

# THE FEMALE ATHLETE TRIAD IN SWIMMERS: A REVIEW OF CURRENT LITERATURE

Brienna K. Buchanan, BA, Victoria E. Bergstein, BA, Evin F. Rothschild, BS, Alexis Coslick, DO

*Johns Hopkins University School of Medicine, Department of Physical Medicine and Rehabilitation,  
Baltimore, Maryland, U.S.A.*

**BACKGROUND:** The female athlete triad, including low energy availability, low bone mineral density, and menstrual dysfunction, has serious implications for female athletes, with extreme cases leading to potentially irreversible consequences. It is unclear how or if the female athlete triad uniquely affects swimmers, for whom weightbearing is not part of their sport. The goal of this systematic review was to analyze studies of the triad pertaining to female swimmers with an emphasis on the volume of literature and the prevalence of individual components of the triad.

**METHODS:** A literature search was conducted on November 8, 2023, through PubMed and Google Scholar using the terms “female athlete triad” and “swimmer” or “swimming.” Of the 259 studies extracted, 17 were selected for inclusion after abstract and full-text screening. Outcomes involving each component of the triad, as well as overall prevalence and risk of the triad, were aggregated to derive means. Quantitative reporting of triad components varied across studies; thus, reported mean percentages were calculated using only the studies that reported the relevant statistics. “Female” was defined in reference to cis-gender females based on self-identified gender identity.

**RESULTS:** The 17 studies varied widely in terms of reported metrics. The 11 studies that reported the number of female swimmers included a total of 478 female swimmers. Menstrual dysfunction was the most frequently documented symptom, with a mean of 41% of swimmers experiencing menstrual irregularity. A mean of nearly 12% of swimmers were found to have low bone mineral density, and 51% were found to have low energy availability. Overall, 41% of female swimmers were estimated to be at risk for the triad.

**CONCLUSION:** With an estimated 4 in 10 female swimmers at risk of the triad, early identification through screening, awareness, and special attention to the most reported symptom, menstrual irregularity, is key to maintaining health of athletes. The overall small number of studies on the triad/REDs in female swimmers, along with the wide heterogeneity of quantitative data point to the need for further research on the female athlete triad to better understand the interplay of each symptom in this unique athletic population.

## INTRODUCTION

The female athlete triad (herein, “triad”) is characterized by low energy availability (LEA), often resulting from disordered eating, amenorrhea or menstrual disturbance, and reduced bone mineral density (BMD).<sup>1</sup> Though the presence of all three components in one athlete is uncommon, with estimates ranging from 0%–16%, some projections report that one or two concurrent components may be found in as many as 50%–60% of young, female athletes.<sup>1</sup> Each component of the triad can be detrimental to a young woman’s health. The triad falls within the more encompassing phenomenon called relative energy deficiency in sport (REDs),

which describes how energy imbalance can lead to impaired physiological function across multiple organ systems.<sup>2</sup> Not only can the triad and REDs diminish an athlete’s current health, but their long-term sequelae are also concerning. Because approximately 50% of bone mass is acquired during adolescence, and women typically attain more than 95% of their total bone mass by age 18, interruptions in bone formation from LEA can increase the risk of osteoporosis and pathological fractures later in life.<sup>3,4</sup> Adolescents with disordered eating and amenorrhea have also been shown to have low bone mass accrual.<sup>4–6</sup> These effects may be irreversible, so early screening for the triad/REDs and effective

interventions are paramount to these athletes' current and future health.<sup>4</sup>

Bone stress injuries (BSIs) are one of the most common reasons to prompt evaluation for the triad/REDs in young, female athletes.<sup>7</sup> Therefore, in sports associated with lower rates of BSI, screening for the triad/REDs may be less common. This situation may be particularly detrimental to swimmers, whose non-weightbearing training does not confer the osteogenic benefits of weightbearing exercise.<sup>8,9</sup> Swimmers are more likely to have BMD similar to that of non-athletic populations, rather than the higher BMD that results from high-impact, gravity-dependent training involving high muscle force.<sup>8,10</sup>

Given the risk of low BMD and the subsequent risk of developing osteoporosis later in life, it is crucial to screen for and promote awareness of the triad among female swimmers. Despite these crucial negative health consequences, studies that assesses these elements in swimmers are limited. Therefore, the purpose of this systematic review was to evaluate the current body of literature on the triad in swimmers with an emphasis on the volume of literature and the prevalence of individual components of the triad.

## METHODS

### *Literature Search*

A literature search was conducted on November 8, 2023, using PubMed and Google Scholar to identify studies that evaluated elements of the triad in swimmers. We first performed a keyword search using the terms "female athlete triad" and "swimmer" or "swimming." Then, the authors manually reviewed the search results and selected articles that contained the search terms. Articles that contained the search terms were uploaded and screened further using Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia).

### *Study Selection*

We included studies that reported data on triad incidence, triad awareness, and/or experiences related to the triad in female swimmers. We excluded studies that did not report on energy availability, bone health, or menstrual dysfunction.

We identified 251 articles through Google Scholar, and subsequently, 8 distinct articles through PubMed, for a total of 259 articles. Two

medical students performed abstract screening of all articles, documenting screenings in Covidence and resolving disagreements through discussions that ended with a unanimous decision of inclusion or exclusion. We excluded 14 duplicate studies; 215 studies that did not include information about both the triad and swimmers; and 2 studies that did not have retrievable results, leaving 28 articles for full-text review. Of these, 6 had no relevant data, 4 were not peer-reviewed studies, and 1 contained duplicate data, leaving 17 articles for inclusion (7 review articles, 5 cross-sectional studies, 2 survey studies, and 2 prospective questionnaire study) (Figure 1).

Of note, synchronized swimming—also known as artistic swimming—is a style distinct from the typical races of collegiate and club swimming that involves a team of swimmers executing a routine of synchronized choreography accompanied by music. This specific type of swimming is discussed separately.

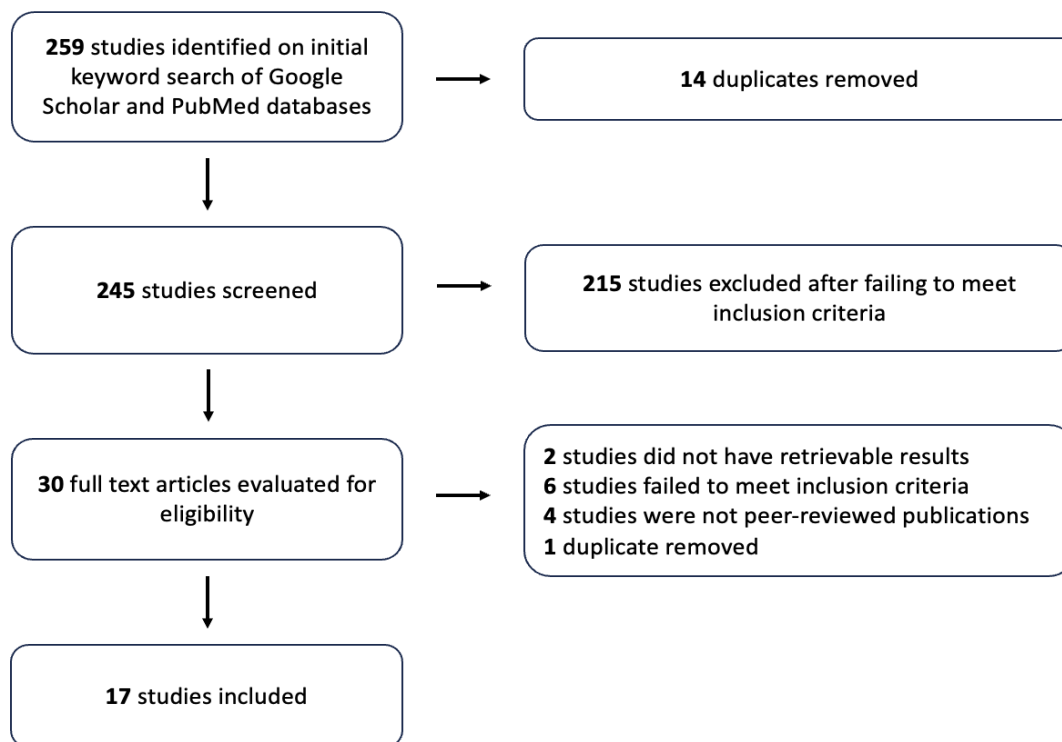
### *Data Extraction*

All authors performed screening of full texts of the selected 17 articles for data extraction. We extracted the following data from the selected studies: sample size, study period, swimming level, mean participant age and age at menarche, percentages of participants with disordered eating, LEA, menstrual irregularity, and low BMD, percentage of participants with 1, 2, and 3 triad components, percentage of participants at risk for the triad, and other relevant information. Results in each category were aggregated to determine means. These means reflected all data that were available for that outcome variable across the included articles.

## RESULTS

### *Swimmer Characteristics*

The mean ( $\pm$  standard deviation) sample size of the 11 studies whose samples consisted exclusively of female swimmers was  $44 \pm 30$  (range, 21–85). However, 1 study also included a variety of other sports, bringing the total sample size to 663. Because it is unknown how many of these athletes were swimmers, this study was not included in the means and only included in the discussion of synchronized swimming.<sup>11</sup>



**Figure 1.** PRISMA flow diagram depicting the article screening process. Five of the 17 selected studies are not included in the summary table because they lacked quantitative data, but they are referenced throughout the manuscript.

The mean follow-up period across 8 studies that reported it was  $3.8 \pm 1.9$  years (range, 1–6). Among the 7 studies that reported swimmer age, the mean was  $20 \pm 3$  years (range, 15–25). Studies reported on athletes from various swimming disciplines: most frequently collegiate swimming ( $n = 7$ ), followed by competitive or club-based swimming ( $n = 5$ ), and synchronized swimming ( $n = 4$ ). Two studies did not specify swimming discipline. In this review,

synchronized swimming is discussed separately from collegiate, competitive or club speed swimming. We begin with the results in each category from studies assessing speed swimmers. Heterogeneity in study design resulted in inconsistent reporting of metrics influenced by the triad, which prevented us from performing a meta-analysis. Demographic information for the included studies is summarized in Table 1.

**Table 1.** Summary of studies included in the review of female athlete triad in swimmers.

| First Author<br>(Year) | Study Design              | No. of Swimmers |        | Swimming Type                     | Location               | Study Years | Mean Patient Age, yr | Unique Areas of Focus                        |
|------------------------|---------------------------|-----------------|--------|-----------------------------------|------------------------|-------------|----------------------|----------------------------------------------|
|                        |                           | All             | Female |                                   |                        |             |                      |                                              |
| da Costa (2013)        | Cross-sectional           | 77              | 77     | Club                              | Rio de Janeiro, Brazil | 2005–2008   | 11–19*               | Protein and vitamin consumption              |
| Hoogenboom (2009)      | Survey                    | 85              | 85     | Division I–III collegiate         | Michigan, USA          | 2005–2006   | 19                   | Nutritional intake                           |
| Klein (2023)           | Survey                    | 30              | 15     | Division III collegiate           | NA                     | NR          | 20                   | Nutritional intake                           |
| Maharam (2022)         | Cross-sectional           | 44              | 6      | Collegiate                        | Malaysia               | NR          | NR                   |                                              |
| Mudd (2007)            | Cross-sectional           | 99              | 9      | Division I collegiate             | NA                     | 2007        | 20                   |                                              |
| Nose-Ogura (2018)      | Review                    | 663             | NR     | Synchroniz-<br>ed/<br>traditional | Japan                  | NR          | NR                   |                                              |
| Pfeifer (2002)         | Review                    | 69              | 69     | NS                                | NA                     | NR          | NR                   | Hormonal and gynecologic considerations      |
| Sawai (2018)           | Cross-sectional           | 531             | 33     | Collegiate                        | Japan                  | 2017        | 20                   |                                              |
| Schtscherbyna (2009)   | Prospective questionnaire | 78              | 78     | Competitive                       | Rio de Janeiro, Brazil | 2005–2008   | 15                   |                                              |
| Tenforde (2017)        | Cohort                    | 323             | 21     | Collegiate                        | California, USA        | 2008–2014   | NR                   |                                              |
| Tenforde (2018)        | Cohort                    | 323             | 21     | Collegiate                        | California, USA        | 2008–2014   | NR                   |                                              |
| Witkos (2022)          | Cross-sectional           | 64              | 64     | Club                              | Krakow, Poland         | 2022        | 25                   | Menstrual function and premenstrual syndrome |

NA, not applicable; NR, not reported.

\*Reported as range.

### Menstrual Dysfunction

Among the 3 symptoms of the triad, menstrual dysfunction was the most widely reported, with 7 studies specifying mean age at menarche and/or percentage of the study sample with menstrual irregularity.

Three studies reported mean age at menarche ranging from 12.4 to 13 years, with a mean across studies of 12.7 years. Menstrual irregularity was documented in 7 studies with a wide range of prevalence of 19% to 82% and mean of 41% ± 21%. Among all studies, the highest documented prevalence of menstrual dysfunction among swimmers was 82%, and of this population, it 12% were reported as having amenorrhea.<sup>12</sup> Of the 50% of swimmers found to be affected by menstrual

dysfunction in the study by Gimunová et al., 19% had primary amenorrhea, 8.7% had secondary amenorrhea, and 22.5% had oligomenorrhea.<sup>13</sup> Five of 7 studies reporting menstrual dysfunction did not specify the type or degree of dysfunction.

In the 3 studies that reported on both mean age at menarche and proportion of swimmers with menstrual dysfunction, a positive correlation was observed. Schtscherbyna et al. reported the lowest mean age at menarche, 12.4 years, and the lowest prevalence of menstrual irregularity of 19%.<sup>14</sup> Witkos et al. documented a mean age at menarche of 12.6 years and a prevalence of menstrual irregularity of 31%.<sup>15</sup> Sawai et al. reported the highest mean age at menarche, 13 years, which corresponded to the highest prevalence of

menstrual irregularity among the 3 studies of 45%.<sup>16</sup> Taken together, these findings suggest a correlation between high prevalence of menstrual irregularity and older age at menarche.

#### *Low BMD*

Although many studies noted that BMD is generally lower in swimmers compared with other athletes, only Nose-Ogura et al. quantified total body BMD in swimmers, reporting a mean of 1.1 g/cm<sup>2</sup>.<sup>11</sup> Mudd et al. confirmed that BMD in swimmers, particularly in the lower extremities, is lower than in athletes in other sports.<sup>17</sup> Swimmers have also been found to have no benefit in terms of BMD over individuals who are not physically active and to have lower BMD compared with other athletes.<sup>18</sup> Among the 4 studies that reported on BMD, a mean of 12% of swimmers had low BMD, with study-specific findings ranging from 3% to 24%.<sup>8,14,16,19</sup>

#### *LEA*

LEA was addressed by only 3 studies (25% of studies with qualitative data) that reported the proportion of swimmers with LEA and 2 studies (17% of studies with qualitative data) that reported the related phenomenon of disordered eating.<sup>14,20–22</sup> Although disordered eating behavior or the presence of an eating disorder is not required for an athlete to be affected by LEA, the two are often interconnected. Among female swimmers in these studies, the mean prevalence of disordered eating was 45%, and the mean prevalence of LEA was 51%.<sup>14,20–22</sup> Only the study by da Costa et al. reported the prevalence of both disordered eating (44%) and LEA (21%).<sup>20</sup> Energy availability was also associated with adaptation to training, with an 8.2% better time trial performance among swimmers with adequate energy availability group compared with a 9.8% poorer performance among those with LEA following a 12-week training program.<sup>23</sup>

#### *Triad Component Prevalence and Risk*

Two studies reported the proportion of female swimmers with 1, 2, or all 3 components of the triad within their study populations.<sup>14,16</sup> One component of the triad was reported in a mean of 55% of swimmers across 4 studies; 2 components of the triad were reported in a mean of 9.2% of swimmers across 2 studies; all 3 components of the triad were reported in a mean of 0.7% of swimmers across 2 studies.<sup>14,16,21,22</sup> The mean proportion of swimmers at risk for the triad was 42%.<sup>8,24</sup>

#### *Synchronized Swimming*

Among synchronized swimmers, Nose-Ogura et al. reported a mean age at menarche of 12.7 years, and Robertson and Mountjoy found a 0.6-year later onset of menarche in synchronized swimmers compared with non-athletes.<sup>11,25</sup> Tenforde et al. reported that 45% of their sample of synchronized swimmers had low BMD, a proportion almost double that of the percentage of collegiate swimmers in the same study.<sup>19</sup> Conversely, Gimunová et al. reported an inverse trend for menstrual dysfunction; prevalence of primary amenorrhea, secondary amenorrhea, and oligomenorrhea was lower in synchronized swimmers (9.1%, 4.6%, and 16%, respectively) compared with traditional swimmers (19%, 8.7%, and 22.5%, respectively).<sup>13</sup>

## **DISCUSSION**

The female athlete triad can impair athletes' well-being and performance. With more than half of female swimmers in this review presenting with at least 1 component of the triad, early recognition and intervention are key. In particular, we call attention to the prevalence of low BMD in the context of this non-weightbearing sport. Although the prevalence of all 3 components of the triad was low among the swimmers analyzed in this review, it is important to recognize that the triad is not problematic only when all 3 components are present. Even the presence of 1 element warrants concern. Other studies have corroborated the gradient of prevalence of 1 vs. 2 vs. all 3 triad components, with Melin et al. reporting that 35% of elite endurance female athletes had 1 component, followed by 32% with 2, and finally 23% with all 3 components.<sup>26</sup> The findings of Yi et al. also align with this trend, noting that 24% of female triathletes had 1 component, whereas only 8% reported all components.<sup>27</sup>

LEA was the triad component least widely documented across studies in this review, despite it being the most prevalent, with approximately half of swimmers experiencing LEA in the studies that reported prevalence. This estimate is higher than the 36% estimate for LEA prevalence in female athletes generally, indicating that female swimmers may be at elevated risk for LEA given the sport's demands for aesthetics and speed.<sup>28</sup> Historically, athletes in sports that emphasize leanness, including swimming, have been shown to be at higher risk for LEA and eating disorders.<sup>29</sup> LEA can

be associated with disordered eating, but this is not the case in all athletes with LEA. Competitive and synchronized swimming require high energy expenditure, which can, unintentionally, be mismatched with caloric intake, resulting in a negative energy balance and LEA.<sup>30-32</sup> Moreover, all forms of disordered eating do not manifest as LEA, as shown in the study by da Costa et al., which was the only study in this review that reported prevalence of both LEA and disordered eating behaviors.<sup>20</sup> When assessing the mean prevalence of disordered eating vs LEA in this review, we found a 5% difference between them.<sup>14,20-22</sup> Therefore, screening for and discussions about LEA should take disordered eating into consideration while keeping in mind that the one condition is not contingent on the other. The discrepancy between the high prevalence of this triad component and the limited quantitative data reported in studies of the triad in swimmers highlights a gap that should be filled by future studies. LEA is associated with REDs, which includes fatigue, endocrine changes, diminished performance, and negative effects on the reproductive, musculoskeletal, cardiovascular, and gastrointestinal systems.<sup>33-35</sup> With so many sequelae and high prevalence among female swimmers, LEA and disordered eating warrant further investigation.

Menstrual dysfunction was the second most widely reported triad component in our review, with a mean of 40% of swimmers reporting menstrual irregularity, including amenorrhea and oligomenorrhea. This estimate is similar to findings among female athletes across sports, which report a mean prevalence of 35% of athletes with menstrual disturbance.<sup>28</sup> There has been a national trend of decreasing age at menarche, with the mean age decreasing from 12.1 in 1995 to 11.9 in 2017.<sup>36</sup> The mean age at menarche of female swimmers in this review was 12.7. A study by Constantini et al. found a significantly older age at menarche in swimmers compared with age-matched controls.<sup>37</sup> The authors proposed a mechanism involving mild hyperandrogenism. This hormonal finding is distinct from the profiles of athletes with menstrual dysfunction who participate in weightbearing sports, such as running; these athletes typically present with hypogonadism.

In addition to older age at menarche, swimmers are also susceptible to sustained menstrual dysfunction, which is associated with several factors, including low body fat, inadequate nutritional intake, low body weight, and high-

intensity training.<sup>38,39</sup> Schtscherbyna et al. studied Brazilian female swimmers and found that oligomenorrheic athletes did not differ significantly in body weight or body fat from eumenorrheic athletes, but rather, were different in terms of age at beginning of swimming training, with oligomenorrheic swimmers having begun training earlier.<sup>40</sup> Menstrual dysfunction has a variety of negative downstream consequences, including a higher risk of injury, loss of BMD, cardiovascular consequences, and reproductive problems.<sup>15</sup> For swimmers with menstrual dysfunction, addressing this issue with physicians, athletic trainers, and other healthcare professionals is paramount to overall well-being.

Low BMD was the triad component reported in the smallest proportion of female swimmers in our review, at less than 12%. Bellew and Gehrig found that swimmers have significantly lower BMD compared with adult female norms provided by the World Health Organization.<sup>41</sup> Compared with athletes who participate in gymnastics, softball, cross-country, track, field hockey, soccer, and rowing, swimmers had lower BMD than athletes in every other sport except running and rowing.<sup>17</sup> The primary hypothesis for this difference is the mechanostat theory of bone adaptation, which postulates that less muscular strain at certain regions decreases the stimulus for osteogenesis.<sup>42</sup> Schipilow et al. has proposed another hypothesis, describing a potential selection bias in swimming for athletes who are genetically predisposed to low BMD.<sup>43</sup> In most sports, low BMD can lead to stress fractures; however, such injuries are rare in swimmers because of the non-weightbearing nature of the sport.<sup>44</sup> In fact, swimming is sometimes recommended as part of the active recovery program for athletes who have sustained lower-extremity BSIs.<sup>45</sup> Therefore, clinicians should not rule out concerns for the triad on the basis of lack of bone injury. Especially in swimmers, clinicians should consider other manifestations of the triad and REDs.

There is substantial room for growth in clinician knowledge of the triad/REDs, particularly with regard to physician comfort in treating the condition. One survey reported that as few as 9% of physicians said they were comfortable treating the triad/REDs.<sup>46</sup> In addition to general triad/REDs education for clinicians, this review highlights the need for further emphasis on sport-specific manifestations and considerations that have the

potential to affect screening, identification, and prevention.

### Limitations

This systematic review has several strengths, including being the only review of which we are aware to focus on the female athlete triad and REDs specifically in the female swimmer and calling attention to this important issue in a uniquely non-weightbearing sport. However, this study also has several limitations. Because of the heterogeneity of findings reported across studies, it was impossible to conduct a meta-analysis. Quantitative reporting of prevalence of each triad component varied, limiting our conclusions. Only one study, by Schtscherbyna et al., reported at least 1 quantitative metric for each component of the triad.<sup>14</sup> Additionally, swimmers across the 17 studies represented a range of levels from club swimming to National Collegiate Athletic Association Division I collegiate swimming. As a result, rigor and training regimens were unequal, which may have affected some aspects of the triad as a result of variable caloric expenditure and physiological stress. Future studies should focus on the relationship between all components of the triad within a single sample to accurately determine prevalence. Additionally, it would be beneficial to analyze whether the type of swimming is associated with prevalence of the triad and/or the proportion of swimmers at risk.

### CONCLUSION

With more than 40% of female swimmers at risk for the triad, it is critical that sports medicine physicians, primary care physicians, dietitians/nutritionists, athletic trainers, and coaches of female swimmers are aware of the triad components and options for management. Furthermore, the small number of studies of the triad among swimmers points to a need for further research in this population.

### Conflict of Interest Statement

The authors declare no conflicts of interest with the contents of this study.

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### Corresponding Author

Alexis Coslick, DO  
The Johns Hopkins University  
601 North Caroline Street  
Baltimore, Maryland 21287  
Email: [acoslic1@jhmi.edu](mailto:acoslic1@jhmi.edu)  
Phone: 443-997-5476

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