



Female athlete triad components in aesthetic sports practitioners: a systematic review

Componentes de la tríada de la atleta femenina en practicantes de deportes estéticos: una revisión sistemática

Authors

Natália Christinne Ferreira de Oliveira ¹
 Júlia Loth Costa ¹
 Beatriz Pardal de Matos ¹
 Juliana Fernandes Filgueiras Meireles ²
 Clara Mockdece Neves ¹

¹ Federal University of Juiz de Fora (Brazil)

² University of Oklahoma Health Sciences Center (USA)

Corresponding author:
 Natália Christinne Ferreira de Oliveira
 natalia.fdo@hotmail.com

How to cite in APA

Oliveira, N., Loth, J., Pardal, B., Meireles, J., & Mockdece, C. (2025). Female athlete triad components in aesthetic sports practitioners: a systematic review. *Retos*, 71, 703-715. <https://doi.org/10.47197/retos.v71.116212>

Abstract

Introduction: Aesthetic sports require technical and artistic skills as well as physical capabilities. These sports are relevant in investigations about risk of eating disorders, and female athlete triad, since athletes who practice this type of sport have a greater risk in these aspects.

Objective: this review aimed to determine how the female athlete triad and its components are assessed by aesthetic sport practitioners and to analyse the prevalence of these components. Furthermore, it sought to identify studies that investigated the associations between these components and the sport-related, anthropometric, sociodemographic, biological and psychological characteristics.

Methodology: this review followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. The studies involved women aged 12 to 44 years practicing aesthetic sports at any competitive level, whether amateur or professional.

Results: a total of 2,950 articles were identified from the search in the first round and 660 in the second round, of which 13 met the inclusion criteria of this review. The study identified various associations between these components and the sport-related, anthropometric, socio-demographic, biological and psychological variables.

Discussion: Regarding the heterogeneity of methodologies and results, it is noteworthy that the use of more costly assessment methods, requires more human and material resources, limiting the ability to include a larger sample from a population that is difficult to capture owing to their sport-dedicated routine.

Conclusions: Methods for assessing the components of the triad and for achieving alignment among the reference values are needed to facilitate the replication and comparison of results.

Keywords

Bone density; feeding and eating disorders; female athlete triad syndrome; menstruation disturbances; systematic review.

Resumen

Introducción: los deportes estéticos exigen habilidades técnicas, artísticas y capacidades físicas. Son relevantes en estudios sobre trastornos alimentarios y la tríada de la atleta femenina, ya que quienes los practican presentan mayor riesgo.

Objetivo: esta revisión buscó analizar cómo se evalúa la tríada de la atleta femenina y sus componentes en deportistas de disciplinas estéticas, así como determinar su prevalencia. Además, se identificaron estudios que relacionan estos componentes con características deportivas, antropométricas, sociodemográficas, biológicas y psicológicas.

Metodología: se siguieron las directrices Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Se incluyeron estudios con mujeres de 12 a 44 años que practicaban deportes estéticos a nivel amateur o profesional.

Resultados: se identificaron 2.950 artículos en la primera búsqueda y 660 en la segunda; 13 cumplieron los criterios de inclusión. Se observaron asociaciones entre los componentes de la tríada y diversas variables deportivas, físicas, sociales, biológicas y psicológicas.

Discusión: la heterogeneidad metodológica y de resultados destaca la dificultad de aplicar métodos costosos de evaluación, que requieren recursos y limitan el tamaño de muestra, especialmente en poblaciones de difícil acceso por sus rutinas deportivas.

Conclusión: es necesario unificar métodos de evaluación y valores de referencia para facilitar la comparación y replicación de estudios futuros.

Palabras clave

Densidad ósea; revisión sistemática; síndrome de la tríada de la atleta femenina; trastornos de alimentación y de la ingestión de alimentos; trastornos de la menstruación.

Introduction

Aesthetic sports (e.g. gymnastics, artistic swimming, figure skating and diving) require technical and artistic skills as well as physical capabilities, such as strength, power, endurance and flexibility (Meng et al., 2020). These sports are relevant in investigations on body image dissatisfaction, eating disorders, and the female athlete triad (Triad), since athletes who practice these sports are at higher risk of suffering from these conditions (Burgon et al., 2023; Chapa et al., 2022; Ferreira et al., 2014; Maimoun et al., 2013; Salas-Morillas et al., 2022).

In 1992, the American College of Sports Medicine defined the Triad and its definition was updated in 2014 to include broader considerations (De Souza et al., 2014; Yeager et al., 1993). The Triad is a syndrome with three interrelated pathological components: low energy availability (LEA), with or without disordered eating (DE); menstrual dysfunction; and low bone mineral density (BMD) (De Souza et al., 2014). These conditions exist on a spectrum with various presentations ranging from health (optimal energy availability, eumenorrhea and optimal bone health) to disease in each component (LEA with or without an eating disorder (ED), functional hypothalamic amenorrhea and osteoporosis), with subclinical conditions throughout this spectrum (De Souza et al., 2014). One of the challenges in recognizing this condition is the limited awareness among coaches, athletes, and health professionals, which contributes to significant underreporting (De Souza et al., 2014; Matzkin et al., 2015). Many athletes may notice symptoms but choose not to disclose them to their healthcare team, further hindering early detection and intervention (De Souza et al., 2014; Matzkin et al., 2015).

More recently, the concept of Relative Energy Deficiency in Sport (RED-S) has been introduced by the International Olympic Committee to broaden the understanding of the consequences of low energy availability beyond the three components of the Triad. RED-S encompasses not only menstrual function and bone health, but also a wide range of physiological and psychological functions affected by energy deficiency, such as metabolic rate, immunity, protein synthesis, cardiovascular health, and mental well-being (Mountjoy et al., 2014; Mountjoy et al., 2023). Although RED-S provides a broader framework, this systematic review focuses exclusively on the classical components of the Female Athlete Triad, and does not address the other aspects included in RED-S.

De Souza et al. (2014) reported the methods employed to diagnose the Triad conditions. Low body mass indice may be a sign of low energy availability and should be checked first (De Souza et al., 2014). The LEA should be diagnosed through dietary intake and energy expenditure calculations based on body composition, in compendiums of physical activity (with values to estimate energy expenditure according to the type of physical exercise), heart rate monitors or accelerometers (De Souza et al., 2014). Additionally, energy metabolism issues are also evaluated by monitoring the levels of cortisol, thyroid hormones and leptin (Mountjoy et al., 2023). LEA can occur with or without the presence of disordered eating/eating disorders (DE/ED), for these, clinical investigation by a multidisciplinary team (physician, mental health provider and sports dietitian) is recommended (De Souza et al., 2014). Menstrual function can be assessed to rule out pregnancies and endocrinopathies and thus verify whether menstrual dysfunction is associated with LEA (De Souza et al., 2014). Questionnaires on menstrual history, physical examination, pregnancy test and hormone levels, such as follicle-stimulating hormone, luteinising hormone, progesterone and oestrogen (De Souza et al., 2014). Finally, bone health can be assessed using dual-energy X-ray absorptiometry (DEXA) as well as the histories of fractures and stress-related bone injuries (De Souza et al., 2014; Mountjoy et al., 2023).

Recent studies have highlighted the prevalence of the Triad among athletes in aesthetic sports. For example, a study with 24 Acrobatics and Tumbling athletes, a popular sport in the United States, showed that more than half (58.3%) of the participants had low energy availability, assessed through 24-hour recalls, a physical activity compendium, and DEXA (De Souza et al., 2024). This study also found that 33.2% had amenorrhea (primary or secondary), measured through questions from the Low Energy Availability in Females Questionnaire (De Souza et al., 2024). Similarly, Smith et al. (2022), a study conducted with cheerleaders, bone mineral density was measured via DEXA, and no athlete presented low bone mineral density. Together, these findings underscore the variability in the presentation of Triad components across different aesthetic sports and emphasize the need for sport-specific investigations to inform prevention and intervention strategies.



There are systematic reviews focusing on the components of the Triad in various sports or artistic contexts that specifically address its components; however, the authors did not identify reviews dealing with the aspects of the Triad, particularly in aesthetic sports (Amorim et al., 2015; Hincapié & Cassidy, 2010; Paludo et al., 2022; Skarakis et al., 2021). It is important to analyse in greater detail the components involved, including the instruments used for assessment and the different sports modalities classified as aesthetic (Reardon et al., 2021). Furthermore, it is important to analyse investigations that explore the possible interconnection of the components of the Triad with the sport-related, sociodemographic, anthropometric, biochemical and psychological characteristics. With a systematic and comprehensive approach, this study helps researchers better comprehend and implement interventions more effectively.

This review aimed to determine how the Triad and its components are evaluated by aesthetic sport practitioners and to analyse their prevalence. It also aimed to identify studies investigating the associations between these components and the sport-related, anthropometric, sociodemographic, biological, and psychological characteristics.

Method

This review followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2020) and is registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the code (PROSPERO registration number masked).

Databases

The searches were performed on Embase, PubMed and Web of Science on 11 March, 2023, and updated on 5 April, 2024.

Search strategy

As the definition of the Triad's components in the form of a spectrum, as understood today, was established in 2007 by the American College of Sports Medicine and reaffirmed by the 2014 Female Athlete Triad Coalition Consensus Statement (De Souza et al., 2014; Nattiv et al., 2007). Consequently, this review includes studies published from 2007 to February 2023. A new search was performed on 5 April, 2024, to include studies published in 2023 and 2024.

The PECO (population, exposure, comparison and outcome) strategy was employed to develop the research question (Table 1). Search terms were selected using Medical Subject Headings (MeSH). The study population included women and exposure focused on athletes in aesthetic sports; the outcome referred to studies evaluating the Triad. The terms related to RED-S and EDs are included within the Triad hierarchy and were also included in the search. For this reason, the authors opted to include search terms related to RED-S in this review. The Boolean operators 'OR' and 'AND' were used between each term and between groups of words, respectively.

Table 1. Search terms based on the PECO search strategy

PECO	Study characteristics	Search terms
Population	Women	(Girls) OR (Girl) OR (Woman) OR (Women Groups) OR (Women Groups) OR (Women's Group) OR (Athlete) OR (Professional Athletes) OR (Athlete, Professional) OR (Athletes, Professional) OR (Professional Athlete) OR (Elite Athletes) OR (Athlete, Elite) OR (Athletes, Elite) OR (Elite Athlete) OR (College Athletes) OR (Athlete, College) OR (Athletes, College) OR (College Athlete) OR (Gymnastic) OR (Gymnastics) OR (Ice Skating) OR (Ice Skatings) OR (Skating, Ice) OR (Skatings, Ice) OR (Bodybuilding) OR (OR (Cheerleading) OR (Artistic Swimming) OR (Diving) OR (Diving's) OR (Swimming) OR (Figure skating)
Exposure	Aesthetic sports athletes	
Comparator	-	
Outcome	Female athlete triad	(Relative Energy Deficiency in Sport) OR (RED-S Relative Energy Deficiency in Sport) OR (RED-S Relative Energy Deficiency in Sport) OR (Female Athlete Triad) OR (Female Athlete Triad Syndrome) OR (Amenorrhoea) OR (Feeding Disorders) OR (Feeding Disorder) OR (Eating Disorders) OR (Disorder, Eating) OR (Disorders, Eating) OR (Eating Disorder) OR (Appetite Disorders) OR (Appetite Disorder)



Eligibility criteria

The articles included in this review were those involving women aged 12 to 44 years (considering reproductive age) practicing aesthetic sports at any competitive level (intercollegiate, university, national and international), whether amateur or professional. The inclusion criteria for the studies and measurements used for each component were defined based on the study conducted by De Souza et al. (2014): Studies that measured LEA through dietary surveys and energy calculations; for menstrual dysfunction, at least a menstrual history was required and for low BMD, studies needed to include BMD measurements through DEXA. To refine the search, the following filters were applied: languages (English, Portuguese and Spanish), age (12–44 years), years (2007–2023), female sex and human species. Studies that investigated only EDs in the population of interest were excluded, whereas those that investigated ED related to LEA were included. During re-screening, articles that also included male athletes and evaluated sports modalities other than aesthetic sports were excluded. Original articles with the following study designs were identified: cross-sectional, cohort, case-control, randomised controlled trials, focus groups and interviews.

Selection process

The selection was independently and blindly performed by two researchers (Author 1 and Author 2), and any doubts and discrepancies were resolved by consulting a third researcher (Author 3). Initially, duplicates were removed, followed by the selection of articles based on their titles and abstracts and finally full-text analysis. The Rayyan software was used for the study selection.

Data extraction

One researcher (Author 1) conducted data extraction and analysis of the articles, which were subsequently reviewed by two other researchers (Author 2 and Author 3). For the data extraction, an Excel spreadsheet was created. The following data were obtained from the texts: 1) full reference (publication year), 2) sample characteristics (including sport modality and level of competition), 3) Triad components investigated, 4) instruments used and 5) main results.

Quality assessment

To assess the quality of the included studies, critical appraisal tools developed and validated by the Joanna Briggs Institute (JBI) were used according to the study design, which could be cross-sectional, case report, case series or cohort (Moola et al., 2020). Each item on the checklists was evaluated with possible responses of 'yes', 'no', 'unclear' or 'not applicable'. The tools for cross-sectional studies and case reports contain 8 items, and studies were classified as low quality (0 to 2 'yes'), moderate quality (3 to 5 'yes'), and high quality (6 to 8 'yes'); the tool for case series contains 10 items, so the study was classified as low quality (0 to 3 'yes'), moderate quality (4 to 7 'yes'), and high quality (8 to 10 'yes'); finally, the tool that analyzes cohort studies has 11 items, and the article was classified as low quality (0 to 4 'yes'), moderate quality (5 to 7 'yes'), and high quality (8 to 11 'yes') (Burgon et al., 2023; Tataryn et al., 2021). This step was performed by the lead author (Author 1) and was reviewed by two authors (Author 2 and Author 3). Additional details on the quality assessment are provided in Supplementary Material 1.

Results

A total of 2,950 articles were identified through database searches. The articles were imported into Rayyan, which is used in conducting reviews. After removing duplicates, 2,633 records remained. Of these, 93 potentially eligible ones were selected based on the title and abstract according to the inclusion/exclusion criteria. In the second analysis, 56 studies were excluded. Thus, 35 articles were screened based on full texts and 12 studies that met the inclusion criteria were identified for this review. In the second manual search performed on April 5, 2024, in the same databases, one article that met the inclusion criteria was identified, thus bringing the total number of articles in this review to 13. No additional articles were identified from other sources (Figure 1).

Majority of the included studies were cross-sectional ($n = 12$) with other study design being cohort ($n = 1$). The investigations were conducted in different countries: United States ($n = 2$), France ($n = 3$), Poland ($n = 2$), China ($n = 1$), Estonia ($n = 1$), Italy ($n = 1$), Norway ($n = 1$), Portugal ($n = 1$) and Turkey ($n = 1$).



The sample included 649 female athletes. Notably, the average age in most of the studies was 20 years. In addition, rhythmic gymnastics was the most investigated sport ($n = 9$) (Table 2).

Low energy availability

Three studies were conducted to evaluate energy availability (kcal) using a specific formula: energy availability = energy intake (kcal/day) – energy expenditure from exercise (kcal/day) divided by fat-free mass (kg) (De Souza et al., 2024; Silva & Paiva, 2014; Smith et al., 2022) (Table 2). For caloric intake assessment, 24-h dietary or food diaries were recorded (De Souza et al., 2024; Silva & Paiva, 2014; Smith et al., 2022). In all cases, information on caloric intake was recorded using a specialised software. All studies used a compendium of physical activities (De Souza et al., 2024) and DEXA was employed to measure the exercise energy expenditure and fat-free mass. In addition, Smith et al. (2022) used polar monitors in their energy expenditure calculations.

Silva & Paiva (2014) defined LEA as values less than 45 kcal/kg of fat-free mass, whereas Smith et al. (2022) and De Souza et al. (2024) established LEA as values below 30 kcal/kg. The prevalence of LEA ranged from 37.3% to 100%. Furthermore, of the 19 cheerleaders in the study by Smith et al. (2020), 10 had LEA associated with the risk of EDs.

Menstrual dysfunction

A total of 11 studies have focused on this aspect (Czajkowska et al., 2019; De Souza et al., 2024; Di Cagno, 2022; Gram et al., 2020; Maïmoun et al., 2013; Meng et al., 2020; Silva & Paiva, 2014; Smith et al., 2022; Roupas et al., 2014; Tatlibal, 2022; Witkoś et al., 2022) (Table 2). In five studies (De Souza et al., 2024; Gram et al., 2020; Meng et al., 2020; Smith et al., 2022; Witkoś et al., 2022) the Low Energy Availability in the Females Questionnaire, a validated questionnaire assessing the risk of Triad, was used, focusing on gastrointestinal function, menstrual history and injuries (Melin et al., 2014). Four of these studies used questionnaires created by the researchers themselves (Czajkowska et al., 2019; Maïmoun et al., 2013; Roupas et al., 2014; Silva & Paiva, 2014). Moreover, studies by Smith et al. (2022) and Meng et al. (2020) assessed oestradiol blood levels as part of their evaluation of this component, in addition to the use of questionnaires.

Different findings were reported across studies. The frequency of irregular menstruation varied from 28.6% to 100% in the studies by Di Cagno et al. (2012), Silva & Paiva (2014), Smith et al. (2022) and Tatlibal (2022). The mean age of menarche was reported by Di Cagno et al. (2012) (15 years); Czajkowska et al. (2019) (13 years); Gram, Clarsen and Bø (2020) (13 years); Maïmoun et al. (2013) (15.6 years); Silva & Paiva (2014) (15.3 years); and Witkoś et al. (2022) (12.6 years). Di Cagno et al. (2012) and Maïmoun et al. (2013) observed that menarche occurred later in gymnasts.

Primary amenorrhoea, defined as the previous absence of menstruation by age 15, ranged from 16.6% to 53.8% in the studies by Meng et al. (2020) [1], Roupas et al. (2014) and De Souza et al. (2024). In addition, De Souza et al. (2024) reported that 16.6% of the athletes had secondary amenorrhoea, defined as the absence of menstruation for three consecutive months in women who had previous menstruation. Oligomenorrhoea, characterised by infrequent menstrual cycles occurring at intervals of >35 days, was observed by Roupas et al. (2014). Conversely, Czajkowska et al. (2019) observed hypermenorrhoea and Witkoś et al. (2022) reported that years of training predicted more pronounced menstrual bleeding among swimmers.

Meng et al. (2020) and Smith et al. (2022) conducted level measurements of oestradiol. The former study found no correlations between oestradiol and the analysed variables, whereas the latter found low oestradiol levels in 2 of 14 cheerleaders analysed. Training hours per week (Di Cagno et al., 2012), physical activity intensity (Czajkowska et al., 2019) and years of training (Witkoś et al., 2022) have also been related to menstrual function. Anthropometric factors also exhibited significant associations with weight and BMI (Di Cagno et al., 2012; Witkoś et al., 2022).

Low bone mineral density

A total of 4 studies were conducted to evaluate low BMD in female athletes using DEXA (Courteix et al., 2007; Jürimäe et al., 2020; Meng et al., 2020; Smith et al., 2022) (Table 2). Moreover, two studies adopted a biochemical approach and collected markers, such as leptin and sclerostin to investigate possible correlations with BMD (Courteix et al., 2007; Jürimäe et al., 2020).

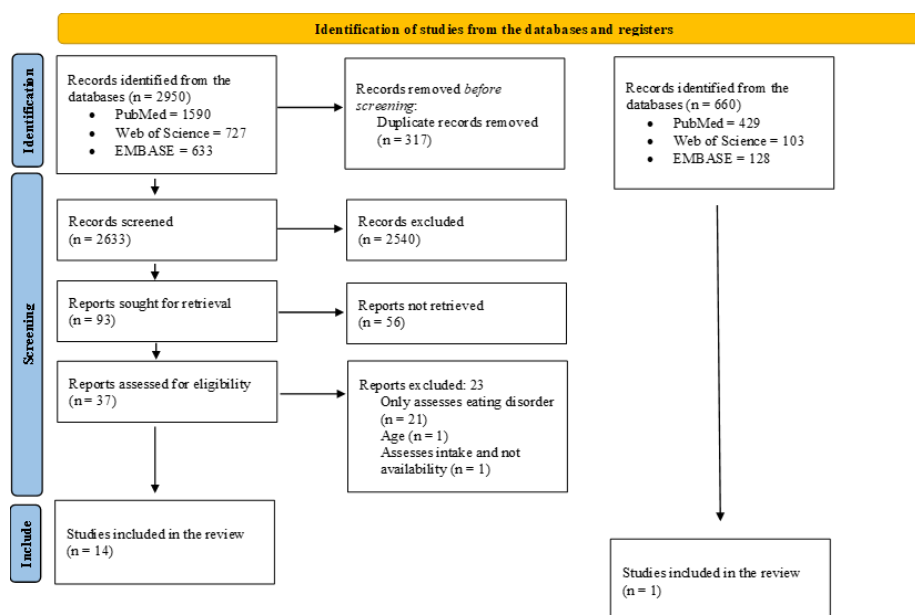


Higher bone values were observed in gymnasts (Courteix et al., 2007; Jürimäe et al., 2020). Meng et al. (2020) and Smith et al. (2022) reported that no gymnast or cheerleader had low BMD. Correlations between bone measures and lean mass, were observed (Courteix et al., 2007). Additionally, Jürimäe et al. (2020) reported that sclerostin levels affect the bone measurements of gymnasts.

Studies that evaluated more than one component

One study evaluated all three aspects of the Triad and none of the athletes combined all three components (Smith et al., 2020). The study conducted by Meng et al. (2020), evaluated menstrual dysfunction and low BMD. Furthermore, the studies by Silva & Paiva (2014) and De Souza et al. (2024) reported results on LEA and menstrual dysfunction. Most studies reporting more than one Triad component did not perform statistical calculations for the associations between variables (De Souza et al., 2024; Smith et al., 2022; Silva & Paiva, 2014) (Table 2).

Figure 1. PRISMA flow diagram.



Characteristics of the included studies

Table 2. Characteristics of Triad and their components

Article	Country	Sample characteristics	Sport	Triad component(s) assessed	Variables associated with the Triad components	Instruments	Key findings
Courteix et al. (2007)	France	36 gymnasts (13.40 ± 1.75 years); 20 controls 12.50 ± 1.65 years)	Rhythmic gymnastics	Low BMD	Lean mass	DEXA, ultrasound, X-ray, blood and urine	Higher bone values in gymnasts; positively correlated with lean mass; no associations with leptin
Czajkowska et al. (2019)	Poland	45 gymnasts (16.28 ± 0.84 years); 40 controls (16.93 ± 1.02 years)	Rhythmic gymnastics	Menstrual dysfunction	Training intensity	Self-developed questionnaire	62.22% reported hypermenorrhea; intense physical activity before menarche, delays menarche
Di Cagno et al. (2012)	Italy	81 gymnasts (15.9 ± 3.1 years); 80 control athletes (16.3 ± 3.7 years)	Rhythmic gymnastics; control: basketball, volleyball, taekwondo and other fitness activities	Menstrual dysfunction	Age, weight and weekly training hours	Menstrual History Questionnaire (MHQ)	Age positively correlated with irregular menstruation and negatively correlated with amenorrhoea; hours of training per week and weight were predictors of age at menarche



Continuation of table 2

Article	Country	Sample characteristics	Sport	Triad component(s) assessed	Variables associated with the Triad components	Instruments	Key findings
Gram, Clarsen and Bø (2020)	Norway	107 gymnasts (14.5 ± 1.6 years)	Rhythmic gymnastics	Menstrual dysfunction	Age, injuries	MD-LEAF-Q	Menarche reduces the chance of substantial injuries.
Jürimäe et al. (2021)	Estonia	22 gymnasts (16.2 ± 1.3 years); 20 swimmers (15.7 ± 0.9 years) and 20 controls (16.5 ± 1.6 years)	Rhythmic gymnastics and swimming	Low BMD	Sclerostin	DEXA and blood sample	aBMD was higher in gymnasts; gymnasts and swimmers had higher sclerostin levels, which were correlated with bone values only in gymnasts; and sclerostin was a predictor of aBMD only in gymnasts
Maïmoun et al. (2013)	France	82 gymnasts (18.3 ± 2.5 years); 51 controls (19.3 ± 3.0 years)	Rhythmic gymnastics	Menstrual dysfunction	Age at menarche, weight and BMI	MD-self-administered questionnaire	Later age at menarche among gymnasts.
Meng et al. (2020)	China	52 elite athletes (20 ± 3 years); 114 recreational athletes (20 ± 2 years)	Trampoline, rhythmic and aerobic gymnastics; dance, cheerleading and dance sports	Menstrual dysfunction and Low BMD	-	MD-LEAF-Q and blood sample; Low BMD-DEXA and LEAF-Q	MD-53.8% of the elite athletes had primary amenorrhoea; MD and Low BMD-no correlation was observed between oestradiol and bone values; Low BMD-none exhibited low BMD
Roupas et al. (2014)	France	80 gymnasts (18.3 ± 2.6 years)	Rhythmic gymnastics	Menstrual dysfunction	-	Custom questionnaire	23.3% had primary amenorrhoea and 45.5% had oligomenorrhea.
Silva and Paiva (2014)	Portugal	67 gymnasts (18.7 ± 2.9 years)	Rhythmic gymnastics	LEA and menstrual dysfunction	-	LEA-24-h dietary recall, physical activity compendium, bioimpedance; MD-self-administered questionnaire	LEA-37.3% had EA < 45 kcal/kg of FFM; 41.9% had EA < 30 kcal/kg of FFM; MD-all had irregular menstrual function
Smith et al. (2022)	United States of America	19 cheerleaders (20.2 ± 1.24 years)	Cheerleaders	LEA, menstrual dysfunction and Low BMD	Risk of ED	LEA-24-h dietary recall, heart rate monitors and DEXA; MD-LEAF-Q and blood sample; Low BMD-DEXA	LEA-100% < 30 kcal/kg of FFM; 52.6% with LEA were at risk of ED; MD-52% reported menstrual dysfunction; 2 of 14 athletes had low oestrogen levels; Low BMD-none were at risk of low BMD.
De Souza et al. (2023)	United States of America	24 athletes: 11 top position (20.1 ± 0.9 years); 13 base position (19.5 ± 1.3 years)	Acrobatics and tumbling	LEA and menstrual dysfunction	-	LEA-24-h dietary recall, physical activity compendium and DEXA; MD-LEAF-Q	LEA-58.3% < 30 kcal/kg of FFM; MD-16.6% primary and 16.6% secondary amenorrhoea
Tatlibal (2022)	Turkey	13 gymnasts (18.31 ± 4.54 years)	Artistic gymnastics	Menstrual dysfunction	-	Menstrual cycle form	28.6% reported irregular menstruation.

Continuation of table 2

Article	Country	Sample characteristics	Sport	Triad component(s) assessed	Variables associated with the Triad components	Instruments	Key findings
Witkoś et al. (2022)	Poland	64 swimmers (24.69 ± 2.15 years)	Swimming	Menstrual function	Weight, BMI, height and years of training	LEAF-Q	Years of training positively predicted menstrual bleeding; negative correlation between menstrual disorders and weight and BMI; more severe menstrual disorders associated with higher injury rates.

Note: DEXA–dual-energy X-ray absorptiometry; MD–menstrual dysfunction; LEAF-Q–Low Energy Availability in Females Questionnaire; aBMD–areal bone mineral density; BMI–body mass index; BMD–bone mineral density; EA–energy availability; FFM–fat-free mass; LEA–low energy availability; ED–eating disorder.

Quality Assessment

All studies were thoroughly analysed using the critical appraisal tools developed by the JBI (Moola et al., 2020). Majority of the studies were classified as moderate quality ($n = 7$), followed by high quality ($n = 4$) and then low quality ($n = 2$). The measurements were objective and standardised across all cross-sectional studies ($n = 12$) and reported as conducted reliably and validly ($n = 10$). However, the sample inclusion criteria were poorly described in 8 of the 13 articles and when confounding factors were evaluated, the criteria were not well elucidated and strategies to address these factors were not employed. Additional details on the quality assessment are provided in Supplementary Material 1.

Discussion

This review aimed to determine how the Triad and its components are assessed by aesthetic sports practitioners and to analyse the prevalence of these components. Among the analysed studies, associations between these components and the sport-related, anthropometric, sociodemographic, biological and psychological characteristics were observed. A total of 13 studies were identified across various aesthetic sports modalities, employing diverse methodologies to investigate the Triad (Table 2).

Low energy availability

Regarding the assessment of LEA, it is noteworthy that only three studies have addressed this measure. An assumption that most studies do not perform this measurement is the additional demand for time, material resources and data collection days required by such assessments [33, 34]. It is also crucial to recognise that the use of calorie measurement instruments, such as food consumption questionnaires, heart rate monitors, accelerometers or standardised tables for energy expenditure calculations, in sports environments does not guarantee an absolute accuracy of energy availability. This is due to substantial variations in measurements depending on the athlete's training phase, their responses and the researcher administering the questionnaire; thus, this limitation should be considered (Burke et al., 2018; Heikura et al., 2022).

In the studies, different limits were established for LEA and varied results were obtained. Historically, a threshold of 30 kcal/kg of fat-free mass has been used to determine the presence of LEA; however, some studies have used values below 45 kcal/kg of fat-free mass as a parameter (Burke et al., 2018). Variations in the limits of energy availability, as well as the difficulty in establishing these thresholds, occur due to individual variability in physiological responses and the different demands of each sport modality (Burke et al., 2018; Heikura et al., 2022). Moreover, reference values are often considered to be more of an ideological concept than a diagnostic tool (Burke et al., 2018).

As regards the associations with energy availability, it is noteworthy that DE is often present in LEA cases in athletes as severe food restrictions and inadequate weight management practices can lead to insufficient energy supply for bodily function and performance (Dambacher et al., 2023).

Menstrual dysfunction



Menstrual dysfunction is mainly evaluated using questionnaires, whether validated or not. From the study results, menstrual questions varied, such as age at menarche, number and duration of cycles, flow intensity as well as premenstrual and menstrual symptoms. In some studies, biochemical markers, such as oestradiol, were also evaluated. In cases of menstrual dysfunction, a thorough investigation covering the athlete's menstrual and family histories, detailed physical examinations and comprehensive laboratory analyses is essential to rule out other gynaecological pathologies and conclude that menstrual disturbance is present as a symptom of Triad (Mountjoy et al, 2014).

Laboratory tests were conducted only in 2 of the 11 studies to measure reproductive hormone levels, possibly due to methodological challenges in female athlete research requiring adequate infrastructure and trained teams (Elliott-Sale et al., 2021; Heikura et al., 2022, 36]. Moreover, the variability in menstrual cycles and hormone levels among athletes may necessitate different approaches and interpretations (Elliott-Sale et al., 2021).

Czajkowska et al. (2019) and Witkoś et al. (2022) observed increased menstrual flow in gymnasts and swimmers. An interesting factor is that in the latter study, such an increase was positively correlated with years of training. In the discussion section, the authors themselves argued that immersion of the body in cold water could lead to a higher internal body temperature, potentially reducing hypothalamic disturbances, which regulate hormones (Witkoś et al., 2022). In addition, swimmers generally have relatively higher body fat levels than other athletes, which provide protection against menstrual cycle disorders (Witkoś et al., 2022). These theories require further investigation for better understanding or refutation as they may sound contradictory because swimming is a sport that values leanness for performance (Burgon et al., 2023). Furthermore, this explanation only covers aquatic sports. Therefore, the causes of hypermenorrhea in gymnasts need to be discussed in future studies.

Associations between menstrual function and training characteristics were found. Scientific literature recognises the influence of training as one of the determining factors of energy availability, which can have a considerable impact on both LEA and other Triad components (Jagim et al., 2022; Logue et al., 2020).

Weight and BMI were the other variables found to have a positive association with this Triad component. Low BMI often reflects inadequate energy and nutritional intake, which can result in a deficiency of essential nutrients, such as calcium, iron and vitamins, negatively affecting hormonal function and menstrual cycles (Jagim et al., 2022). Finally, one study found a positive correlation between age and irregular menstruation and a negative correlation between age and amenorrhoea, which may sound contradictory as amenorrhoea is a type of menstrual dysfunction (De Souza et al., 2024).

Low bone mineral density

To measure Low BMD, the consensus of the Female Athlete Triad Coalition explained that DEXA assessment, as well as stress reaction/fracture histories should be used to investigate the athletes' low BMD (De Souza et al., 2014).

None of the studies found low BMD, whereas Courteix et al. (2007) found higher BMDs in gymnasts and swimmers than in controls, suggesting that sports practice may positively contribute to bone health, particularly as they involve high-impact activities that significantly stress bones, muscles and joints, with one of the benefits being promotion of bone strength (Courteix et al., 2007; Jürimäe et al., 2020).

In terms of associations between gymnastics and sclerostin, the high-impact nature of gymnastics may explain this association (Jürimäe et al., 2020). Sclerostin is an inhibitory protein of bone formation; thus, it should be indirectly proportional to bone measurements; however, the positive association found in the study 'may reflect the possibility of neutralising constant increases in bone formation and bone mass' due to high-impact activities (Jürimäe et al., 2020).

Jointly assessed components

Most studies that addressed more than one Triad component did not conduct statistical analyses of the associations between them. Such a statistical analysis helps understand the interactions among the different Triad components. Among the only study that explored the correlation, between menstrual dysfunction and low BMD, there were no statistically significant results.

General aspects of the review



Regarding the heterogeneity of methodologies and results, it is noteworthy that the use of more costly assessment methods, such as DEXA, dietary questionnaires and blood measurements, requires more human and material resources, limiting the ability to include a larger sample from a population that is difficult to capture owing to their sport-dedicated routine, alongside the lack of standardisation in reference values (Burke et al., 2018; Heikura et al., 2018). Concerning the quality assessment of the studies, although most studies were of high quality and used objective measurements, attention to the inclusion criteria and confounding factors diminishes the possibility of a comprehensive and robust analysis of the results.

One strength of this study is its comprehensive approach, which exclusively extends beyond the analysis of Olympic sports, providing detailed information on the evidence related to the instruments used and the individual aspects comprising Triad and their associations.

The searches were performed only in Portuguese, English and Spanish, which is a bias as it may have excluded relevant studies in other languages. Moreover, future research should consider developing a more comprehensive view of the phenomenon. As a limitation, this study exclusively focused on athletes involved in aesthetic sports, excluding comparisons or investigations involving other populations, such as non-athletes, former athletes and para-athletes. It is noteworthy that studies involving former athletes should also be considered considering the potential long-term consequences of Triad.

Another limitation lies in its search strategy, focused on the primary terms based on the MeSH hierarchy. Specific components like “low energy availability,” “menstrual dysfunction” and “bone mineral density” were excluded to avoid overly broad results. Conversely, “feeding and eating disorders” was included due to its relevance and link to low energy availability. Although justified, this approach may have overlooked studies centered on isolated components.

Conclusions

This systematic review encompassed a collection of studies dedicated to the analysis of athletes in sports where maintaining a lean body composition is emphasised. The selected studies employed diverse research methods and instruments to examine the various Triad components. Moreover, the study found numerous associations between these components and the sport-related, anthropometric, socio-demographic, biological and psychological variables, illustrating how the Triad is interconnected with other health conditions and athlete characteristics. This includes aspects such as body composition, the presence of EDs and alterations in crucial proteins affecting bone function. The studies investigated factors predisposing athletes to that syndrome such as the risk of EDs, as well as long-term consequences such as the time required to restore bone mass and recover from injuries.

This review highlighted that a wide array of methodologies and non-standardised results can limit comparisons between studies and hinder precise conclusions regarding the prevalence of that in aesthetic sports. Therefore, there is a crucial need for a better alignment of assessment methods and reference values to facilitate the replication and comparison of results. Future studies should strive in this direction by seeking reliable evidence on Triad.

Disseminating knowledge about Triad is essential for various audiences, including athletes, coaches, healthcare professionals and athletes' families. Promoting programmes and guidelines to monitor weight, nutrition, menstrual cycles and bone measures can be effective. Educational efforts should encompass the risks, treatment and prevention of that syndrome, with information widely disseminated across all levels of competition, sport and age. This educational approach is crucial for ensuring balanced sports participation, athletic performance and health preservation.



References

- Amorim, T., Wyon, M., Maia, J., Machado, J. C., Marques, F., Metsios, G. S., Flouris, A. D., & Koutedakis, Y. (2015). Prevalence of low bone mineral density in female dancers. *Sports Med*, 45(2), 257–268. <https://doi.org/10.1007/s40279-014-0268-5>
- Burgon, R. H., Beard, J., & Waller, G. (2023). Body image concerns across different sports and sporting levels: A systematic review and meta-analysis. *Body image*, 46, 9–31. <https://doi.org/10.1016/j.bodyim.2023.04.007>
- Burke, L. M., Lundy, B., Fahrenholtz, I. L., & Melin, A. K. (2018). Pitfalls of Conducting and Interpreting Estimates of Energy Availability in Free-Living Athletes. *Int J Sport Nutr Exerc Metab*, 28(4), 350–363. <https://doi.org/10.1123/ijsnem.2018-0142>
- Chapa, D. A. N., Johnson, S. N., Richson, B. N., Bjorlie, K., Won, Y. Q., Nelson, S. V., Ayres, J., Jun, D., Forbush, K. T., Christensen, K. A., & Perko, V. L. (2022). Eating-disorder psychopathology in female athletes and non-athletes: A meta-analysis. *Int J Eat Disord*, 55(7), 861–885. <https://doi.org/10.1002/eat.23748> 2022
- Courteix, D., Rieth, N., Thomas, T., Van Praagh, E., Benhamou, C. L., Collomp, K., Lespessailles, E., & Jaffré, C. (2007). Preserved bone health in adolescent elite rhythmic gymnasts despite hypoleptinemia. *Horm Res*, 68(1), 20–27. <https://doi.org/10.1159/000098546>
- Czajkowska, M., Plinta, R., Rutkowska, M., Brzęk, A., Skrzypulec-Plinta, V., & Drosdzol-Cop, A. (2019). Menstrual Cycle Disorders in Professional Female Rhythmic Gymnasts. *Int J Environ Res Public Health*, 16(8), 1470. <https://doi.org/10.3390/ijerph16081470>
- Dambacher, L., Pritchett, K., Pritchett, R., & Larson, A. (2025). Risk of Low Energy Availability, Disordered Eating, and Menstrual Dysfunction in Female Collegiate Runners. *J Athl Train*, 60(2), 177–184. <https://doi.org/10.4085/1062-6050-0454.23>
- De Souza, L. C., Moris, J. M., Lee, K. M., Fant, K. H., Gallucci, A., & Funderburk, L. K. (2024). Dietary Intake and Menstrual Health among Acrobatics and Tumbling NCAA Division I Student-Athletes. *J Am Nutr Assoc*, 43(1), 101–109. <https://doi.org/10.1080/27697061.2023.2218458>
- De Souza, M. J., Nattiv, A., Joy, E., Misra, M., Williams, N. I., Mallinson, R. J., Gibbs, J. C., Olmsted, M., Goolsby, M., Matheson, G., & Expert Panel (2014). 2014 Female Athlete Triad Coalition Consensus Statement on Treatment and Return to Play of the Female Athlete Triad: 1st International Conference held in San Francisco, California, May 2012 and 2nd International Conference held in Indianapolis, Indiana, May 2013. *Br J Sports Med*, 48(4), 289. <https://doi.org/10.1136/bjsports-2013-093218>
- Di Cagno, A., Marchetti, M., Battaglia, C., Fiorilli, G., Piazza, M., Giombini, A., Calcagno, G., & Buonsenso, A. (2012). Is menstrual delay a serious problem for elite rhythmic gymnasts? *J Sports Med Phys Fitness*, 52(6), 647–653.
- Elliott-Sale, K. J., Minahan, C. L., de Jonge, X. A. K. J., Ackerman, K. E., Sipilä, S., Constantini, N. W., Lebrun, C. M., & Hackney, A. C. (2021). Methodological Considerations for Studies in Sport and Exercise Science with Women as Participants: A Working Guide for Standards of Practice for Research on Women. *Sports Med*, 51(5), 843–861. <https://doi.org/10.1007/s40279-021-01435-8>
- Ferreira, M. E. C., Castro, M. R., & Morgado, F. F. R. (Orgs.). (2014). *Imagem corporal: Reflexões, diretrizes e práticas de pesquisa*. Editora UFJF.
- Gram, M. C. D., Clarsen, B., & Bø, K. (2021). Injuries and illnesses among competitive Norwegian rhythmic gymnasts during preseason: a prospective cohort study of prevalence, incidence and risk factors. *Br J Sports Med*, 55(4), 231–236. <https://doi.org/10.1136/bjsports-2020-102315>
- Heikura, I. A., Stellingwerff, T., & Areta, J. L. (2022). Low energy availability in female athletes: From the lab to the field. *Eur J Sport Sci*, 22(5), 709–719. <https://doi.org/10.1080/17461391.2021.1915391>
- Hincapié, C. A., & Cassidy, J. D. (2010). Disordered eating, menstrual disturbances, and low bone mineral density in dancers: a systematic review. *Arch Phys Med Rehabil*, 91(11), 1777–1789.e1. <https://doi.org/10.1016/j.apmr.2010.07.230>
- Jagim, A. R., Fields, J., Magee, M. K., Kerksick, C. M., & Jones, M. T. (2022). Contributing Factors to Low Energy Availability in Female Athletes: A Narrative Review of Energy Availability, Training Demands, Nutrition Barriers, Body Image, and Disordered Eating. *Nutrients*, 14(5), 986. <https://doi.org/10.3390/nu14050986>



- Jürimäe, J., Karvelyte, V., Rimmel, L., Tamm, A. L., Purge, P., Gruodyte-Raciene, R., Kamandulis, S., Maasalu, K., Gracia-Marco, L., & Tillmann, V. (2021). Sclerostin, preadipocyte factor-1 and bone mineral values in eumenorrheic adolescent athletes with different training patterns. *J Bone Miner Metab*, 39(2), 245–252. <https://doi.org/10.1007/s00774-020-01141-x>
- Logue, D. M., Madigan, S. M., Melin, A., Delahunt, E., Heinen, M., Donnell, S. M., & Corish, C. A. (2020). Low Energy Availability in Athletes 2020: An Updated Narrative Review of Prevalence, Risk, Within-Day Energy Balance, Knowledge, and Impact on Sports Performance. *Nutrients*, 12(3), 835. <https://doi.org/10.3390/nu12030835>
- Maïmoun, L., Coste, O., Georgopoulos, N. A., Roupas, N. D., Mahadea, K. K., Tsouka, A., Mura, T., Philibert, P., Gaspari, L., Mariano-Goulart, D., Leglise, M., & Sultan, C. (2013). Despite a high prevalence of menstrual disorders, bone health is improved at a weight-bearing bone site in world-class female rhythmic gymnasts. *J Clin Endocrinol Metab*, 98(12), 4961–4969. <https://doi.org/10.1210/jc.2013-2794>
- Matzkin, E., Curry, E. J., & Whitlock, K. (2015). Female Athlete Triad: Past, Present, and Future. *J Am Acad Orthop Surg*, 23(7), 424–432. <https://doi.org/10.5435/JAAOS-D-14-00168>
- Melin, A., Tornberg, A. B., Skouby, S., Faber, J., Ritz, C., Sjödin, A., & Sundgot-Borgen, J. (2014). The LEAF questionnaire: a screening tool for the identification of female athletes at risk for the female athlete triad. *Br J Sports Med*, 48(7), 540–545. <https://doi.org/10.1136/bjsports-2013-093240>
- Meng, K., Qiu, J., Benardot, D., Carr, A., Yi, L., Wang, J., & Liang, Y. (2020). The risk of low energy availability in Chinese elite and recreational female aesthetic sports athletes. *J Int Soc Sports Nutr*, 17(1), 13. <https://doi.org/10.1186/s12970-020-00344-x>
- Moola, S., Munn, Z., Tufanaru, C., Aromataris, E., Sears, K., Sfetcu, R., Currie, M., Qureshi, R., Mattis, P., & Mu, P. (Eds.). (2020). *JBİ manual for evidence synthesis*. JBİ. <https://synthesismanual.jbi.global>
- Mountjoy, M., Ackerman, K. E., Bailey, D. M., Burke, L. M., Constantini, N., Hackney, A. C., Heikura, I. A., Melin, A., Pensgaard, A. M., Stellingwerff, T., Sundgot-Borgen, J. K., Torstveit, M. K., Jacobsen, A. U., Verhagen, E., Budgett, R., Engebretsen, L., & Erdener, U. (2023). 2023 International Olympic Committee's (IOC) consensus statement on Relative Energy Deficiency in Sport (REDs). *Br J Sports Med*, 57(17), 1073–1097. <https://doi.org/10.1136/bjsports-2023-106994> Erratum published in *Br J Sports Med*, 58, e4. <https://doi.org/10.1136/bjsports-2023-106994corr1>
- Mountjoy, M., Sundgot-Borgen, J., Burke, L., Carter, S., Constantini, N., Lebrun, C., Meyer, N., Sherman, R., Steffen, K., Budgett, R., & Ljungqvist, A. (2014). The IOC consensus statement: beyond the Female Athlete Triad--Relative Energy Deficiency in Sport (RED-S). *Br J Sports Med*, 48(7), 491–497. <https://doi.org/10.1136/bjsports-2014-093502>
- Nattiv, A., Loucks, A. B., Manore, M. M., Sanborn, C. F., Sundgot-Borgen, J., Warren, M. P., & American College of Sports Medicine (2007). American College of Sports Medicine position stand. The female athlete triad. *Med Sci Sports Exerc*, 39(10), 1867–1882. <https://doi.org/10.1249/mss.0b013e318149f111>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., ... Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ (Clinical research ed.)*, 372, n71. <https://doi.org/10.1136/bmj.n71>
- Paludo, A. C., Paravlic, A., Dvořáková, K., & Gimunová, M. (2022). The Effect of Menstrual Cycle on Perceptual Responses in Athletes: A Systematic Review With Meta-Analysis. *Front Psychol*, 13, 926854. <https://doi.org/10.3389/fpsyg.2022.926854>
- Reardon, C. L., Hainline, B., Aron, C. M., Baron, D., Baum, A. L., Bindra, A., Budgett, R., Campriani, N., Castaldelli-Maia, J. M., Currie, A., Derevensky, J. L., Glick, I. D., Gorczynski, P., Gouttebauge, V., Grandner, M. A., Han, D. H., McDuff, D., Mountjoy, M., Polat, A., Purcell, R., ... Engebretsen, L. (2019). Mental health in elite athletes: International Olympic Committee consensus statement (2019). *Br J Sports Med*, 53(11), 667–699. <https://doi.org/10.1136/bjsports-2019-100715>
- Roupas, N. D., Maïmoun, L., Mamali, I., Coste, O., Tsouka, A., Mahadea, K. K., Mura, T., Philibert, P., Gaspari, L., Mariano-Goulart, D., Leglise, M., Sultan, C., & Georgopoulos, N. A. (2014). Salivary adiponectin levels are associated with training intensity but not with bone mass or reproductive function in elite Rhythmic Gymnasts. *Peptides*, 51, 80–85. <https://doi.org/10.1016/j.peptides.2013.11.003>
- Salas-Morillas, A., Gutiérrez-Sánchez, Águeda, & Vernetta-Santana, M. (2022). Insatisfacción corporal y trastornos de conducta alimentaria en gimnastas: revisión sistemática (Body dissatisfaction and



- eating disorders in gymnasts: a systematic review). *Retos*, 44, 577–585. <https://doi.org/10.47197/retos.v44i0.91042>
- Silva, M. R., & Paiva, T. (2015). Low energy availability and low body fat of female gymnasts before an international competition. *Eur J Sport Sci*, 15(7), 591–599. <https://doi.org/10.1080/17461391.2014.969323>
- Skarakis, N. S., Mastorakos, G., Georgopoulos, N., & Goulis, D. G. (2021). Energy deficiency, menstrual disorders, and low bone mineral density in female athletes: a systematic review. *Hormones (Athens, Greece)*, 20(3), 439–448. <https://doi.org/10.1007/s42000-021-00288-0>
- Smith, A. B., Gay, J. L., Arent, S. M., Sarzynski, M. A., Emerson, D. M., & Torres-McGehee, T. M. (2022). Examination of the Prevalence of Female Athlete Triad Components among Competitive Cheerleaders. *Int J Environ Res Public Health*, 19(3), 1375. <https://doi.org/10.3390/ijerph19031375>
- Tataryn, N., Simas, V., Catterall, T., Furness, J., & Keogh, J. W. L. (2021). Posterior-Chain Resistance Training Compared to General Exercise and Walking Programmes for the Treatment of Chronic Low Back Pain in the General Population: A Systematic Review and Meta-Analysis. *Sports Med Open*, 7(1), 17. <https://doi.org/10.1186/s40798-021-00306-w>
- Tatlibal, P. (2022). Eating attitudes, menstruation cycles and physical profiles of Turkish female elite artistic gymnasts. *PJMHS*, 16(2), 689–692. <https://doi.org/10.53350/pjmhs22162689>
- Witkoś, J., Błazejewski, G., Hagner-Derengowska, M., & Makulec, K. (2022). The Impact of Competitive Swimming on Menstrual Cycle Disorders and Subsequent Sports Injuries as Related to the Female Athlete Triad and on Premenstrual Syndrome Symptoms. *Int J Environ Res Public Health*, 19(23), 15854. <https://doi.org/10.3390/ijerph192315854>
- Yeager, K. K., Agostini, R., Nattiv, A., & Drinkwater, B. (1993). The female athlete triad: disordered eating, amenorrhea, osteoporosis. *Med Sci Sports*, 25(7), 775–777. <https://doi.org/10.1249/00005768-199307000-00003>

Authors' and translators' details:

Natália Christinne Ferreira de Oliveira
 Júlia Loth Costa
 Beatriz Pardal de Matos
 Juliana Fernandes Filgueiras Meireles
 Clara Mockdece Neves

natalia.fdo@hotmail.com
 julia.lothc@gmail.com
 beatriz.pardal@estudante.uff.br
 juliana-meireles@ouhsc.edu
 claramockdece.neves@uff.br

Author
 Author
 Author
 Author
 Author

