Prevalence of Individual and Combined Components of the Female Athlete Triad

JENNA C. GIBBS, NANCY I. WILLIAMS, and MARY JANE DE SOUZA

Women’s Health and Exercise Laboratory, Noll Laboratory, Department of Kinesiology, Pennsylvania State University, University Park, PA

ABSTRACT

GIBBS, J. C., N. I. WILLIAMS, and M. J. DE SOUZA. Prevalence of Individual and Combined Components of the Female Athlete Triad. Med. Sci. Sports Exerc., Vol. 45, No. 5, pp. 985–996, 2013. Purpose: The female athlete triad (Triad) is a syndrome linking low energy availability (EA) with or without disordered eating (DE), menstrual disturbances (MD), and low bone mineral density (BMD) in exercising women. The prevalence of Triad conditions (both clinical and subclinical) has not been clearly established. The purpose of this review is to evaluate the studies that determined the prevalence of clinical or subclinical Triad conditions (low EA, DE, MD, and low BMD) in exercising women and in women participating in lean (LS) versus nonlean sports (NLS) using self-report and/or objective measures. Methods: A review of publications using MEDLINE and PubMed was completed. Randomized controlled trials and observational studies that evaluated the prevalence of clinical and subclinical Triad conditions (MD, low BMD, low EA, and DE) in exercising women were included. Results: Sixty-five studies were identified for inclusion in this review (n = 10,498, age = 21.8 ± 3.5 yr, body mass index = 20.8 ± 2.6 kg m⁻²; mean ± SD). A relatively small percentage of athletes (0%–15.9%) exhibited all three Triad conditions. The prevalence of any two or any one of the Triad conditions in these studies ranged from 1.5% to 6.7% and from 0% to 2.0%, respectively. The prevalence of all three Triad conditions in LS athletes versus NLS athletes ranged from 2.7% to 27.0% and from 16.0% to 60.0%, respectively. The prevalence of all three Triad conditions in LS athletes versus NLS athletes ranged from 1.5% to 6.7% and from 0% to 2.0%, respectively. LS athletes demonstrated higher prevalence rates of MD and low BMD (3.3% vs 1.0%), MD and DE (6.8%–57.8% vs 5.4%–13.5%), and low BMD and DE (5.6% vs 1.0%) than the NLS athletes. Conclusions: Although the prevalence of individual/subclinical Triad conditions is concerning, our review demonstrates that additional research on the prevalence of the Triad using objective and/or self-report/field measures is necessary to more accurately describe the extent of the problem. Key Words: LOW ENERGY AVAILABILITY, MENSTRUAL DISTURBANCES, LOW BONE MINERAL DENSITY, EXERCISING WOMEN

The female athlete triad (Triad) was first recognized two decades ago based on the association of disordered eating (DE), functional hypothalamic amenorrhea (FHA), and osteoporosis observed in recreational and elite-level exercising women (41). In 2007, the American College of Sports Medicine published a position stand (41) with updated scientific information and recommendations for screening, diagnosis, prevention, and treatment of the Triad. The most recent conceptual model of the Triad is a syndrome linking low energy availability (EA) (with or without DE), menstrual disturbances (MD), and low bone mineral density (BMD) across a continuum of healthy (optimal EA, normal and regular menstrual cycles, and optimal BMD) to unhealthy and increasingly severe clinical presentations of each component (41). The Triad is a detrimental consequence of the failure to ingest adequate energy to compensate for energy expended during exercise, a condition called low EA. As such, the Triad is commonly observed in exercising women (14,41), particularly those women involved in leanness, aesthetic, and/or endurance sports and activity (63). Low EA with or without DE may be induced for a variety of reasons to include the following: 1) intentional, i.e., modifying body size and composition to achieve appearance or performance goals; 2) compulsive, i.e., demonstrating DE and/or pathological weight control behavior; or 3) inadvertent, i.e., failing to match energy intake to exercise-induced energy expenditure (37). Low EA often results in an energy deficiency, which when sustained for prolonged periods of time translates to metabolic and reproductive suppression (72). The result is the development of both subclinical (luteal phase defects [LPD] and anovulation) and clinical MD (FHA and oligomenorrhea), musculoskeletal complications, e.g., low BMD and stress fractures (41), and other clinical sequelae, that is, endothelial dysfunction (29,45).

A large body of literature exists wherein the prevalence of individual disorders of the Triad has been determined (MD, low BMD, and DE/eating disorders). Several publications have reported the prevalence of clinical MD (FHA
and oligomenorrhea) in female athletes to include both high school (4,30,42,43) and premenopausal women (6,7,14,18, 19,40,49,51,53,66,70). The earliest prevalence estimates of clinical MD were determined predominantly in the most at risk populations to include runners (17,24,28,58,60,73) and dancers (1,12). In general, clinical manifestations of MD have been shown to range from 1% to 61% in exercising women and are documented at much higher rates than that in nonathletic, premenopausal women (3,47,61). Subclinical MD have only been assessed in a few studies (8,18, 19,22,76), but there is evidence suggesting that approximately half of exercising women experience subclinical MD (LPD and anovulation) and that self-reported menstrual history alone does not provide the appropriate information to indicate presence of subclinical MD (LPD and anovulation) (19). Because the method of self-report can only identify those MD readily apparent to women as an absence of menses for greater than 3 months (FHA) or irregularities in menstrual cycle length (oligomenorrhea), investigators reporting on the prevalence of MD as a component of the Triad, determined using self-report methods, are likely to have underestimated the percent of women with the Triad. In addition, most Triad prevalence reports have included clinical eating disorders and/or DE as a component of the syndrome (6,43,49,59,68,70). Previous findings indicate a higher proportion, up to 70%, of clinical eating disorders and/or DE are present in elite female athletes compared with controls, particularly in athletes participating in sports focused on leanness, aesthetic appearance, and weight control (11,62,64,67). However, it is important to acknowledge that despite a higher frequency of DE in female athletes, clinical DE is not always observed in exercising women presenting with Triad-related clinical sequelae.

A notable absence in Triad prevalence investigations is the assessment of EA, except for a prospective study in high school athletes compared with age-matched controls (30). Because EA is suggested to be one of the key components of the Triad (41), further evaluation of its prevalence alongside other Triad conditions is warranted. Lastly, the prevalence of low BMD in female athletes is not as well documented, particularly because of recent technological advancements in measurement tools and the inconsistency in criteria used to identify low BMD. In earlier reports, investigators inappropriately used the World Health Organization (WHO) criteria to define low BMD and osteoporosis in premenopausal exercising women. Because the WHO criteria are intended for postmenopausal women, these prevalence estimates for low BMD and osteoporosis are suggested to be inaccurate. The definition of low BMD in the 2007 American College of Sports Medicine Position Stand on the Triad includes a z-score of $< -1.0$ (specifically between $-1.0$ and $-2.0$) in the presence of additional clinical factors such as hypogonadism. This criterion is based on the premise that athletes in weight-bearing sports should present with BMD 5%–15% higher than nonathletes (30,41). Therefore, a BMD z-score between $-1.0$ and $-2.0$ warrants attention. To date, the prevalence of low BMD in amenorrheic athletes ranges from 1.4% to 50.0% (4,6,10, 30,43,48,49,51,57,59,77) and estimates of osteoporosis are lower (0%–13.0%) (10,48,57,77). As such, few studies have examined the prevalence of low BMD in high school (4,30,43,51,59) and premenopausal exercising women (6,49), and its prevalence alongside other Triad conditions requires further investigation.

Establishing the prevalence of the Triad and its components is a difficult task. Concerns exist related to the methods of detection used in reports, the lack of appropriate definitions and criteria used for each Triad component, and the limitations in the experimental design and methods of assessment (20,41). Recent investigators have demonstrated that large discrepancies in prevalence exist between the presentation of all three Triad conditions compared with estimates of two or one of the Triad disorders. However, this information has yet to be summarized, and as such, the magnitude of the syndrome has not been thoroughly evaluated. In addition, the prevalence of two or three of the Triad conditions across the continuum (subclinical vs clinical) is not well documented and requires examination. We will investigate these factors in our review and discuss such limitations related to the study of prevalence related to the Triad.

To date, this is the first review examining the prevalence of any two or all three of the Triad conditions in a systematic manner, specifically evaluating the prevalence of both clinical and subclinical conditions. This review will also represent an updated examination of prevalence reports on individual disorders of the Triad as there have been several investigators that have determined the prevalence of MD, low BMD, or DE/eating disorders in exercising women. Furthermore, several studies have been completed (6,42,50,68) in which the investigators have categorized the participants based on sport type (lean vs nonlean) and reported the prevalence of the Triad conditions. To this end, a summary of those findings would be valuable in better understanding the Triad etiology and provide a comparison in the prevalence of the Triad disorders between athletes in lean sports versus those in nonlean sports. Prevention and treatment policy decisions rely on accurate estimates of the Triad, and as such, a better understanding of the clinical relevance of the Triad is warranted. The purposes of this systematic review is 1) to evaluate the prevalence of Triad conditions (low EA with or without DE, MD, and/or low BMD) (clinical or subclinical) using self-report and/or objective measures and 2) to evaluate the prevalence of Triad conditions (low EA with or without DE, MD, and/or low BMD) (clinical or subclinical) in women participating in lean versus nonlean sports.

**SEARCH STRATEGY**

**Data sources.** An electronic search of the computerized databases PubMed and MEDLINE was performed for the period 1975–2011 using the search terms: female athlete

---


Copyright © 2013 by the American College of Sports Medicine. Unauthorized reproduction of this article is prohibited.
triam, low EA, DE, eating disorders, FHA, athletic amenorrhoea, anorexia athletica, MD, energy deficiency, low bone mass, low BMD, osteoporosis, female athletes, and exercising women. In addition, when relevant articles were not included in the electronic search of PubMed and MEDLINE, the first author hand searched for the key articles and cited references. We excluded studies not published in English. We did not search for abstracts nor did we evaluate any case studies or unpublished studies. No contact with authors was made for this review.

**Study inclusion and exclusion criteria.** Studies of the prevalence of at least one of the clinical and/or subclinical Triad disorders were included in this review. We included all published randomized controlled trials, observational (prospective and retrospective) cohort, and cross-sectional studies that assessed the prevalence of one or more of the Triad conditions in high school and premenopausal exercising women using self-report and/or objective measures. We acknowledge that there are distinct physiological and developmental differences between high school and premenopausal women; however, based on previous research (4,30, 42,43,65), it is clear that the Triad is a significant clinical problem in high school female athletes, similar to premenopausal exercising and athletic women. Reports with or without control groups were included. The Triad was operationally defined as follows: 1) low EA (with or without DE), or if EA was not evaluated, the presence of clinical eating disorders or DE; 2) FHA (primary or secondary), oligomenorrhea, or subclinical MD to include LPD and anovulation; and 3) low BMD. Methods of evaluation and definitions of the clinical and subclinical presentations of the Triad used by studies included in this review are outlined in Table 1. Reports on the clinical and/or subclinical Triad disorders between lean and nonlean sport athletes were also included in this review. Lean sport athletes were defined as participants in sports that place an emphasis on endurance training, low body weight, lean physique, and aestheticism (68); whereas nonlean sport athletes were defined as participants in sports emphasizing technical and/or ball-related skill and/or power training (68). Torstveit and Sundgot-Borgen (68) outlined the specific sports that meet these criteria in another manuscript. Data on the incidence of musculoskeletal injuries and endothelial dysfunction were not included in this review.

**Independent review and analysis.** Independent extraction of articles by the first author was completed in a standardized manner. Information extracted from each article included characteristics of study participants (including age [yr], body mass index [kg m⁻²], geographical source, and type of sport or exercise group) and the prevalence of the Triad conditions, both clinical and subclinical.

**RESULTS**

**Summary of studies on the prevalence of the Triad conditions in exercising women.** A total of 65
studies were identified for inclusion in this systematic review. The search of MEDLINE and PubMed databases provided a total of 169 citations. Of these, 47 studies were discarded because after reviewing the abstracts, it seemed that these articles clearly did not meet our established criteria. The full text of the remaining 122 citations was examined. Of those citations examined, 57 studies did not meet our inclusion criteria as described. Among all of these studies, there were 10,498 participants with a mean age of 21.8 ± 3.5 yr and a body mass index of 20.8 ± 2.6 kg m⁻². The source population for the studies varied geographically; 39 studies from the United States, 8 studies from Norway, 6 studies from the United Kingdom, 3 studies from Australia, 2 studies from Germany, and 1 study each from Turkey, Malaysia, Iran, Sweden, Croatia, South Africa, and Brazil. Twenty-nine studies focused on competitive athletes from multiple sports, 15 studies on endurance runners, 9 studies on competitive dancers, 3 studies on endurance athletes, 3 studies on recreationally active women, 2 studies on competitive gymnasts, and 1 study each on recreational triathletes, competitive swimmers, competitive figure skaters, and recreational weight lifters. Twenty-three studies included nonathlete/sedentary controls in their analyses.

Nine studies were identified wherein the investigators evaluated the prevalence of all three Triad conditions individually or in combination (6,10,30,31,43,49,59,68,70) (Table 2) (see Table 1 for the definition of subclinical and clinical conditions for each Triad condition). A more specific evaluation of prevalence was completed wherein investigators determined the prevalence of two Triad conditions (MD and low BMD, MD and DE, low BMD and DE, MD and low EA, and low EA and low BMD) and revealed 1) four studies on clinical MD and low BMD (6,10,30,68), 2) eight studies on clinical MD and clinical DE (9,14,26,43,50,65,68,70), 3) two studies on clinical DE and low BMD (6,68), 4) one study on low EA and clinical MD (30), and 5) one study on low EA and low BMD (30). Three studies on subclinical DE and clinical MD (27,44,71) were also included.

In terms of clinical presentation of individual Triad conditions, there were 1) 35 studies on clinical MD, 2) eight studies on low BMD (z-score ≤ −2.0), 3) 29 studies on clinical eating disorders/DE, and 4) one study on low EA (<30 kcal·d⁻¹·kg⁻¹ lean body mass [LBMI]). In terms of subclinical presentation of individual Triad conditions, there were 1) four studies on subclinical MD, 2) six studies on low BMD (z-score between −1.0 and −2.0), 3) six studies on subclinical DE, and 4) one study on low EA (<45 kcal·d⁻¹·kg⁻¹ LBM). The prevalence estimates from these published reports are summarized in Tables 3–5.

We included five studies wherein the investigators determined the prevalence of two of three Triad conditions in lean versus nonlean sport athletes and thirteen studies wherein the prevalence of individual Triad conditions were evaluated. The prevalence estimates from these published reports are summarized in Table 6.

**Prevalence studies on all three Triad conditions presenting simultaneously.** The prevalence of all three, any two, and any one of the Triad conditions in exercising women is presented in Table 2. A relatively small percentage of athletes (0%–15.9%) exhibited all three Triad conditions in the published studies (nine studies, n = 991). In reports on solely high school athletes, the prevalence of all three Triad conditions ranged from 1.0% to 1.3% (three studies, n = 328). The prevalence of any two Triad conditions in these studies ranged from 2.7% to 27.0% (seven studies, n = 865) (Table 2). The prevalence of any one of the Triad conditions in these studies ranged from 16.0% to 60.0% (six studies, n = 537) (Table 2).

**Prevalence studies on the different combinations of two components of the Triad.** The specific evaluation on the prevalence of the different combinations of two Triad conditions revealed 1) the prevalence of MD and low

### TABLE 2. Studies on the prevalence of all three, any two, and any one of the Triad conditions in exercising women.

<table>
<thead>
<tr>
<th>Investigators</th>
<th>Participants</th>
<th>Prevalence of all Triad Conditions (%)</th>
<th>Prevalence of Any Two Triad Conditions (%)</th>
<th>Prevalence of Any One Triad Conditions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoch et al. (30)</td>
<td>80 varsity female high school athletes</td>
<td>1.0</td>
<td>4.0–18.0</td>
<td>16.0–54.0</td>
</tr>
<tr>
<td>Nicholls et al. (43)</td>
<td>80 sedentary controls</td>
<td>1.0</td>
<td>5.0–10.0</td>
<td>21.0–39.0</td>
</tr>
<tr>
<td>Schtscherbyna et al. (59)</td>
<td>78 female swimmers</td>
<td>1.3</td>
<td>15.4</td>
<td>47.4</td>
</tr>
<tr>
<td>Beals and Hill (6)</td>
<td>112 collegiate female athletes</td>
<td>0.9</td>
<td>9.0</td>
<td>52.7</td>
</tr>
<tr>
<td>Burrows et al. (10)</td>
<td>82 physically active females</td>
<td>0.0</td>
<td>NR</td>
<td>22.0</td>
</tr>
<tr>
<td>Hoch et al. (31)</td>
<td>15 women from club triathlon team</td>
<td>0.0</td>
<td>27.0</td>
<td>60.0</td>
</tr>
<tr>
<td>Pollock et al. (49)</td>
<td>44 elite female endurance athletes</td>
<td>15.9</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Torstveit and Sundgot-Borgen (68)</td>
<td>186 female elite athletes</td>
<td>4.3</td>
<td>5.4–26.9</td>
<td>NR</td>
</tr>
<tr>
<td>Vardar et al. (70)</td>
<td>145 control participants</td>
<td>3.4</td>
<td>12.4–15.2</td>
<td>NR</td>
</tr>
<tr>
<td></td>
<td>224 female athletes</td>
<td>1.4</td>
<td>2.7</td>
<td>NR</td>
</tr>
</tbody>
</table>

*Study included prevalence data on both high school and premenopausal female participants.
NR, data not reported.
BMD was 0%–7.5% (four studies, n = 460), 2) the prevalence of MD and DE was 2.7%–50.0% (eight studies, n = 1136), 3) the prevalence of low BMD and DE was 0.9%–3.2% (two studies, n = 298), 4) the prevalence of MD and low EA was 17.5% (1 study, n = 80), and 5) the prevalence of low BMD and low EA was 3.75% (1 study, n = 80).

Prevalence studies on MD. The studies wherein the investigators evaluated the prevalence of MD are summarized in Table 3. All studies used self-report methods, except three studies that used hormonal analyses (8,18,19) and one study wherein pooled serum hormone levels for early follicular and midluteal phases of the cycle were used (76).

The prevalence of secondary amenorrhea ranged from 1.0% to 60.0% (34 studies, n = 5607). The prevalence of primary amenorrhea ranged from 0% to 56.0% (13 studies, n = 2216). The range in the prevalence of oligomenorrhea was 0.9%–52.5% (23 studies, n = 4044). In the four studies that assessed the prevalence of subclinical MD (LPD and anovulation), the prevalence of LPD and anovulation ranged from 5.9% to 43.0% (n = 118) and from 12.0% to 30.0% (n = 101), respectively.

Prevalence studies on DE. Table 4 presents the studies wherein the investigators evaluated the prevalence of clinical eating disorders and DE (subclinical and clinical presentations) in exercising women. The prevalence of clinical eating disorders ranged from 0% to 48.0% (17 studies, n = 2869), whereas the prevalence of clinical and subclinical DE ranged from 7.1% to 89.2% (17 studies, n = 2867) and from 2.9% to 60.0% (6 studies, n = 1363), respectively.

Prevalence studies on low EA. Hoch et al. (30) demonstrated that athletes (n = 80) had a significantly lower prevalence of low EA (≤45 kcal·kg⁻¹·LBM) (P < 0.05) in comparison with sedentary students/control subjects (n = 80), 36% versus 39%. Furthermore, in the athletic group with low EA (≤45 kcal·kg⁻¹·LBM), 6% had an EA less than 30 kcal·kg⁻¹·LBM compared with 4% in sedentary students/control subjects.

Prevalence studies on low BMD. Table 5 presents the studies wherein the investigators evaluated the prevalence of low BMD (defined as both z-score between −1.0 and −2.0 and z-score ≤ −2.0) in exercising women.
Prevalence of low BMD defined as $z$-score between $-2.0$ and $-1.0$ ranged from $0.0$ to $39.8\%$ (seven studies, $n = 677$).

Prevalence studies on Triad conditions: lean versus nonlean sport athletes. The prevalence estimates from the investigations comparing lean versus nonlean sport athletes for the prevalence of individual and combined Triad conditions are summarized in Table 6. From the investigation on the prevalence of all three Triad conditions in female athletes categorized by sport type (lean vs nonlean), there were no investigators that reported the prevalence estimates.

Prevalence of low BMD defined as $z$-score $\leq -2.0$ ranged from $0\%$ to $15.4\%$ (eight studies, $n = 755$), whereas the prevalence of low BMD defined as $z$-score between $-1.0$ and $-2.0$ ranged from $0\%$ to $39.8\%$ (seven studies, $n = 677$).

Table 5. Studies on the prevalence of low BMD in exercising women.

<table>
<thead>
<tr>
<th>Investigators</th>
<th>Study Population</th>
<th>$z$-score $\leq -1.0$ (%)</th>
<th>$z$-score $\leq -2.0$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrack et al. (4)</td>
<td>93 female adolescent competitive endurance runners</td>
<td>39.8</td>
<td>11.9</td>
</tr>
<tr>
<td>Beals and Hill (6)</td>
<td>112 female collegiate athletes</td>
<td>9.8</td>
<td>1.8</td>
</tr>
<tr>
<td>Hoch et al. (31)</td>
<td>15 recreational female triathletes</td>
<td>0.0$^*$</td>
<td>0.0</td>
</tr>
<tr>
<td>Hoch et al. (30)</td>
<td>80 high school female athletes</td>
<td>13.9$^*$</td>
<td>3.0</td>
</tr>
<tr>
<td>Nichols et al. (43)</td>
<td>170 female high school athletes</td>
<td>21.8</td>
<td>4.1</td>
</tr>
<tr>
<td>Pollock et al. (49)</td>
<td>44 elite female endurance athletes</td>
<td>34.2$^*$</td>
<td>7.3</td>
</tr>
<tr>
<td>Rauh et al. (51)</td>
<td>163 female athletes</td>
<td>22.1</td>
<td>4.3</td>
</tr>
<tr>
<td>Schtscherbyna et al. (59)</td>
<td>78 elite female swimmers</td>
<td>NR</td>
<td>15.4</td>
</tr>
</tbody>
</table>

$^*$Low BMD was defined as $z$-score between $-1.0$ and $-2.0$. NR, data not reported.

Table 4. Studies on the prevalence of clinical eating disorders (ED) and disordered eating (DE) (subclinical and clinical) in exercising women.

<table>
<thead>
<tr>
<th>Investigators</th>
<th>Prevalence of Subclinical DE (%)</th>
<th>Prevalence of Clinical DE (%)</th>
<th>Prevalence of Clinical ED (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beals and Hill (6)</td>
<td>NR</td>
<td>20.0</td>
<td>AN: 1.8</td>
</tr>
<tr>
<td>Beals and Manore (7)</td>
<td>32.4</td>
<td>15.2</td>
<td>AN: 3.3</td>
</tr>
<tr>
<td>Burrows et al. (10)</td>
<td>NR</td>
<td>15.0</td>
<td>AN: 2.0</td>
</tr>
<tr>
<td>Byrne and McLean (11)</td>
<td>NR</td>
<td>NR</td>
<td>AN: 4.0</td>
</tr>
<tr>
<td>Cobb et al. (14)</td>
<td>NR</td>
<td>25.6</td>
<td>AN: 33.0</td>
</tr>
<tr>
<td>Evers (23)</td>
<td>NR</td>
<td>NR</td>
<td>AN: 25.0</td>
</tr>
<tr>
<td>Hoch et al. (31)</td>
<td>60.0</td>
<td>NR</td>
<td>AN: 31.0</td>
</tr>
<tr>
<td>Hoch et al. (30)</td>
<td>80 high school female athletes</td>
<td>7.1</td>
<td>AN: 16.0</td>
</tr>
<tr>
<td>Hoch et al. (32)</td>
<td>15 recreational female triathletes</td>
<td>16.0</td>
<td>AN: 12.0</td>
</tr>
<tr>
<td>Johnson et al. (34)</td>
<td>2.9–9.2</td>
<td>NR</td>
<td>AN: 0.0</td>
</tr>
<tr>
<td>Martensen et al. (39)</td>
<td>NR</td>
<td>44.7</td>
<td>AN: 8.0</td>
</tr>
<tr>
<td>Nichols et al. (43)</td>
<td>NR</td>
<td>10.0–18.0</td>
<td>AN: 6.8</td>
</tr>
<tr>
<td>Nichols et al. (42)</td>
<td>NR</td>
<td>20.0</td>
<td>AN: 4.1</td>
</tr>
<tr>
<td>Quah et al. (50)</td>
<td>NR</td>
<td>89.2</td>
<td>AN: 49.8</td>
</tr>
<tr>
<td>Rauh et al. (51)</td>
<td>NR</td>
<td>16.0</td>
<td>AN: 41.7</td>
</tr>
<tr>
<td>Raymond-Barker et al. (52)</td>
<td>NR</td>
<td>10.2</td>
<td>AN: 2.0</td>
</tr>
<tr>
<td>Rosendahl et al. (55)</td>
<td>26.7</td>
<td>NR</td>
<td>AN: 18.0</td>
</tr>
<tr>
<td>Rucinski et al. (56)</td>
<td>NR</td>
<td>NR</td>
<td>AN: 44.0</td>
</tr>
<tr>
<td>Schtscherbyna et al. (59)</td>
<td>NR</td>
<td>44.9</td>
<td>NR</td>
</tr>
<tr>
<td>Sundgot-Borgen (63)</td>
<td>NR</td>
<td>NR</td>
<td>AN: 1.3</td>
</tr>
<tr>
<td>Sundgot-Borgen and Torstveit (64)</td>
<td>NR</td>
<td>NR</td>
<td>AN: 8.0</td>
</tr>
<tr>
<td>Thein-Nissenbaum et al. (65)</td>
<td>NR</td>
<td>35.4</td>
<td>AN: 4.0</td>
</tr>
<tr>
<td>Torstveit et al. (67)</td>
<td>NR</td>
<td>46.2</td>
<td>AN: 4.8</td>
</tr>
<tr>
<td>Vardar et al. (70)</td>
<td>NR</td>
<td>16.8</td>
<td>AN: 1.0</td>
</tr>
<tr>
<td>Walberg and Johnston (74)</td>
<td>12.3–25.1</td>
<td>NR</td>
<td>AN: 3.6</td>
</tr>
<tr>
<td>Weight and Noakes (75)</td>
<td>NR</td>
<td>14.0</td>
<td>NR</td>
</tr>
</tbody>
</table>

AN, anorexia nervosa; BN, bulimia nervosa; AA, anorexia athletica; EDNOS, eating disordered not otherwise specified; NR, data not reported.
of all three Triad conditions defined as low EA with or without DE, MD, and low BMD. The prevalence of all three Triad conditions defined as DE, MD, and low BMD in lean sport athletes ranged from 1.5% to 6.7% versus nonlean sport athletes wherein the prevalence ranged from 0% to 2.0% (three studies, n = 365). Similar findings were observed when evaluating the studies wherein the investigators assessed the prevalence of two Triad conditions with the lean sport athletes demonstrating higher prevalence of MD and low BMD (3.3% vs 1.0%) (one study, n = 186), MD and DE (6.8%–57.8% vs 5.4%–13.5%) (four studies, n = 987), and low BMD and DE (5.6% vs 1.0%) (one study, n = 186) than the nonlean sport athletes. No studies measured any combination of subclinical Triad components.

In terms of the individual Triad disorders, lean sport athletes demonstrated a higher prevalence compared with nonlean sport athletes for MD (0.7%–27.7% vs 0%–16.5%; five studies, n = 1032) and low BMD (3.1%–15.4% vs 0%; one study, n = 112). However, the prevalence of DE was similar between groups, 1.5%–89.2% in lean sport athletes and 0.0%–89.2% in nonlean sport athletes (12 studies, n = 2186). Notably, the prevalence of EA has yet to be determined in female athletes categorized by sport type (lean vs nonlean).

**DISCUSSION**

To date, our review is the first to evaluate the prevalence of Triad conditions (clinical or subclinical) occurring individually and in combination in high school and premenopausal exercising women. We also address the notable discrepancy in the prevalence of the Triad conditions occurring simultaneously or in combination versus individual presentations (MD, low EA, eating disorders/DE, or low BMD). Our review demonstrates that despite a large body of evidence determining the prevalence of the individual Triad disorders in exercising and athletic women, the prevalence of Triad conditions presenting simultaneously or in varying combinations is not well documented. The lack of good documentation is attributable to the methodological difficulties in measuring the Triad in a research setting to include the lack of established and consistent definitions and criteria used for each Triad component, selection bias in limiting studies to female athletes with the exclusion of recreational exercising women, and limitations in experimental design and methods of assessment. Ongoing research into the prevalence of EA is advancing our understanding of the etiology of MD and bone loss in exercising and athletic women. However, the calculation of EA is limited by the error associated with some methods of assessing its components, to include energy intake and nonobjective assessments of exercise energy expenditure (EEE) and fat-free mass (FFM). Methods with greater precision for assessing FFM, one of the determinants of EA, that is, DXA scans, are costly and difficult to access, and therefore, this challenge may prevent the proper measurement of EA in a research or field setting.

Prevalence estimates of all three Triad conditions presenting simultaneously are generally low in female athletes, ranging from 0% to 16%. A greater percentage of these female athletes present with any two of the Triad conditions, ranging from 3% to 27%, and an even greater proportion present with any one of the Triad conditions ranging from 16% to 60%. There are many reasons for this apparent discrepancy observed in the literature, such as inconsistencies and limitations in study methodology, criteria defining the Triad, and experimental design. In general, a substantially
greater number of female athletes present with MD, low EA, eating disorders/DE, or low BMD alone compared with those female athletes actually presenting with multiple disorders of the Triad. In particular, the prevalence of low BMD is lower in comparison with estimates of MD or clinical eating disorders/DE, which may affect the prevalence of combinations of the Triad (6,30,43,68). However, low EA may also have a detrimental effect on bone (33) and without an appropriate nutritional intervention; bone loss may continue to occur despite pharmacological treatment and the resumption of normal menses. To date, the prevalence of low EA is not well established, and further investigation of the prevalence of this Triad component may offer insight regarding the discrepancy in prevalence estimates for the Triad conditions presenting in combination versus individually. Lastly, prevalence study on the subclinical Triad disorders is notably absent from the literature. Further evaluation of the prevalence of all Triad conditions before the presentation of clinical severity is warranted.

**Prevalence studies of the Triad conditions presenting simultaneously.** One of the earliest studies measuring the prevalence of the simultaneous occurrence of the Triad conditions was completed in female soldiers (35). Lauder et al. (35) demonstrated that none of the 423 active-duty military personnel in their 12-month prospective cross-sectional study met the criteria for all Triad conditions presenting simultaneously despite a high prevalence of participants (26%) being identified as at risk for the Triad. Of those women identified as at risk for the Triad, only 3.3% presented with low BMD according to the WHO criteria (T-score value between −1.0 and −2.5 SD below average) at the lumbar spine, whereas none presented with osteoporosis (T-score less than or equal to −2.5 SD). Although the study by Lauder et al. (35) was conducted in military women, this work initiated interest in determining the prevalence of Triad conditions presenting simultaneously in female athletes, and it was clear that the clinical relevance of the Triad needed to be further investigated. Numerous cross-sectional studies of the simultaneous presentation of all Triad conditions in collegiate/elite female athletes were subsequently completed (6,10,30,31,43,49,50,59,68,70). Consistent with the findings of Lauder et al. (35), the prevalence of all Triad conditions presenting simultaneously was low in most these studies, except for a study completed in female cross-country runners (49). Notably, none of these studies objectively measured menstrual status, determined the prevalence of low EA, or evaluated the presence of subclinical MD.

**Prevalence studies of the Triad conditions presenting in varying combinations.** Several investigators have determined the prevalence of any of the combinations of the Triad conditions, and these reports support the notion of interrelatedness among clinical manifestations of this syndrome. Cobb et al. (14) were the first to examine the interrelationships among MD, low BMD, and DE in female athletes. These investigators demonstrated several key findings with relevant implications for Triad research, such as exhibiting associations between both DE and oligo/amenorrhea and low BMD and oligo/amenorrhea. They also observed a link between DE and low BMD, specifically in eumenorrheic athletes (14). However, Cobb et al. (14) did not report whether all Triad conditions presented simultaneously in any of the athletes they studied.

Torstveit and Sundgot-Borgen (68,69) were the first to assess the simultaneous existence of the Triad components in a population of female athletes and compare their findings to a control group. Their findings demonstrated that a significant percentage of female athletes presented with varying combinations of Triad conditions, and additionally, they exhibited that recreationally active women (controls) also presented with Triad conditions. The relevance of these findings extends beyond elite female athletes to recreationally active women with 12%–15% of controls presenting with varying combinations of Triad conditions. Further analyses of these control participants suggested that it was their use of pathological weight control methods in attempts to lose weight that may have contributed to prolonged periods of low EA coupled with less weight-bearing activity compared with female athletes. However, it is important to highlight that Torstveit and Sundgot-Borgen (68) did not directly measure the physiological processes underlying the Triad and presented associations between risk factors rather than causal relationships between Triad conditions (36). Hoch et al. (30) demonstrated in their sedentary/control group that 5%–39% of controls presented with any two of Triad conditions. Interestingly, 20% and 10% of these participants met the criteria for low BMD (z-score between −1.0 and −2.0 and z-score ≤ −2.0, respectively). It is clear that a lack of weight-bearing exercise combined with low EA increases the risk of developing Triad disorders. Unlike Torstveit and Sundgot-Borgen (68), Hoch et al. (30) measured EA in their participants; however, the control participants may have underreported energy intake and/or overreported EEE to result in such a high prevalence of low EA. To this end, the clinical representation of the incidence of the Triad in female athletes in comparison with controls is still unclear, and furthermore, additional investigation into the prevalence of the Triad conditions in recreationally active women is required.

**Prevalence of the subclinical Triad conditions presenting simultaneously or in varying combination.** To date, the prevalence of subclinical Triad conditions presenting simultaneously and in varying combinations have only been determined by a few investigators predominantly assessing subclinical DE or MD. One particular concern involves the use of self-report menstrual history to categorize menstrual status in Triad prevalence studies. The method of self-report only indicates MD that is readily apparent to women by the absence and/or irregular intervals of menses. De Souza et al., using daily urinary reproductive hormonal analyses, have shown that approximately half of exercising women present with subclinical MD (LPD...
and anovulation) despite experiencing cycles of regular intermenstrual intervals and seemingly “normal” menstrual cycles (18, 19). These findings confirm that investigators may underestimate the incidence of MD in exercising women using self-report. This is especially concerning considering the wide range of estimates of MD (0%-60%) in published reports. Therefore, to objectively measure menstrual status as a component of the Triad and report the prevalence, daily urinary reproductive hormone analyses should ideally be used to determine accurate estimations of both subclinical and clinical MD. However, it is important to consider the feasibility of self-report methods as field measures or screening tools that may indicate the need for future, more comprehensive evaluation of menstrual status using daily urinary measures of reproductive hormones in certain exercising and athletic women.

Three studies have included an evaluation of the prevalence of MD in exercising women with subclinical DE behavior, such as a high drive for thinness (27, 44) and high dietary cognitive restraint (71). These reports demonstrated that clinical MD (FHA and oligomenorrhea) are significantly more prevalent (17%-23%) in women with high drive for thinness or dietary cognitive restraint compared with those women without such subclinical DE behaviors. However, the prevalence of subclinical DE has not been investigated alongside presentations of low EA and/or low BMD.

Prevalence studies of the Triad conditions in high school female athletes. The Triad is not restricted to premenopausal women, and the magnitude of this syndrome in adolescent and high school female athletes is not well documented. Nichols et al. (43) were the first to report prevalence estimates of MD and low bone mass in adolescents. It is important to mention that menstrual irregularity is common after menarche, and cycles may regulate within approximately 2 yr (2). On establishing that true MD exists, it is critical to evaluate bone mass using DXA to have a baseline measurement for comparative purposes, and as such, the lack of exposure to estrogen may result in a failure to achieve peak bone mass. Because adolescence is such a critical time for bone mineral accrual, the negative effect of MD on bone mass during this phase of the life span may be severely detrimental and may affect the attainment of peak bone mass (43). Prevalence studies in younger populations of exercising women are necessary to bring awareness to the number of young girls at risk for the Triad. In addition, preventative strategies are necessary in youth to avoid development of potential long-term health consequences of the Triad, such as FHA, low BMD/osteoporosis, and stress fractures.

Prevalence studies of the Triad conditions presenting simultaneously and in varying combinations: lean versus nonlean athletes. It is well documented that Triad-related conditions predominate in sports emphasizing leanness (7, 11, 42, 53, 55, 62, 67-69). These types of athletes are suggested to be at a greater risk of demonstrating low EA and/or DE based on the high prevalence of energy restriction and/or dieting behavior reported in these athletes. Such behavior may lead to MD and, subsequently, pathological bone loss.

Torstveit and Sundgot-Borgen (69) found that a higher percentage of athletes competing in lean sports (70%) were categorized as “at risk” of the Triad versus athletes competing in nonlean sports (55%). Beals and Hill (6) examined the prevalence of all three, any two, or one of the Triad conditions (defined as DE, MD, and low BMD) using a z-score below −2.0) between lean sport and nonlean sport athletes. The only athlete that met the criteria for all three Triad disorders (using the criterion of a z-score below −2.0 for low BMD) was notably in the lean sport group (a cross-country runner). The identification of two more athletes (both lean sport participants) with all three Triad conditions resulted when using a less conservative definition of low BMD (z-score below −1.0). However, there were no significant differences in the prevalence of any two of the Triad conditions between lean sport and nonlean sport athletes in this study. Torstveit and Sundgot-Borgen (68) also demonstrated that the prevalence of all three Triad conditions presenting simultaneously was more common in lean sport athletes. These findings differed from Beals and Hill (6) such that Torstveit and Sundgot-Borgen (68) observed more athletes participating in lean sports with any two of the Triad conditions. Notably, 77% of those lean sport athletes presented with any two of the Triad conditions versus 39% of nonlean sport athletes. Accordingly, these investigators reported that six of the eight athletes diagnosed with all three of the Triad conditions were lean sport athletes. More specifically, 58% of lean sport athletes met the criteria for eating disorders/DE and MD versus 29% of their nonlean sport counterparts, supporting the notion that a higher frequency of DE occurs in athletes competing in sports that emphasize leanness and a low body weight (62). Most investigators report an increased incidence of DE behavior among athletes competing in lean sports (11, 62, 67), although there are investigators that failed to find differences between lean sport and nonlean sport groups (39, 55). It is notable that there are potential limitations in comparing the prevalence of DE behavior between lean and nonlean sport athletes to include underreporting of DE symptoms in elite athletes, selection bias, small subsamples of athletes in certain sport types, and the lack of sport-specific instruments designed for athletes in different kinds of sports and competition levels (39, 55, 67).

Limitations of prevalence studies of the Triad conditions presenting simultaneously or in varying combinations. This review suggests that there are notable methodological limitations associated with the study of the Triad. As such, further investigation into the prevalence of the simultaneous presentation of the Triad disorders needs to be completed. To obtain more reliable estimates of the prevalence of the Triad, consistent definitions and criteria must be used and employment of optimal experimental
design and methods of assessment for each Triad condition is necessary.

One of the major limitations in Triad research is the failure to evaluate both subclinical and clinical outcomes of the Triad (41). FHA, osteoporosis, and clinical DE are the most studied conditions of the Triad based on their severity and notable effect on the health and quality of life of exercising and athletic women. However, it must be stressed that the “less” severe conditions related to the Triad are associated with similar negative outcomes and may result in long-term clinical consequences if appropriate treatment does not take place. Thus, accurate prevalence estimates of these subclinical conditions are required to fully appreciate the effect of the Triad from a clinical standpoint (20,41). Future research is required to identify the point at which each of the subclinical Triad conditions can reliably predict risk of future negative health consequences to effectively prevent the development of clinical Triad conditions (20).

In addition, it is clear that the study of exercising and athletic women is difficult, particularly due to personal and sensitive nature of the research relating to eating behavior and menstrual history. It is difficult to infer any conclusions from data with respect to MD and DE behavior in this population using self-report methods alone. Self-report can only identify those women with clearly recognizable MD, and unless objective measures are used, subclinical disturbances would not be captured and prevalence of the Triad would be underestimated. Self-report also relies on the honest and accurate recall of data. Data using hormone analyses would improve the accuracy of measuring the prevalence of the Triad conditions presenting simultaneously and in varying combinations. Underreporting of DE behavior and response bias on questionnaires is common and may distort prevalence estimates for eating disorders and DE in this population. As such, a clinical interview may represent an optimal approach.

To date, only one study (30) has measured EA as a component of the Triad in a prevalence study. EA is notably difficult to measure, and the calculation of EA is limited by the error associated in determining its components, to include, energy intake, EEE, and FFM. EA is often measured using 3- or 7-d diet records to calculate energy intake and a physical activity compendium or heart rate monitors to calculate EEE. There are limitations to this approach, and under- or overreporting of energy intake alone or in combination with poor compliance in recording EEE constitute challenges to determining the prevalence of low EA. Methods with greater precision for assessing FFM, a necessary component of EA, that is, DXA scans, are costly and difficult to access, and therefore, this challenge may prevent the measurement of EA in a research or field setting. Moreover, there is debate whether the concept of EA is more useful than the concept of energy balance for managing the diets of athletes (37), and future research should determine whether EA or energy balance is more superior as an index of energy status for athletes in a field setting and for research/clinical purposes. Nonetheless, prevalence study on EA alone and in combination with other Triad conditions would improve our understanding of the etiology and interrelationships of the Triad components (41).

**CONCLUSIONS**

This review provides a comprehensive summary of the relevant publications that have determined the prevalence of the Triad conditions (subclinical and clinical), occurring simultaneously, in combination, and individually. It is clear that by establishing accurate prevalence estimates of the Triad, we could further our understanding of the physiological mechanisms and clinical relevance of this interrelated syndrome. Our review demonstrates that additional investigation using objective measures and self-report/field measures as necessary is required to determine the prevalence of the Triad. Because objective measures may not always be feasible, self-report/field measures may be necessary in evaluating some components of the Triad to include menstrual status using self-report menstrual history (if daily urinary analyses of reproductive hormones are not accessible), energy intake using 3- or 7-d diet logs, EEE using physical activity compendium (if heart rate monitors or another validated, objective technique is not obtainable), body composition using field techniques or surrogate measures (body weight) (if DXA is not available to measure FFM), and eating behavior using validated questionnaires and self-report (if a clinical interview is not feasible). It is notable that to measure bone density, DXA or other appropriate imaging assessment must be used. Regardless, further prevalence research on the Triad conditions alone or in combination in exercising and athletic women would enable more accurate estimation of the magnitude of this problem. In addition, prevalence estimates are important for developing effective preventive measures, screening criteria, reliable field assessment tools, and treatment strategies for the Triad conditions.

Lastly, it must be underscored that in order for any improvement in Triad prevention and treatment policies to ensue, the prevalence of this syndrome, both subclinical and clinical outcomes, must be accurately measured in a research setting. To date, the clinical representation of the incidence of the Triad in female athletes in comparison with controls is still unclear; furthermore, additional investigation into the prevalence of the Triad conditions in recreationally active women is required. Moreover, there has yet to be comprehensive comparison between (1) those exercising women presenting with all three conditions of the Triad compared with those with one or two conditions and (2) those women with subclinical presentations versus those with clinical presentations of the Triad. These comparisons would be insightful for this area of research and also useful for identifying potential risk factors for the most severe
presentation of Triad-related clinical sequelae. Also, participants must be evaluated longitudinally to better describe the development or recovery of all Trial clinical and subclinical conditions.

REFERENCES


No funding was used to assist in the preparation of the manuscript. The authors have no conflict of interest. The results of the present study do not constitute endorsement by the American College of Sports Medicine.


