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# Female athlete triad syndrome: A bibliometric analysis

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## ABSTRACT

**Introduction:** Menstrual disruption, lack of energy availability (with or without an eating disorder), and decreased bone mineral density are collectively known as the female athlete triad. It is common among young women who engage in athletic activities. This study aimed to identify the female athlete triad patterns and provide nutritional recommendations for female athletes to prevent triad syndrome. **Methods:** This study used a quantitative method with a bibliometric study approach. The inclusion criteria were document type 'Article,' publication stage 'Fully published articles,' source type 'Journal,' and language 'English,' from 2018-2024. Data were analysed using Scopus, VOSviewer, Nvivo 12 Plus, and Rstudio. **Results**: Research on female athlete triad syndrome showed a notable increase in 2014 and 2022. The United States (52 papers), Canada (ten papers), and Japan (nine papers) were the leading contributors. Five key clusters were identified: energy and metabolism, bone mineral density, menstrual disorders, sports injuries, and athlete performance. To effectively address the nutritional needs of female athletes and mitigate the risk of triad syndrome, it is essential to consider these five key clusters. The development of the triad in female athletes is primarily due to insufficient nutrition and calorie intakes, leading to a negative energy balance. **Conclusion:** There is still much to learn, but recent research has focused on minimising risks and maximising benefits for young female athletes by addressing the key clusters identified in this study. Healthcare professionals should educate patients, parents, and coaches about female athletes' potential challenges and the best strategies to support them.

**Keywords:** female athletes, nutrition, triad syndrome

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## INTRODUCTION

The female athlete triad is a medical disorder that impacts female individuals who participate in sports training. The American College of Sports Medicine describes the triad as a cluster of conditions that include low energy availability (LEA) with or without eating disorder (ED), menstrual dysfunction, and low or atypical bone mineral density (BMD) (Cleary Chi & Feinstein, 2018; De Souza *et al.*, 2014; Matzkin, Curry & Whitlock, 2015; Raj, Creech & Rogol, 2023). It has been implicated in a spectrum of long-term health repercussions affecting multiple physiological systems, such as the endocrine, reproductive, cardiovascular, skeletal, and psychological domains (Nattiv *et al.*, 2007).

The concept of relative energy deficiency in sport (RED-S), introduced by the International Olympic Committee in 2014, serves to broaden the understanding of the triad by incorporating additional aspects such as reduced metabolic rate, compromised physiological health, and diminished immune function (Mountjoy *et al.*, 2014). The RED-S descriptions have specific critical differences from the triad descriptions, including the fact that LEA can exist in RED-S when energy intake (EI) and total daily energy expenditure (TDEE) are balanced, indicating that there is no energy deficit at that time (De Souza *et al.*, 2014; Mountjoy *et al.*, 2014). Athletes who remain untreated may confront significant clinical manifestations, including eating disorders and osteoporosis (Hasdemir *et al.*, 2016).

To lose weight or keep a trim figure, patients with disordered eating may engage in various unhealthy behaviours such as dietary restriction, bingeing, and purging. An athlete with severe eating disorders may be at a higher risk of serious illnesses and death. Many athletes do not actually meet the stringent criteria for anorexia nervosa (AN) or bulimia nervosa (BN) (Hobart & Smucker, 2000). To meet the formal criteria for the Diagnostic and Statistical Manual of Mental Disorders bulimia nervosa, athletes need to engage in binge eating and use a purge method, such as vomiting, using laxatives, or diuretics, at least twice a week for a period of three months (Johnson, Powers & Dick, 1999). Additionally, they have to have elevated scores on the Drive for Thinness and Body Dissatisfaction subscales of the Eating Disorder Inventory-2 (EDI-2). Only 1.1% of females reportedly met these criteria for bulimia nervosa, while no males did (Johnson *et al.*, 1999). Women exhibiting the triad may not fulfil the diagnostic criteria for anorexia or bulimia, yet they demonstrate an elevated mortality risk relative to the general population. For health professionals to diagnose eating disorders, they must identify specific diagnostic criteria. Accurate diagnosis of eating disorders necessitates adherence to rigorous criteria established by health professionals (American Psychiatric Association, 2013).

The female athlete triad syndrome has the potential to impact athletes of both genders. Based on the research conducted by Thomas *et al.* (2021), it was observed that a significant proportion of female participants engage in combat sports. Approximately 38% of female collegiate and elite athletes are at risk of female athlete triad, with eating disorders or disordered eating estimated between 15% and 62% (Beals & Manore, 2002; Cobb *et al.*, 2003; Torstveit & Sundgot-Borgen, 2005). The prevalence of disordered eating ranges from 0% to 27% among female athletes and 0% to 21% among the general population (Coelho *et al.,* 2014). The lack of standardised assessment tools for disordered eating can lead to prevalence

estimates as high as 62% among female athletes (Bonci *et al.,* 2008).

Secondary amenorrhoea occurs in about 69% of women in sports like ballet or running, focusing on appearance, compared to 2% to 5% in the general population (Dusek, 2001). About 70% of elite athletes in weight-class sports use disordered eating practices to lose weight before competitions (Sundgot-Borgen & Torstveit, 2010). Between 16% and 47% of female elite athletes reported experiencing a clinical eating disorder (Byrne & McLean, 2002; Sundgot-Borgen & Torstveit, 2010). Participating in sports that prioritise aesthetics and leanness often leads to low energy intake and eating disorders (Krentz & Warschburger, 2013). It has been noted that diets and body dissatisfaction are prevalent among elite figure skaters (Jonnalagadda, Ziegler & Nelson, 2004). The pursuit of weight loss for improved athletic performance is linked to changes in disordered eating at an individual level (Krentz & Warschburger, 2013). Athletic activities like ballet, figure skating, gymnastics, long-distance running, swimming, and diving that emphasise a slim physique can heighten the risk of female athlete triad (Tosi *et al.*, 2019). Low body weight, primary amenorrhea, and irregular periods have been associated with adolescent dance participation (Castelo-Branco *et al.*, 2006). A study of ultra-marathon runners in South Africa found that 7.5% were aware of the triad, and 44.1% were at risk (Folscher *et al.*, 2015). Teenagers, skaters, and runners have a lower risk of the triad syndrome, but young adults and dancers have a higher risk (Tosi *et al.*, 2019).

Evaluating female athletes for the triad is crucial to preserve bone mineral density, especially since women lose the most bone mass during the first four to six years after menopause (Hobart & Smucker, 2000). Interventions for amenorrhoeic athletes should occur before significant bone loss happens. Recent research showed that peak bone mass is reached earlier than age 30, typically between 18 and 25 years old. Therefore, support for women with irregular or delayed menstruation should begin in youth (Hobart & Smucker, 2000). A study found that amenorrhoeic women who resumed regular periods saw an average increase in bone mineral density of 6% after 14 months (Hobart & Smucker, 2000). The growth rate dropped to 3% the following year, resulting in bone mineral density well below normative levels for their age. This highlights the importance of early intervention to prevent permanent bone density loss (Hobart & Smucker, 2000).

Dietary deficits should prompt an assessment by a primary care or sports medicine practitioner (Holtzman & Ackerman, 2021). Athletes who consult a sports dietitian can gain substantial benefits, as they are often overwhelmed by misleading nutritional information on social media, where many promote unverified diets for performance and appearance enhancement (Holtzman & Ackerman, 2021). Many athletes may face health risks from specific regimens too. Around 47% of female athletes are at risk of inadequate calorie intake, leaving them vulnerable to poor nutrition advice (Ackerman *et al.*, 2019; Bratland-Sanda & Sundgot-Borgen, 2013). This study aimed to identify trends in the female athlete triad syndrome and provide recommendations and suggestions to prevent the triad syndrome in female athletes, particularly in nutrition.

## METHODOLOGY

### Materials

This study used a qualitative literature review methodology. A qualitative systematic review involves systematically searching for research evidence

from primary qualitative studies and synthesising the findings (Seers, 2015). This methodology aligns with the study's goals of identifying patterns related to the female athlete triad and providing nutritional guidance for female athletes regarding triad syndrome. Internationally recognised peer-reviewed journals were sourced from Scopus, a meticulously curated database known for its stringent selection process, where articles were reviewed and chosen by an independent Content Selection and Advisory Board (CSAB) composed of experts across various scientific fields, ensuring that only high-quality content is indexed, affirming Scopus's credibility (Baas *et al.*, 2020). Many studies on female athlete triad syndrome were available in the Scopus database using the keywords "female athlete" and "triad syndrome". Undergraduate bibliometric analysis can evaluate the effectiveness and performance of academic journals through citations and authors (Zhao & Strotmann, 2015). Citations elucidate the relationships among individual authors and various elements such as subject matter, topics, methodologies, and co-authors.

**Research strategy and selection criteria**

This study employed the Scopus database, recognised for its extensive collection of peer-reviewed literature, to investigate female athlete triad syndrome. The focus was on research articles published from 2013 to 2024, with a systematic search conducted on December 26, 2024, highlighting the necessity of incorporating recent references to contextualise the discussion. The literature search aimed to identify topics sufficiently detailed for specific exploration, while remaining broad enough to facilitate broader theoretical or practical applications. Selection criteria for inclusion stipulated that articles should be research-based, published in medicine, in English, and finalised between 2018 and 2022. Articles not in the final publication stage and those outside medicine were excluded from the review. The methodology is outlined in Figure 1.

**Data extraction**

Keywords and data on publication year were gathered and subsequently filtered by subject area and final article, focusing on English texts. This information is essential for researchers to identify and analyse patterns and trends associated with the female athlete triad syndrome.

**Analysis of data**

Data were exported in RIS format for sharing research maps. Analyses were done using tools like VOSviewer, Nvivo 12 Plus, and RStudio, applying descriptive methods to Scopus results by publication year, country, and topic. In the interim, VOSviewer created a bibliometric map of research progress based on the critical topic of female athlete triad syndrome. VOSviewer, version 1.6.18 (Leiden University's Centre for Science and Technology, Leiden, Netherlands, released on January 24, 2022) was used. The data were refined numerous times to obtain information on female athlete triad syndrome. The NVivo 12 Plus (Lumivo, Colorado, United States of America, released on March 20, 2018) application examined the correlations between the indicators, variables, and keywords used in this study. The dataset was transformed into BibTeX format and analysed using Bibliometrics in R version 3.6.3 (Posit PBC, Vienna, Austria, released on February 29, 2020). The dataset included information on the distribution of publications by country/region, year of publication, authors, and keywords. This correlation was done to assess the female athlete triad syndrome. VOSviewer software also mapped the

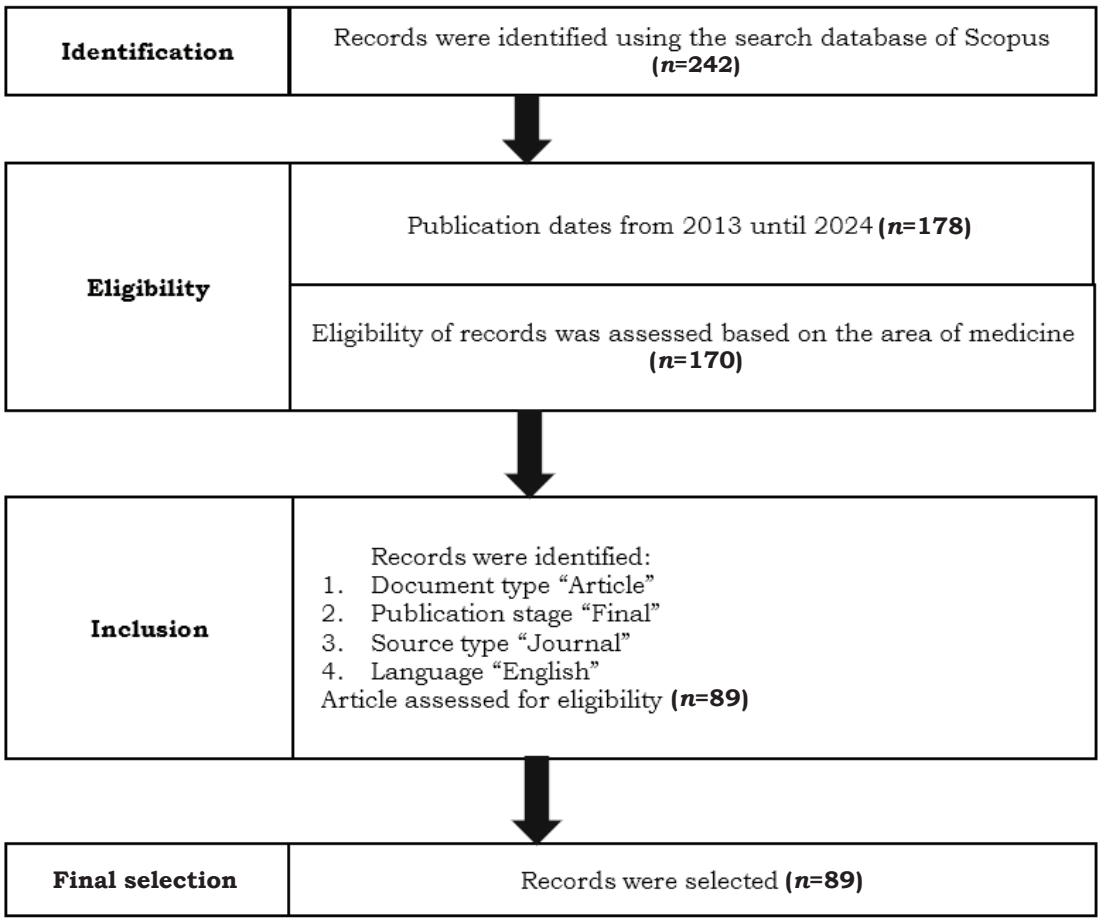


**Figure 1.** Steps in collecting article

most popular terms when researching the female athlete triad syndrome. The author's or title's keyword was used to construct the context of sports sciences. These results contained 89 documents from the Scopus database.

## RESULTS

### Document publications

The trend of papers about female athlete triad syndrome in the last ten years is shown in Figure 2. These findings were derived from the leading nation identified by Scopus over the past ten years, in conjunction with the top ten publications associated with the foremost ten athletes. The top ten nations were ranked based on the performance of their athletes in international sporting events, as evidenced by research output articles. Studies on female athlete triad syndrome across 71 countries were built upon several papers. It depicted how scientific production was distributed geographically in the United States (52 papers), Canada (ten papers), Japan (nine papers), the United Kingdom (seven papers), Australia (six papers), Norway (five papers), Brazil (four papers), Denmark (three papers), Israel (three papers), and Sweden (three papers).

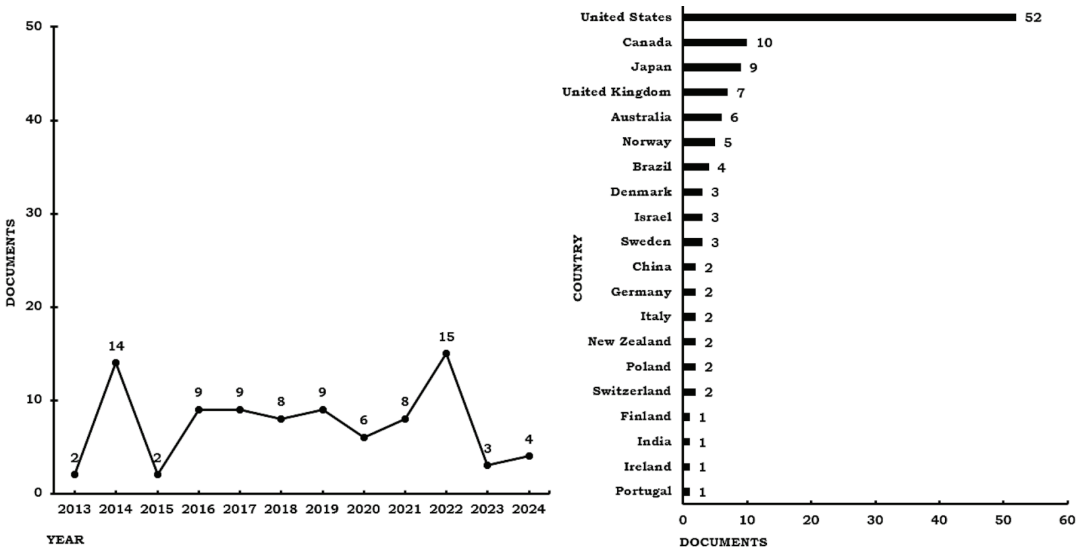


**Figure 2.** Number of document publications by year (left) and by country (right) on triad syndrome in female athletes

**Keyword analysis**

The analysis of 89 documents in this study encompassed the years 2013 through 2024. Over the past decade, more publications on female athlete triad syndrome have appeared, especially in 2014 and 2022, indicating an annual increase in trends. Discussions on lumbar spine, body mass, and amenorrhoea occurred in 2020. Research in 2021 discussed energy deficiency, LEA, energy metabolism, and sport. In 2022, there were LEA, menstrual cycle, female athletes, and triad syndrome. The trend in 2023 was relative energy deficiency in sports, while in 2024, it was bone health. These data are in line with the graphic obtained from Rstudio. The trends from 2013 to 2024 were also associated with the female athlete triad, amenorrhoea, bone mineral density, disordered eating, LEA, energy availability, relative energy efficiency, running, and bone health (Figure 3).

Table 1 shows the most popular keyword mappings from the authors and the databases. Authors frequently used the keywords "Female athlete triad syndrome" (*n*=1514), "Female athlete triad" (*n*=1288), and "Athlete" (*n*=941). Moreover, in the author's plus, the repeated keywords were "Sports" (*n*=1597), "Bone" (*n*=1304), and "Athlete" (*n*=1118). The chosen keywords should encompass the entire research subject and serve as a trend indicator for more studies. The keywords in the authors' and author's plus are related. They have similar top keywords. Based on the bibliography periodicity requirements of at least five words each year, the width or size of the circle showed the frequency of the author's keyword phrases. Keywords like sports (*n*=1597), bone (*n*=1304), athlete (*n*=1118), triad (*n*=1118), and energy (*n*=791) became the top five keywords.

NVivo 12 Plus was used to analyse Table 1 and present the Pearson correlation coefficient score for the female athlete triad syndrome keywords. Table 1 presents the degree of similarity for each pair of items based on the chosen similarity metric. Items with a high similarity index (maximum=1) indicated a strong resemblance. The

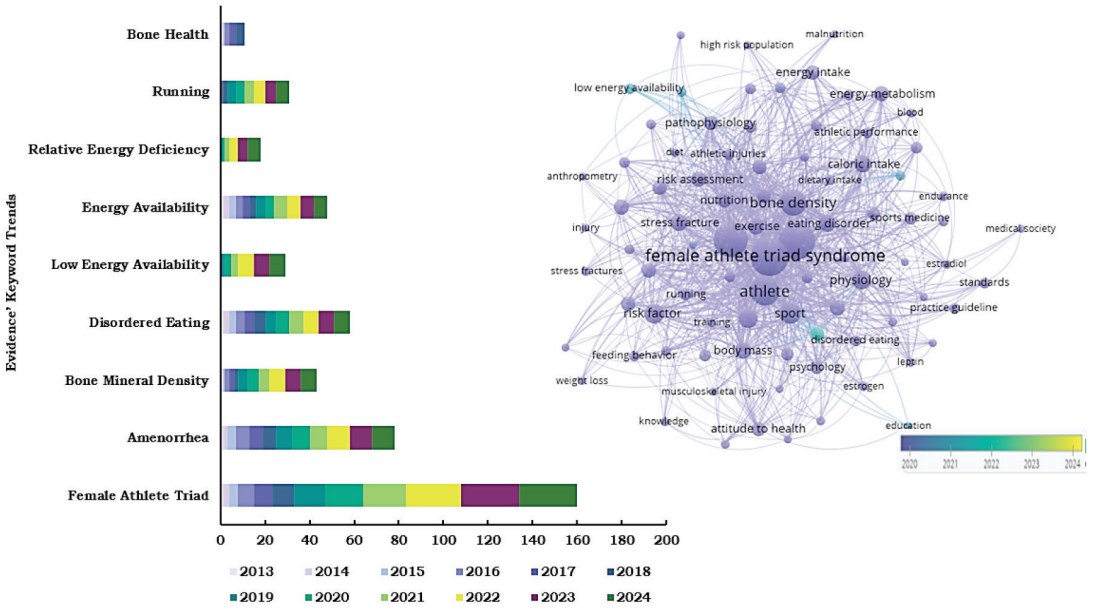


**Figure 3.** Keyword trends of triad syndrome in female athletes by year (left: RStudio, right: VOSviewer)

researchers discovered a substantial positive association between female athletes with the triad, risk factors, density, eating, sports, body, energy, stress, bone, and injury, ranging from 0.97 to 0.83 (Table 1).

VOSviewer was used to assess all the keywords that were retrieved. The bibliometric mapping of female athlete triad syndrome was segmented into five clusters using VOSviewer (Table 2): Cluster 1 examined energy and metabolism, Cluster 2 discussed bone mineral density, Cluster 3 covered menstrual disorder, Cluster 4 examined sports injury, and Cluster 5 discussed athlete performance.

## DISCUSSION

The analysis of research output revealed that the top ten countries publishing on female athlete triad syndrome include the United States (52 papers), Canada (ten), Japan (nine), and the United Kingdom (seven). These nations also rank prominently in global sports competitions. While participation in sports and exercise is beneficial for women across all age groups, extreme dieting and intensive training regimens may lead to serious health ramifications, particularly in the female athlete triad. Evidence suggests that athletes engaged in sports requiring subjective evaluation, such as figure skating, gymnastics, and elite ballet, as well as endurance sports that emphasise leanness, face increased risks for developing this condition. Additionally, individual sports have a significantly higher prevalence of at-risk athletes than team sports (Dipla *et al.*, 2021). Nevertheless, it is crucial to highlight that symptoms of the triad can manifest in both female athletes and non-athletes across many sports (Matzkin *et al.*, 2015).

Female athletes who experience the triad may experience impacts on their energy availability, menstrual function, and bone mineral density. This can lead to issues like disordered eating, irregular periods, and stress fractures (Thein-

**Table 1.** Keywords correlation using NVivo 12 Plus

| *Using VOSviewer* | | *Using NVivo 12 Plus* | | *Keywords correlation using Nvivo 12 Plus* | | | *Pearson correlation coefficient* |
|---|---|---|---|---|---|---|---|
| *Authors' Keywords* | *Frequent* | *Authors' Plus* | *Frequent* | *Main Keyword* | *Code A* | *Code B* | |
| Female athlete triad syndrome | 1514 | Sports | 1597 | | Female athlete | Triad | 0.97 |
| Female athlete triad | 1288 | Bone | 1304 | | Female athlete | Risk | 0.87 |
| Athlete | 941 | Athlete | 1118 | | Female athlete | Factors | 0.87 |
| Bone density | 883 | Triad | 1118 | | Female athlete | Density | 0.86 |
| Sport | 547 | Energy | 791 | Female athlete triad syndrome | Female athlete | Eating | 0.86 |
| Amenorrhoea | 524 | Eating | 588 | | Female athlete | Sports | 0.85 |
| Risk factor | 481 | Medicine | 569 | | Female athlete | Body | 0.84 |
| Physiology | 480 | Risk | 558 | | Female athlete | Energy | 0.84 |
| Eating disorder | 424 | Health | 507 | | Female athlete | Stress | 0.83 |
| Body mass | 414 | Stress | 482 | | Female athlete | Bone | 0.83 |

Nissenbaum, 2013). Tosi *et al.* (2019) stated that the triad has been linked to short-term and long-term health and sports performance problems. The phenomenon encompasses various factors, such as diminished energy availability (EA), irregular menstrual cycles, and reduced or anomalous BMD (De Souza *et al.*, 2014; Edama *et al.*, 2021; Patel *et al.*, 2024; Tosi *et al.*, 2019). The three elements of the triad are interrelated (Cleary *et al.*, 2018), each with a different response, from typical to varying levels of pathological manifestations (Dipla *et al.*, 2021).

This research highlighted that trends of the triad syndrome in female athletes are related to energy and metabolism, bone mineral density, menstrual disorders, sports injuries, and athlete performance. In contrast to other studies, this research did not find a connection between triad syndrome and injuries such as bone stress fractures or bursitis (Edama *et al.*, 2021; Rauh, Barrack & Nichols, 2014; Tenforde *et al.*, 2018). Energy balance and metabolic function are critical factors in the development and progression of the female athlete triad syndrome. Athletes experiencing negative energy balance due to insufficient nutrition or caloric intake, stemming from behaviours such as dieting, veganism, food restriction, purging, stimulant use, or laxative abuse, are at a heightened risk for the emergence of a clinically defined eating disorder (Brown *et al.*, 2017). According to Areta, Taylor & Koehler (2021) and Loucks (2014), the amount of dietary energy that remains accessible after workouts for all other

**Table 2.** Identification of published documents on female athlete triad syndrome

| *Clusters' Themes* | *Items* | *Total* | *Percentage* |
|---|---|---|---|
| Cluster 1: Energy and metabolism | Blood, bone health, caloric intake, diet, dietary intake, energy availability, energy expenditure, energy intake, energy metabolism, estradiol, estradiol blood level, oestrogen, female athletes, leptin, menstruation disorder, metabolism, oral contraceptive agent, physiology, progesterone, protein intake, resistance training, thyrotropin, vitamin D, weight reduction | 24 | 27% |
| Cluster 2: Bone mineral density | Absorptiometry, body composition, body height, bone, bone density, bone mineral density, complication, endurance, feeding and eating disorder, low energy availability, low energy availability intake, lumbar spine, lumbar vertebra, photon absorptiometry, physical activity, physical endurance, relative energy deficiency in sport, secondary amenorrhoea, sport, weight loss | 20 | 22% |
| Cluster 3: Menstrual disorder | Amenorrhoea, anorexia nervosa, body mass, body mass index, disordered eating, eating disorder, feeding behaviour, mass screening, menarche, menstrual irregularity, menstruation, menstruation disturbance, oligomenorrhea, osteoporosis, physical examination, prevalence, training | 17 | 19% |
| Cluster 4: Sport injury | Athletic injuries, body image, body weight, exercise, fractures, stress, injury, nutrition, pathophysiology, risk factor, running, sport injury, sports nutritional physiological phenomena, stress fracture, swimming | 15 | 17% |
| Cluster 5: Athlete performance | Athlete, athlete performance, attitude to health, dancing, female athlete triad syndrome, health knowledge, attitude, menstrual cycle, practice guideline, procedures, psychology, risk assessment, sports medicine, standards | 14 | 16% |

physiological activities in an athlete's body is considered energy availability (Areta *et al.*, 2021; Loucks, 2014). The efficiency of operation relies on energy supply, defined as the balance between energy consumed during physical activity and lean body mass. Decreased energy availability can therefore lead to insufficient energy for bodily functions, causing a homeostatic imbalance known as LEA (Areta *et al.*, 2021; Oxfeldt *et al.*, 2023).

The links between female athlete triad (FAT) syndrome with energy metabolism, BMD, menstrual disorders, and sports injuries can vary significantly among athletes. Studies have shown a clear connection between FAT factors—

LEA, menstrual dysfunction, and low BMD, with an increased risk of injuries, particularly stress fractures and overuse injuries, in female athletes (De Souza *et al.*, 2014; Kim & Weber, 2023; Nattiv *et al.*, 2007). However, research has also shown that athletes with LEA, particularly in non-weight-bearing sports like swimming and cycling, do not always experience BMD or menstrual dysfunction declines. Some studies indicated that these athletes can maintain normal bone density despite significant energy deficits, challenging the assumption of universal bone loss in all sports (Grabia *et al.*, 2024; Warrick *et al.*, 2023). Performance outcomes are not always negatively affected by menstrual irregularities or LEA. Some endurance athletes maintain high performance despite menstrual dysfunction, indicating that factors like training intensity and recovery practices can mitigate the effects of FAT (Grabia *et al.*, 2024; Warrick *et al.*, 2023). Research has also shown that sports injuries, especially non-stress fractures, are not always linked to FAT, with injury patterns differing by sport-specific demands (Warrick *et al.*, 2023). These findings challenge the simple link between FAT and athletic performance, highlighting the need for a more personalised understanding of how the triad components affect various athletes.

Previous studies have shown that when energy availability (EA) drops below 30 kcal $kg^{-1}$, it may affect pulsatile luteinising hormone (LH) secretion, defining "low EA." An EA of about 45 kcal per kg of fat-free mass per day is suggested as optimal for maintaining body mass while allowing athletes to focus on skill development (Holtzman & Ackerman, 2021). Low EA is a crucial aspect of the triad, as it activates various endocrine systems that reduce energy expenditure (Hutson *et al.*, 2023; Loucks, 2014). Based on pathophysiology, Raj *et al.* (2023) explained that energy availability is the most critical factor in disordered eating, whether intentional or not. It involves a nutritious diet, fasting, skipping meals, and using diet pills. Insufficient energy availability can lead to menstrual disorders and lower mineral density in female athletes (Amoruso *et al.*, 2024; Jagim *et al.*, 2022; Logue *et al.*, 2020). According to Brown *et al.* (2017), a reduction in EA has been observed to alter the pulsatile release of Gonadotropin-Releasing Hormone (GnRH), potentially resulting in a state of hypoestrogenism in athletes (Brown *et al.*, 2017). The influence is facilitated by the mechanisms of LH and follicle-stimulating hormone (FSH). Hypoestrogenism is associated with disruptions in the regularity of menstrual cycles and a reduction in bone mineral density.

Adolescent athletes with the triad may experience menstrual disorders such as amenorrhoea, oligomenorrhoea, and ovulation issues. Menstrual function ranges from eumenorrhoea to amenorrhoea, with primary amenorrhoea after age 15, secondary amenorrhoea lasting three cycles, and oligomenorrhoea defined as a cycle every 35 days or fewer than nine cycles per year (Brown *et al.*, 2017; Matzkin *et al.*, 2015). Hypothalamic amenorrhoea is a condition often seen in individuals with dietary disorders and elite female athletes. It disrupts menstrual cycles and is linked to increased exercise and weight loss due to suppressed GnRH secretion, leading to oestrogen deficiency and anovulation (Nazem & Ackerman, 2012; Podfigurna & Meczekalski, 2021). Women with chronic energy deficits may experience menstrual cycle disruptions and reduced oestrogen levels, leading to amenorrhoea. This increases their risk of bone density loss and musculoskeletal injuries (Heikura *et al.*, 2018).

Female athletes may also experience hypothalamic dysfunction, which leads to low oestrogen levels. Oestrogen plays a vital role in bone formation; it reduces bone remodelling and resorption, increasing and enhancing bone production (Matzkin *et al.*, 2015). Oestrogen deficiency decreases BMD, raising fragility fracture risk. Although athletes generally have higher BMD, stress fractures are more common in amenorrhoeic athletes (Raj *et al.*, 2023). In addition, Mehta, Thompson & Kling (2018) also stated that LEA and menstruation disorders that result in oestrogen deficiency cause low BMD (Mehta *et al.*, 2018). Irregular menstruation can lead to low oestrogen and excessive osteoclast activity, while poor energy availability may cause vitamin D and calcium deficits. This negatively impacts bone density and health, making athletes with low bone density and insufficient calcium intake more susceptible to stress fractures (Knechtle *et al.*, 2021).

Female athlete triad is associated with the possibility of sports injury. Female athletes with relative energy shortage may be more susceptible to an elevated risk of injury (Edama *et al.*, 2021). According to Mallinson and De Souza, (2014), athletes with triad components are three to five times more likely to suffer bone-stress fractures compared to those without triad components. Stress injuries are frequently associated with both intrinsic and extrinsic risk factors. Notable characteristics include the presence of eating disorders, menstrual irregularities, and diminished bone density, all of which have been correlated with the occurrence of stress injuries (Goolsby & Boniquit, 2017). The triad can increase injury risk among female athletes due to lower bone mineral density, raising the likelihood of fractures and bone injuries (Rauh *et al.*, 2014). The triad negatively affects athletic performance, leading to lower BMD, higher stress fracture risk, and reduced energy availability (Charlton, Forsyth & Clarke, 2022; Kelly & Hecht, 2022; Kim & Weber, 2023; Patel *et al.*, 2024). Diminished energy availability can lead to fatigue and reduced performance, severely impacting training and competition. The condition also has significant physiological and psychological effects, including anxiety, depression, and eating disorders, which can affect motivation. Therefore, increased education and screening are necessary (Darlington, 2012).

Body image is a crucial aspect of sports and exercise psychology, significantly influencing physical activity and sports behaviour (Sabiston *et al.*, 2019). Female athletes face sociocultural and sport-specific pressures to achieve an ideal body, leading to a risk of body dissatisfaction (Reel *et al.*, 2013). Female athletes, especially dancers and gymnasts, showed higher body dissatisfaction than those in ball sports, regardless of participation level (Varnes *et al.*, 2013). Previous studies indicated that individuals with elevated levels of body dissatisfaction are more inclined to exhibit eating disorder behaviours (Chen, Luo & Chen, 2020; Cruz-Sáez *et al.*, 2020; Patel *et al.*, 2024), including dieting, unhealthy eating, and weight control practices (Li *et al.*, 2024). Specifically, these behaviours are often used to lose weight and attain a desired body image (Li *et al.*, 2024). Maintaining a positive body image prevents unhealthy weight-related behaviours, particularly among female athletes (Białek-Dratwa *et al.*, 2022). The assessment of individuals' self-perceptions of their physical appearance is crucial for identifying and predicting the likelihood of developing eating disorders, especially in this demographic (Białek-Dratwa *et al.*, 2022), as they are particularly vulnerable to various societal and

cultural influences on body image and self-esteem.

Insufficient nutritional intake and calorie consumption among female athletes may result in a negative energy balance, significantly contributing to inadequate energy availability (Heikura *et al.*, 2018). According to Jagim *et al.* (2021), athletes frequently need to pay attention to their energy requirements, which complicates EA evaluation and increases the likelihood of insufficient energy consumption. To enhance training efficacy, athletes must ensure adequate caloric intake to fulfil their training requirements and facilitate physiological adaptations (Jenner *et al.*, 2019). Female athletes must maintain an adequate energy supply to prevent the triad and its associated health consequences. This can be accomplished by monitoring energy consumption and expenditure (Raj *et al.*, 2023). In addition, healthcare professionals must be aware of the triad and its components and screen female athletes for risk factors (Melin *et al.*, 2015). Having a qualified physician, including a team physician, to discuss gynaecological issues with coaches and athletes is vital for the health and well-being of female athletes (Tsukahara *et al.*, 2023). Educating female athletes regarding the syndrome's components and potential risk factors is also crucial to preventing the triad.

It is vital to guide young athletes in developing sustainable nutritional habits to optimise their performance. Regular breakfast consumption is recommended, focusing on increased protein, carbohydrates, iron, and calcium intakes, with meals containing fibre-rich foods, whole grains, fruits, and dairy. Moreover, consuming pre- and post-activity snacks or meals can significantly enhance performance and aid recovery. However, the effectiveness of nutrition education programmes has produced mixed outcomes. This study had certain limitations, including its exclusive focus on fully published articles in English from journals. Additional research is needed to understand how nutrition can improve female athletes' performance and examine the potential variables influencing the link between FAT and athletic injury. This identified gap underscores the need for further studies to clarify the impact of these factors on injury prevention strategies among athletes.

## CONCLUSION

In recent years, there has been a marked increase in research focused on the female athlete triad syndrome, particularly during 2021 and 2022. This syndrome, which primarily affects female athletes, involves a range of interconnected issues, including energy balance, BMD, menstrual disorders, sports injuries, and overall athletic performance. It typically arises from inadequate nutrition and energy intakes, resulting in a negative energy balance. Effectively addressing the female athlete triad requires a comprehensive, multi-disciplinary approach that includes healthcare professionals such as sports medicine physicians, dietitians, gynaecologists/endocrinologists, physical therapists, athletic trainers, and psychiatrists. It is essential for these professionals to educate patients, parents, and coaches about the potential risks female athletes face and to provide necessary support. Furthermore, under the revised diagnostic criteria, increasing awareness is crucial for early detection to prevent the syndrome from progressing to more severe stages. Despite the significant health risks linked to the female athlete triad, it is essential to acknowledge that the benefits of regular exercise and physical activity outweigh the potential hazards.

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**Authors' contributions**

Maria U, principal investigator, conceptualised and designed the study, prepared the draft of the manuscript and reviewed the manuscript; Meiky F, conceptualised and designed the study, advised on data analysis and interpretation, and reviewed the manuscript; Roslee R, Merve IE, Esti W, advised on data analysis and interpretation, and reviewed the manuscript.

**Conflict of interest**

The authors have no conflicts of interest to declare.

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