal alterations contribute to menstrual dysfunction and impaired bone health.

*Low Energy Availability–Induced Suppression of the HPG Axis*

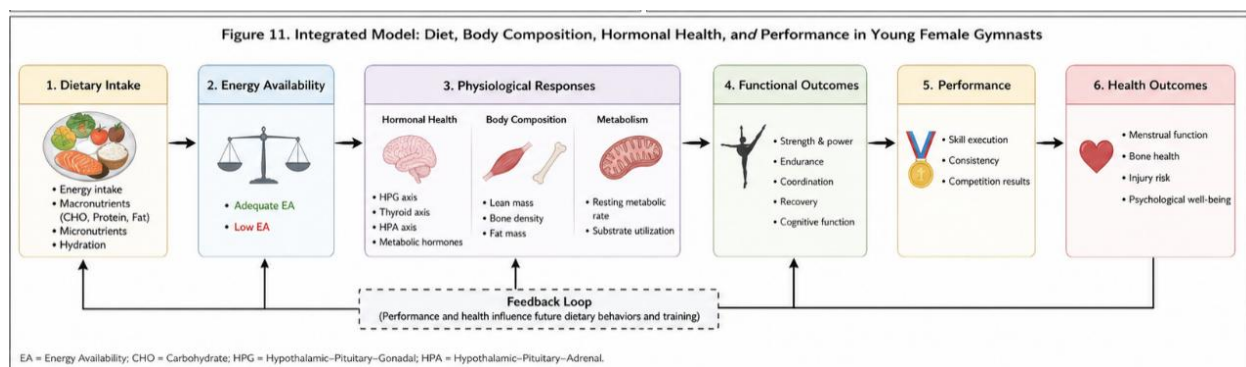


As LEA persists, menstrual disturbances may progress from irregular cycles to functional hypothalamic amenorrhea (FHA), reflecting chronic suppression of the HPG axis and increased long-term health risk [5].

### 4.3 Integrated Hormonal Effects and Dietary Intervention

Hormonal disruption in gymnasts involves multiple endocrine pathways, including reproductive, metabolic, and stress-related systems. LEA may therefore negatively affect bone density, metabolic rate, and recovery capacity in addition to menstrual function..

#### *Integrated Endocrine Model of Energy Availability in Female Gymnasts*



Dietary interventions that restore adequate energy availability can improve hormonal balance and partially reverse endocrine dysfunction, particularly when implemented early. However, prolonged energy deficiency may produce lasting skeletal consequences, emphasizing the importance of prevention and early nutritional management.

### 5 Effects of Dietary Interventions on Athletic Performance

In young female gymnasts, high training loads and limited recovery make performance highly sensitive to nutritional status [10]. Low energy availability (LEA) reduces glycogen stores, impairs mitochondrial function, and weakens neuromuscular efficiency, leading to fatigue, reduced training tolerance, and poorer execution consistency [14].

Carbohydrate availability is critical for high-intensity output; insufficient intake accelerates glycogen depletion, decreasing power and increasing technical errors [10]. In contrast, adequate protein intake supports muscle protein synthesis and recovery by supplying essential amino acids for repair and adaptation [16].

Hormonal status also modulates performance, as estrogen supports muscle function and neuromuscular coordination. LEA-related reductions in estrogen may therefore impair both physical capacity and technical precision [8].

## 6 Research limitations

Most existing studies are cross-sectional, which limits causal inference between dietary intake and physiological outcomes. In addition, many have small sample sizes, especially in elite gymnast populations, and there is no standardized method for assessing energy availability in free-living athletes.

Furthermore, much of the evidence is derived from adult cohorts, with limited data on adolescent gymnasts, leaving an important gap given their distinct developmental and physiological needs [12].

## Conclusion

Dietary interventions play a central role in determining body composition, hormonal health, and athletic performance in young female gymnasts. Chronic low energy availability remains a prevalent issue, with significant implications for endocrine function, bone health, and performance capacity.

Evidence indicates that restoring energy balance through targeted nutritional strategies can effectively improve physiological and performance outcomes. However, successful intervention requires a comprehensive approach that integrates dietary planning, behavioral support, and multidisciplinary collaboration.

Future research should prioritize longitudinal and intervention-based studies to further refine evidence-based guidelines. Ultimately, the goal is to create a sustainable framework that enables young female gymnasts to achieve peak performance while maintaining optimal health throughout their athletic careers and beyond.

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