NUTRITIONAL CHALLENGES AND ENERGY AVAILABILITY IN SCHOOL-AGED FEMALE GYMNASTS: IMPLICATIONS FOR HEALTH AND PERFORMANCE

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Abstract: School-aged female gymnasts are particularly vulnerable to inadequate energy intake due to sport-specific aesthetic demands and high training loads. This narrative review examines the current evidence on energy availability and macronutrient distribution and their effects on growth, body composition, hormonal balance, and athletic performance in young female gymnasts. Low energy availability (LEA) has been consistently associated with delayed maturation, menstrual dysfunction, reduced bone mineral density, and increased injury risk. In addition, imbalanced macronutrient intake—especially insufficient carbohydrate and fat consumption—can further impair metabolic and endocrine function. Practical nutritional strategies, including adequate caloric intake, balanced macronutrient distribution, and individualized dietary planning, are essential for optimizing both health and performance outcomes. Future studies should focus on longitudinal and intervention-based designs in youth athletic populations.

Key words: Energy availability; Female gymnasts; Nutrition; Adolescents; Body composition; Female Athlete Triad (FAT); RED-S

1 Introduction

Artistic gymnastics is characterized by early specialization, high training intensity, and an emphasis on maintaining a lean physique. These demands place young female athletes at increased risk of inadequate energy intake. Energy availability (EA), defined as dietary energy intake minus exercise energy expenditure relative to fat-free mass, is a key concept in understanding athlete health [1,2].

Low EA is strongly associated with the development of Female Athlete Triad (FAT) and the broader condition of Relative Energy Deficiency in Sport (RED-S), which affect multiple physiological systems, including reproductive, skeletal, and metabolic functions [1,3].

Recent literature emphasizes that low energy availability (LEA) is highly prevalent in aesthetic sports such as gymnastics and can lead to multisystem dysfunction if not addressed [1,4]. Therefore, understanding dietary challenges in this population is critical.

2 Energy Availability in Young Female Gymnasts

2.1 Prevalence and Sport-Specific Risk Profile

LEA is highly prevalent in aesthetic sports, with gymnastics consistently identified as a high-risk discipline [1,4]. Recent reviews report that a substantial proportion of adolescent female athletes exhibit behaviors or physiological markers consistent with LEA, even when body mass appears stable [1]. This apparent paradox reflects compensatory reductions in resting metabolic rate and non-essential physiological processes.

2.2 Assessment and Quantification of Energy Availability

2.2.1 Direct and Indirect Measures

①Dietary assessment (24 h recall, food diaries): prone to underreporting in adolescents ②Exercise energy expenditure estimation: variability across training types (e.g., technical vs conditioning sessions) ③Body composition assessment (e.g., DXA, skinfolds): required for FFM normalization

2.2.2 Clinical Screening Tools

①RED-S Clinical Assessment Tool (RED-S CAT) ②Low Energy Availability in Females Questionnaire (LEAF-Q)

These tools integrate physiological and behavioral indicators, including menstrual function, injury history, and gastrointestinal symptoms, providing a multisystem perspective on LEA risk [1,3].

3 Macronutrient Distribution and Its Role

3.1 Carbohydrates

Carbohydrates are the primary energy source for high-intensity and intermittent exercise, which characterizes gymnastics training. Adequate carbohydrate intake is essential for maintaining muscle glycogen stores, supporting neuromuscular performance, and delaying fatigue [8].

Gymnastics routines require precise coordination and explosive movements, both of which depend heavily on adequate carbohydrate availability. Chronic carbohydrate restriction may also contribute to increased reliance on protein as an energy source, potentially compromising muscle maintenance [9].

Recent guidelines suggest that adolescent athletes should consume approximately 3–6 g/kg/day of carbohydrates, depending on training load and intensity [8]. However, studies indicate that many female gymnasts fail to meet these recommendations due to intentional dietary restriction [6].

3.2 Protein

Current evidence suggests that adolescent athletes require approximately 1.2–1.7 g/kg/day of protein to support training demands [9]. However, while protein intake is often adequate or even excessive in some athletes, it cannot compensate for insufficient total energy intake.

Furthermore, excessive emphasis on protein at the expense of carbohydrates may negatively impact glycogen replenishment and overall performance [7].

3.3 Fat

In adolescent female athletes, adequate fat intake is essential for maintaining hormonal balance and reproductive health [10].

Fat intake should generally account for 20–30% of total daily energy intake. However, in aesthetic sports, fat is often disproportionately restricted due to misconceptions about its role in body composition [6].

Emerging evidence suggests that insufficient fat intake may exacerbate the endocrine disturbances associated with LEA, particularly within the framework of RED-S [1,10].

3.4 Micronutrient Considerations (Contextual Integration)

Although this review focuses on macronutrients, it is important to acknowledge that macronutrient imbalance often coexists with micronutrient deficiencies in young female athletes.These deficiencies may further compound the negative effects of LEA, particularly in relation to bone mineral density and performance [11,12].

3.5Practical Implications for Young Female Gymnasts

Macronutrient distribution is a key determinant of health and performance in young female gymnasts. Inadequate intake of carbohydrates and fat, combined with overall energy deficiency, can lead to impaired physiological function and reduced athletic capacity. Balanced and individualized dietary strategies are essential to support optimal development and performance outcomes [6–10].

4 Effects on Growth and Body Composition

4.1 Growth and Maturation

LEA has been associated with delayed growth velocity and pubertal progression, particularly in sports that emphasize leanness such as gymnastics [1,13].

Additionally, reduced levels of insulin-like growth factor-1 (IGF-1), a key mediator of growth, have been observed in athletes with insufficient energy intake [14].

4.2 Bone Health and Peak Bone Mass

One of the most critical consequences of LEA in adolescent female athletes is impaired bone health. Approximately 90% of peak bone mass is achieved by late adolescence, making this period essential for long-term skeletal integrity.

These changes result in reduced bone mineral density (BMD) and increased susceptibility to stress fractures [13,14].

Recent studies indicate that adolescent athletes with LEA exhibit significantly lower BMD compared to their adequately nourished counterparts, particularly in weight-bearing skeletal sites [1].

4.3 Limitations of Body Mass Index (BMI)

Body mass index (BMI) is commonly used to assess weight status; however, it has significant limitations in athletic populations. BMI does not distinguish between fat mass and lean mass and may therefore misclassify athletes. For example:

- A gymnast with low body fat but high muscle mass may appear "normal" or even "overweight" by BMI standards

4.4 Practical Implications

LEA and inadequate nutrition have significant effects on growth and body composition in young female gymnasts. While achieving a lean physique may be desirable for performance, excessive dietary restriction can lead to impaired growth, reduced bone mineral density, and loss of lean body mass. Balanced nutritional strategies are therefore essential to support optimal development and athletic performance [1,6,13–15].

5 Hormonal and Metabolic Consequences

5.1 Strength and Power Output

Studies have shown that insufficient energy intake leads to decreased muscle strength and reduced peak power output, especially in high-intensity activities [7,15]. In adolescent athletes, these effects may be more pronounced due to concurrent growth demands.

Additionally, inadequate carbohydrate intake further limits anaerobic performance capacity, reducing the ability to sustain repeated high-intensity efforts [8].

5.2 Injury Risk and Musculoskeletal Health

One of the most significant consequences of LEA is an increased risk of injury. This is particularly relevant in gymnastics, where repetitive loading and high-impact movements place significant stress on the musculoskeletal system.

Stress fractures are especially common in athletes with chronic energy deficiency and are closely linked to impaired bone health [13,14].

5.3 Practical Implications for Performance Optimization

LEA has a multifaceted negative impact on athletic performance in young female gymnasts, affecting strength, coordination, fatigue resistance, recovery, and injury risk. Although short-term reductions in body mass may seem advantageous, chronic energy deficiency ultimately compromises both performance and long-term athlete development. Adequate nutrition is therefore essential not only for health but also for achieving optimal performance outcomes [6–8,13–15].

5.4 Impact on Athletic Performance

Although short-term weight reduction may improve aesthetics, chronic LEA negatively impacts performance.

Long-term performance decline is often associated with increased injury risk and impaired recovery [4,5].

Conclusion

School-aged female gymnasts are particularly vulnerable to low energy availability (LEA) due to the combined effects of high training demands, aesthetic expectations, and restrictive dietary practices. This review demonstrates that inadequate energy intake and unbalanced macronutrient distribution negatively affect multiple physiological systems, including endocrine, skeletal, metabolic, and reproductive function. During adolescence, these effects are especially concerning because this developmental period is critical for growth, pubertal maturation, and peak bone mass acquisition. The evidence reviewed in this study highlights that LEA is not only a nutritional issue but also a significant health and performance concern in young athletes [1-5].

In addition to its physiological consequences, LEA substantially influences athletic performance. Although short-term reductions in body mass may appear beneficial in aesthetic sports such as gymnastics, chronic energy deficiency ultimately impairs strength, power, coordination, recovery capacity, and training adaptation. Furthermore, inadequate nutrition increases the risk of fatigue, overtraining, and musculoskeletal injuries, particularly stress fractures. These findings emphasize that maintaining an extremely low body weight does not necessarily improve competitive outcomes and may instead compromise long-term athlete development and overall well-being [6-15].

Regular monitoring of growth, menstrual function, body composition, and training load is recommended to identify early signs of LEA and RED-S. Future research should prioritize longitudinal and intervention-based studies focusing specifically on youth female athletes in aesthetic sports. Establishing evidence-based nutritional guidelines tailored to developing gymnasts may help optimize both athletic performance and long-term health outcomes.

References:

[1] Grabia M, Perkowski J, Socha K, et al. Female Athlete Triad and Relative Energy Deficiency in Sport (RED-S): Nutritional Management. Nutrients. 2024.

[2] Cabre HE, Moore SR, Smith-Ryan AE, et al. Relative Energy Deficiency in Sport (RED-S): Scientific and Practical Implications. Dtsch Z Sportmed. 2022.

[3] Coelho AR, Cardoso G, Brito ME, et al. Female Athlete Triad/RED-S Review. Rev Bras Ginecol Obstet. 2021.

[4] Recent epidemiological and review data on female athlete triad prevalence. Science & Sports. 2024.

[5] Contemporary endocrine and metabolic perspectives on LEA in female athletes (review synthesis, 2021–2024 literature).

[6] Logue DM, Madigan SM, Melin A, et al. Low energy availability in athletes: A review. Sports Med. 2018.

[7] Melin A, Tornberg ÅB, Skouby S, et al. Energy availability and athlete health. Int J Sport Nutr Exerc Metab. 2019.

[8] Thomas DT, Erdman KA, Burke LM. Position of the Academy of Nutrition and Dietetics: Nutrition and Athletic Performance. J Acad Nutr Diet. 2016.

[9] Phillips SM, Van Loon LJ. Dietary protein for athletes: From requirements to metabolic advantage. Appl Physiol Nutr Metab. 2017.

[10] Elliott-Sale KJ, Tenforde AS, Parziale AL, et al. Endocrine effects of low energy availability. Sports Med. 2018.

[11] Tenforde AS, Fredericson M. Influence of sports participation on bone health. PM&R. 2016.

[12] Mountjoy M, Sundgot-Borgen J, Burke L, et al. RED-S updated clinical model. Br J Sports Med. 2018.

[13] Ackerman KE, Holtzman B, Cooper KM, et al. Low energy availability and bone health. Curr Opin Endocrinol. 2019.

[14] Cano Sokoloff N, Misra M, Ackerman KE. Exercise, nutrition, and bone health. Endocrinol Metab Clin. 2020.

[15] Heikura IA, Uusitalo ALT, Stellingwerff T, et al. Macronutrient intake in elite athletes. Nutrients. 2021.