

Pubertal development and menarche in rhythmic gymnastics athletes: The influence of training load and energy availability

Milena Gonçalves Mojuski* and Maria Gisele dos Santos

Federal University of Paraná (UFPR), Curitiba, Paraná, Brazil.

World Journal of Biology Pharmacy and Health Sciences, 2026, 27(01), 037–041

Publication history: Received on 23 May 2026; revised on 07 July 2026; accepted on 09 July 2026

Article DOI: <https://doi.org/10.30574/wjbphs.2026.27.1.0381>

Abstract

Rhythmic gymnastics is a sport characterized by high technical demands, intensive training schedules, and strong aesthetic expectations. Because participation often begins during childhood and continues throughout critical stages of growth and development, concerns have been raised regarding the potential effects of training and nutritional practices on biological maturation. This narrative review aimed to analyze the scientific evidence regarding the influence of training load and energy availability on pubertal development and menarche in rhythmic gymnastics athletes. A literature search was conducted using PubMed/MEDLINE, SciELO, and Google Scholar, including publications from 1999 to 2023. The reviewed studies indicate that intensive training combined with low energy availability may contribute to alterations in endocrine function and delayed pubertal development. Menarche has frequently been reported to occur at a later age among elite rhythmic gymnasts compared with non-athlete populations. However, the interpretation of these findings remains complex due to methodological limitations and the potential influence of genetic and constitutional factors. Current evidence suggests that maintaining adequate energy availability and providing multidisciplinary support are essential for promoting healthy growth and reproductive development while preserving athletic performance. Further longitudinal studies are needed to clarify the long-term effects of intensive training on adolescent athletes and to support evidence-based strategies that protect both health and competitive success.

Keywords: Rhythmic Gymnastics; Pubertal Development; Menarche; Energy Availability; Adolescent Athletes; Biological Maturation

1. Introduction

Rhythmic Gymnastics (RG) is widely recognized as one of the most aesthetically demanding sports disciplines. By combining elements of dance, artistic expression, flexibility, coordination, and apparatus manipulation, the sport requires athletes to develop a unique set of physical and technical skills from an early age. Competitions are characterized by routines performed to music using official apparatus such as the hoop, ball, clubs, ribbon, and rope, demanding exceptional precision and body control.

Over the past decades, RG has evolved into a highly competitive sport in which success depends not only on technical proficiency but also on the ability to meet strict physical and aesthetic expectations. As a result, many athletes begin specialized training during early childhood, often between five and seven years of age. Intensive training programs are introduced at a stage when growth and biological maturation are still actively occurring, raising concerns about their potential effects on long-term health and development.

* Corresponding author: Milena Gonçalves Mojuski.

One of the distinctive characteristics of rhythmic gymnastics is the emphasis placed on a lean physique. Traditionally, athletes with long limbs, low body fat levels, and a slender appearance have been favored within the sport. This cultural and competitive environment may encourage strict dietary control and continuous monitoring of body weight, sometimes leading to energy intake that does not adequately support the physiological demands of growth and training.

The period during which training volume increases substantially often coincides with puberty, a critical stage characterized by hormonal changes, accelerated growth, and the development of reproductive function. Adequate nutritional status and energy availability are essential during this phase to ensure healthy maturation and optimal skeletal development. However, when high training loads are combined with insufficient energy intake, important physiological processes may be affected.

For this reason, researchers, health professionals, and sports organizations have increasingly investigated the relationship between intensive athletic training, energy availability, and biological maturation in young female athletes. Particular attention has been given to the timing of pubertal development and menarche, as alterations in these processes may indicate disruptions in normal endocrine function.

The present narrative review aims to analyze the current scientific evidence regarding the influence of training load and energy restriction on pubertal development and the onset of menarche among rhythmic gymnastics athletes. By examining the available literature, this study seeks to contribute to a better understanding of the potential health implications associated with intensive participation in this sport and to support the development of training practices that promote both athletic performance and long-term well-being.

2. Methodology

This study was conducted as a narrative literature review, a methodological approach that allows for a broad examination and critical discussion of existing scientific knowledge on a specific topic. The narrative review format was selected because it enables the integration of findings from different types of studies while providing a comprehensive understanding of the relationship between intensive training, energy availability, and biological maturation in rhythmic gymnastics athletes.

The literature search was performed using three major electronic databases widely recognized in the fields of health and sports sciences: PubMed/MEDLINE, SciELO (Scientific Electronic Library Online), and Google Scholar. Publications released between 1999 and 2023 were considered eligible for analysis. This time frame was chosen to include both pioneering investigations on growth and maturation in gymnasts and more recent studies addressing advances in sports medicine and athlete health monitoring.

The search strategy combined descriptors in English and Portuguese using the Boolean operators AND and OR. The main search terms included “Rhythmic Gymnastics,” “Biological Maturation,” “Menarche,” “Growth,” “Young Athletes,” “Pubertal Development,” and “Pubertal Delay.” Additional combinations were applied whenever necessary to identify relevant publications.

Studies were included if they investigated the effects of rhythmic gymnastics training on pubertal development, age at menarche, body composition, hormonal responses, or growth patterns in female athletes. Original research articles, longitudinal and cross-sectional studies, systematic reviews, dissertations, and theses were considered. Studies focused exclusively on other gymnastics disciplines, publications lacking methodological clarity, and investigations involving athletes who had already completed pubertal development before entering competitive training were excluded.

After the selection process, the information extracted from the eligible studies was organized into thematic categories. The findings were then analyzed and discussed according to their relevance to biological maturation, endocrine adaptations, energy availability, and the potential consequences of intensive training during childhood and adolescence.

3. Review literature

3.1. Biological Maturation and Menarche

Biological maturation is a gradual process that encompasses the physical, hormonal, and functional changes leading an individual from childhood to adulthood. During this period, puberty represents one of the most significant developmental stages, characterized by profound endocrine adjustments and accelerated somatic growth.

In females, pubertal development is primarily regulated by the activation of the hypothalamic-pituitary-gonadal (HPG) axis. The release of gonadotropin-releasing hormone (GnRH) from the hypothalamus stimulates the secretion of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) by the pituitary gland. These hormones act on the ovaries, promoting estrogen production and supporting the development of secondary sexual characteristics, reproductive function, and menstrual cyclicity.

Menarche, defined as the first menstrual period, is widely considered one of the most important indicators of female biological maturation. In most healthy populations, menarche occurs between 11 and 13 years of age, although individual variability is expected due to genetic, environmental, and nutritional factors.

The timing of menarche is influenced by more than chronological age alone. Adequate energy availability, body composition, and overall health status play essential roles in the initiation and maintenance of normal reproductive function. When the body experiences prolonged periods of nutritional insufficiency or excessive physiological stress, adaptive mechanisms may suppress reproductive processes in order to preserve energy for vital functions.

Consequently, inadequate energy intake, excessive training demands, or a combination of both may alter hormonal signaling within the HPG axis. Such alterations can contribute to delayed pubertal progression and a later onset of menarche, particularly among young female athletes participating in sports characterized by high training volumes and strict aesthetic expectations.

3.2. Factors Associated with Delayed Pubertal Development in Rhythmic Gymnasts

Delayed pubertal development among elite rhythmic gymnasts is considered a multifactorial phenomenon resulting from the interaction of intensive training, reduced energy availability, and the aesthetic demands traditionally associated with the sport. Rather than being attributed to a single cause, current evidence suggests that these factors act simultaneously and may influence hormonal regulation during critical stages of growth and maturation.

One of the most frequently discussed contributors is the high training volume commonly observed in competitive rhythmic gymnastics. Elite athletes often participate in training programs that involve several hours of daily practice, multiple times per week, beginning at an early age. Such routines generate substantial physical stress and increase overall energy expenditure. When recovery and nutritional support are insufficient, physiological adaptations may occur that affect endocrine function.

Energy availability has emerged as a particularly important factor in this context. Energy availability refers to the amount of dietary energy remaining for normal physiological processes after accounting for exercise-related energy expenditure. When energy intake does not adequately compensate for the demands of training and growth, the body may enter a state of low energy availability. This condition has been associated with alterations in reproductive hormones, menstrual dysfunction, and delayed maturation.

Body composition may also play a relevant role. Rhythmic gymnastics has historically favored a lean physique, encouraging athletes to maintain low levels of body fat. Because adipose tissue contributes to hormonal regulation through the secretion of metabolic signals such as leptin, extremely low fat stores may influence the mechanisms involved in pubertal progression. Reduced leptin concentrations have been linked to decreased stimulation of the hypothalamic-pituitary-gonadal axis, potentially contributing to later menarche.

Several studies have reported that elite rhythmic gymnasts tend to experience menarche at a later age than non-athlete adolescents or athletes from sports with lower aesthetic demands. Although the magnitude of this difference varies across investigations, the trend has been consistently observed in the scientific literature. The combined effects of intensive training, low energy availability, and pressure to maintain a specific body composition appear to create conditions that may delay the normal progression of reproductive maturation.

It is important to emphasize, however, that delayed menarche does not occur in all gymnasts. Individual responses are influenced by genetic background, nutritional habits, training characteristics, and environmental factors. Therefore, the interaction among these variables should be considered when evaluating the developmental profile of young athletes.

3.3. Current Evidence, Limitations, and Research Gaps

Although numerous studies have explored the relationship between rhythmic gymnastics and biological maturation, important limitations remain within the available body of evidence. As a result, caution is required when interpreting findings and establishing causal relationships.

A significant proportion of published studies employ cross-sectional designs, which provide valuable information regarding the characteristics of athletes at a specific moment but do not allow researchers to determine long-term developmental trajectories. Consequently, it is often difficult to establish whether delayed maturation is a direct consequence of training practices or whether other factors contribute to the observed outcomes.

Another challenge involves the influence of genetic and constitutional characteristics. Some researchers have proposed that girls who naturally mature later and possess body proportions that fit the aesthetic profile favored in rhythmic gymnastics may be more likely to remain in the sport and achieve higher competitive levels. This phenomenon, often referred to as selection bias, complicates efforts to distinguish the effects of training from pre-existing biological characteristics.

Furthermore, differences in study design, sample size, athlete classification, nutritional assessment methods, and definitions of delayed maturation contribute to inconsistencies among findings. Variability across countries and competitive systems may also influence the interpretation of results.

In recent years, increasing attention has been directed toward athlete health and long-term development. Modern training programs have progressively incorporated multidisciplinary support teams composed of physicians, nutritionists, psychologists, physiotherapists, and exercise specialists. These professionals work collaboratively to monitor growth, nutritional status, psychological well-being, and training adaptation.

Such developments represent an important shift in the culture of high-performance sport. Rather than focusing exclusively on competitive success, contemporary approaches emphasize the balance between athletic achievement and the preservation of physical and mental health. Nevertheless, additional longitudinal investigations are still needed to clarify the long-term effects of intensive rhythmic gymnastics training on pubertal development and reproductive health.

4. Conclusion

The evidence examined in this review indicates that rhythmic gymnastics is a sport characterized by substantial physical, technical, and psychological demands. The combination of intensive training schedules, elevated energy expenditure, and pressures related to body composition may influence important physiological processes during adolescence, particularly those associated with growth, pubertal development, and reproductive maturation.

Current scientific findings suggest that delayed menarche and alterations in normal pubertal progression are more frequently observed among elite rhythmic gymnasts than in the general population. Low energy availability appears to be one of the principal mechanisms underlying these outcomes, as inadequate energy intake may interfere with endocrine pathways responsible for regulating reproductive function.

Despite these observations, the available literature does not support simplistic conclusions. The interaction between genetics, training characteristics, nutritional status, and environmental influences remains complex and incompletely understood. Existing methodological limitations, especially the shortage of long-term longitudinal studies, highlight the need for further research capable of providing stronger evidence regarding causality and long-term health consequences.

From a practical perspective, protecting the health of young athletes should be considered a fundamental priority. Training programs should be designed to support normal growth and development while allowing athletes to reach their competitive potential. Regular monitoring of nutritional status, energy availability, growth indicators, and menstrual health can contribute to the early identification of potential risks and facilitate timely intervention.

Ultimately, the pursuit of excellence in rhythmic gymnastics should not come at the expense of healthy biological development. A balanced approach that integrates scientific knowledge, ethical coaching practices, and multidisciplinary support offers the most effective pathway toward sustainable athletic success and long-term well-being for young gymnasts.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

- [1] BORDALO, M. F. S. Evaluation of the effects of two sports training methodologies on growth, biological maturation, and motor fitness of young rhythmic gymnastics athletes. Thesis (Doctorate) – Faculty of Physical Education, State University of Campinas, Campinas, 2012.
- [2] GEORGOPOULOS, N. A. et al. Growth and pubertal development in elite female rhythmic gymnasts. The Journal of Clinical Endocrinology & Metabolism, vol. 84, no. 12, p. 4525-4530, 1999.
- [3] MALINA, R. M.; BOUCHARD, C.; BAR-OR, O. Growth, maturation, and physical activity. 2. ed. São Paulo: Phorte, 2009.
- [4] VIEIRA, J. L. L. et al. Eating behavior disorders and body image distortion in the competitive context of rhythmic gymnastics. Brazilian Journal of Sports Medicine, v. 15, n. 1, p. 35-39, 2009.