Chapter 19
Osteoporosis and the Female Athlete Triad

Christina V. Oleson and Tracy E. Ransom

Components of the Female Athlete Triad

Over the past four decades, an increase in the number of girls and women participating in sports has led to growing concerns about a series of three interrelated disorders observed by those involved in caring for the health of this cohort, namely, parents, coaches, athletic trainers, team physicians, and administrators at the high school and college level and, to a certain extent, at the level of professional sports. The American College of Sports Medicine (ACSM) was the first to identify the components of the female athlete triad in a "position stand," originally issued in 1992 and updated in 1997 and 2007 [1]. It identified the three components along a spectrum of dysfunction (Fig. 1).

Broadly defined, the components are:

1. Energy availability, from optimal energy availability to an end point of low energy availability with or without eating disorders
2. Menstrual function, from amenorrhea (normal menses) to an end point of amenorrhea (delayed menses or cessation for a period of three months)
3. Bone mineral density (BMD), from optimal bone density to an end point of osteoporosis

Although this book focuses on osteoporosis, it is important to understand that each of these components has implications for the next. Energy deficiency associated with eating disorders has a causal role in the development of menstrual irregularities; both energy deficiency and the hypoestrogenic environment linked to amenorrhea affect BMD. In addition, recent research suggests that this hypoestrogenic state could lead to endothelial dysfunction, resulting in cardiovascular disease. As Temme and Hoch have observed, this association could turn the triad into a tetrad [2].

C.V. Oleson, *Osteoporosis Rehabilitation*, DOI 10.1007/978-3-319-45084-1_19

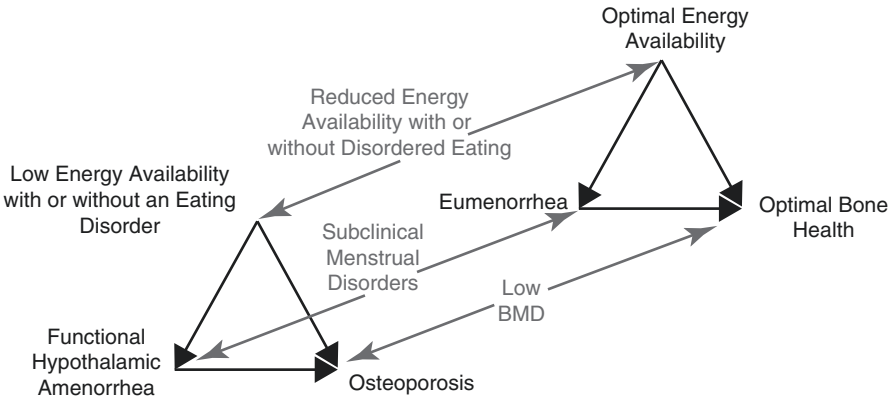

Fig. 1 Female athlete triad. The spectrum of energy availability, menstrual function, and bone mineral density (*Source*: Nattiv et al. [1]. Reproduced with permission)

Table 1 Sports most affected by the female athlete triad

Categorization of sports	Examples
Sports in which performance is subjectively scored	Dance, figure skating, diving, gymnastics, aerobics
Endurance sports emphasizing a low body weight	Distance running, cycling, cross-country skiing
Sports requiring body-contour-revealing clothing for competition	Volleyball, swimming, diving, cross-country running and skiing, track, speed skating, cheerleading
Sports using weight categories	Equestrian, some martial arts, wrestling, rowing
Sports emphasizing a prepubertal body for performance success	Figure skating, gymnastics, diving

Source: Otis et al. [3]

The ACSM 1997 Position Stand identifies several sports disciplines at high risk for promoting the development of one or more of the triad components (Table 1). It should be noted that triad components also occur in adolescent girls whose pursuit of thinness is influenced by role models in films, television, music, fashion, and other aspects of social media. According to a study by Ferguson et al., peer pressure may be even more significant than thin "idols" in promoting eating disorders [4].

Prevalence

Since the identification of the female athlete triad, numerous studies have been undertaken on the prevalence of this condition as a whole, for two or more components, and for individual components [2]. One of the most recent and

comprehensive set of findings, developed by Gibbs et al., examines 65 studies ($n = 10{,}498$) of female high school students and premenopausal exercising women identified through an electronic search of the computerized databases PubMed and MEDLINE [5].

Findings from nine of these studies ($n = 991$) indicate that only a small percentage of athletes, 0–15.9 %, suffer from all three conditions presenting simultaneously. When two of the three components were considered, the prevalence ranged from 2.7 % to 27.0 % (seven studies, $n = 328$), but when only one component was taken into account, the prevalence increased markedly to a range of 16–60 % (six studies, $n = 537$). In another study, Thein-Nissenbaum and Carr used the self-report Eating Disorder Examination Questionnaire to determine that eating disorders and low energy availability (LEA) were present in 35.4 % of 331 female athletes [6]. A more recent analysis of professional ballet dancers by Hoch et al. found LEA in 77 %, eating disorders in 32 %, menstrual disorders in 36 %, low BMD in 23 %, and abnormal brachial artery flow-mediated dilitation (FMD)—the possible fourth component—in 64 % of the cohort [7].

Although significant advances have been made in determining the prevalence of the triad, comparisons among studies remain hindered by the use of different methodologies and varying definitions of the triad components as well as limitations in methods of assessment. In addition, there have been relatively few studies of the subclinical conditions along the spectrum of the triad. Although they may be less severe than the end point, these subclinical conditions remain linked with similar negative outcomes. Studies of subclinical conditions are needed to understand the full effect of the triad from a clinical perspective. Moreover, the highly personal nature of the triad research inevitably results in data often based on inaccurate self-reports, rather than on objective methods such as hormone analyses. If advances are to be made in the prevention and treatment of the triad, both subclinical and clinical outcomes must be measured in a research setting [5].

Causes and Consequences

Low Energy Availability and Eating Disorders

Low energy availability (LEA) is generally regarded as the amount of energy remaining for all physiological functions after it is expended for growth, exercise, and other daily activities. Ideal energy balance in the young occurs at an energy availability (EA) of about 45 kcal per kg of free fatty mass per day; bone formation and reproductive functions are diminished when the level falls to under 30 kcal [8]. The ACSM identifies EA, generally defined as energy intake minus energy expenditure, as the driving force in the triad [1]. The causes of LEA encompass a set of interrelated

biological, social, cultural, and psychological factors. Young females at the greatest risk include those who:

- Intentionally or inadvertently restrict caloric intake
- Adhere to vegetarian diets
- Engage in prolonged periods of exercise, particularly in sports that favor lean physiques
- Begin their sport-specific training early
- Suddenly increase their training intensity

Quite apart from athletic participation, dieting has been identified as the principal factor in determining LEA in adolescents and young women. Patton et al. have shown that 8 % of 15-year-old girls dieted at a severe level and another 60 % dieted at a moderate level. Those who dieted at a severe level were 18 times more likely to develop an eating disorder within six months of initiating the diet; those who dieted at a moderate level were five times more likely to develop the disorder within the same time period [9]. Together and separately, comorbid psychological conditions including depression, anxiety, obsessive–compulsive disorder, low self-esteem, and hormonal factors, specifically decreased leptin and increased ghrelin, underlie the compulsion to diet. These influences can be encompassed under the term "psychiatric morbidity," as applied to competitive, determined women who are also perfectionists [16]. Athletes with high psychiatric morbidity can have a more than six times increased risk of developing an eating disorder.

In athletes, LEA may occur unintentionally if they fail to recognize that their caloric intact is insufficient to meet their training needs. Studies have shown that although dietary restriction increases hunger, energy deficiency caused by increased energy expenditure does not; thus, LEA can develop without clinical eating disorders [1]. More likely, however, it occurs deliberately when individuals engaged in excessive or highly competitive exercise knowingly reduce their caloric intake or increase their energy expenditure. In addition to the factors precipitating LEA in general, this behavior may be motivated by an athlete's internal pressure to be thin as well as by pressure from coaches, parents, and peers.

As noted earlier, LEA occurs across a spectrum, ranging from inadequate food intake to abnormal eating behaviors including skipping meals, fasting, diet pills, laxatives, diuretics, and vomiting to clinical disorders, specifically anorexia nervosa, bulimia nervosa, binge eating disorder (BED), and other feeding or eating disorders. The consequences of LEA are manifold and, in the case of severe anorexia nervosa, life threatening. The health of the individual is seriously affected when energy used for exercise is diverted from such physiological mechanisms as growth, reproduction, and cellular maintenance. For athletes, LEA can lead to decreased immunocompetence, which limits endurance and results in an increased chance of infection and declining performance levels. The greatest effect on performance is demonstrated by athletes in endurance sports, such as

distance running and swimming as opposed to those with lower energy demands such as gymnastics and diving [10]. Moreover, in a study of long-distance runners, the ACSM reported that a tenfold increase in training intensity, <13 to >113 km week^{-1}, resulted in an increase in the prevalence of amenorrhea from 3 % to 60 % [1].

Anorexia nervosa (AN) is the most devastating type of eating disorder (ED), with the highest mortality rate of any psychiatric illness. Death rates are estimated as high as 17 % with 20 % of deaths attributable to suicide [11, 12]. It has been proposed that individuals with anorexia may be predisposed to suicide because they engage not only in dangerous eating behaviors to the point of starvation but also in self-harm behaviors: 25–45 % of individuals with ED engage in self-injury [13]. Of the patients who did not die from suicide, less than half recovered, one-third improved, and a fifth remained chronically ill [14].

Menstrual Disorders

Menstrual abnormalities include primary amenorrhea, secondary amenorrhea, and oligomenorrhea as defined below:

- Primary amenorrhea: the absence of menarche by the age of 15
- Secondary amenorrhea: loss of three or more periods after menarche has begun for a woman who is not pregnant
- Oligomenorrhea: the occurrence of cycles greater than 35 days apart

LEA, caused by insufficient dietary intake and/or excessive exercise, is the principal cause of what is termed "functional hypothalamic amenorrhea," characterized by suppression of the hypothalamic–pituitary–ovarian axis without an identifiable anatomic or organic cause.

In the absence of sufficient energy, the female body reacts by reducing the amount of energy used for growth and reproduction. With this condition, the pulsatile secretion of the gonadotropin-releasing hormone (GnRH) is disrupted, leading in turn to a disruption in the pulsatile secretion of the luteinizing hormone (LH) from the pituitary. Studies indicate that menstruation is impossible if levels of leptin, the "satiety hormone" that regulates the amount of fat stored in the body, fall below a critical level. Other metabolic hormones that contribute to menstrual dysfunction include ghrelin, the "hunger hormone" which signals hunger to the brain and has a role in regulating body weight, adiponectin which increases with prolonged fasting and weight reduction, as well as insulin, insulin-like growth factor-1, and cortisol [8].

The EA required to maintain normal menstruation is 30 kcal.kg^{-1} of lean body mass per day; LH pulsatility is disrupted when EA drops below that level. Neither

intense athletic training nor low body weight can in themselves cause menstrual disorders, indicating that disrupted LH pulsatility is more directly attributable to low energy availability [15].

The consequences of menstrual dysfunction include infertility, decreased immune function, increased cardiovascular risks, and decreased BMD [10]. Unfortunately many young athletes and their coaches are unaware of these conditions or tend to ignore them; in fact, some women are actually relieved by the absence of their periods. However, there is now sufficient evidence to indicate that unless the situation is addressed, it will have long-term implications for the health of women in their training years and later in life.

Low Bone Density

In females, the greatest accretion of bone mass occurs between the ages of 11 and 14, with 25 % of bone mass accrual in the two years surrounding menarche. Healthy young women generally achieve 92 % or more of their total bone mineral content by age 18 and 99 % by age 26 [16]. Since bone mineral deposition occurs early in life, it is critical that a diagnosis be made in adolescence to detect high-risk females and avoid irreparable bone damage.

Evidence suggests that weight-bearing exercise at the pivotal times of bone deposition during puberty may result in improved BMD. Oleson and colleagues reported on a group of competitive figure skaters ages 14–20, all of whom were performing double and/or triple jumps. Those who had begun landing double jumps prior to menarche had statistically higher bone density as determined by quantitative ultrasound. Moreover, 10 of the 36 skaters evaluated had experienced fractures. This group on average mastered double jumps nearly two years later than the skaters without fractures, leading the authors to propose that an osteogenic stimulus contributes to the higher estimated BMD. Full advantage of this osteogenic stimulus appears to be possible only when present on or before menarche [17].

As in all aspects of the female athlete triad, bone density passes through a continuum from peak bone strength to osteopenia—BMD that is lower than peak but not as low as osteoporosis—to osteoporosis itself which is characterized by extremely low BMD, microarchitectural deterioration, and heightened risk of fractures. Decreased BMD is caused by reduced bone formation coupled with increased bone resorption. The causes of osteoporosis in postmenopausal females differ from the causes in younger women. Several decades ago, it was believed that osteoporosis in the young was caused by an estrogen deficiency, as is the case following menopause. Estrogen replacement therapy was used in an attempt to reverse the process but without significant benefit, even after years of such therapy. Estrogen has not been dismissed as a contributing factor in low BMD but more recent research

reveals that the primary cause of osteoporosis in the young is lack of energy availability and low weight. When the body is malnourished, there is an inadequate intake of macronutrients including amino and fatty acids, as well as a lack of vitamins and minerals specifically calcium and vitamin D. Calcium is a critical factor in bone health and calcium deficiencies in young females can result in a 5–10 % difference in peak bone mass. When the body lacks sufficient energy, it can also experience hormonal changes, including high levels of cortisol and low levels of leptin and IGF-1, which contribute to further bone deterioration [18].

Female adolescents with anorexia nervosa are particularly predisposed to osteoporosis. Anorexia typically begins during the teenage years, at the same time that bones are growing and strengthening, thereby slowly or halting bone development. Moreover, if left untreated, anorexia can continue through the 20s and beyond, causing further bone loss. If females can recover from anorexia in their teens and 20s and bone loss is at a minimum, they may be able to recoup normal bone mass. However, a positive outcome will be affected by such factors as the amount of bone developed before the onset of anorexia, the amount lost during the period with anorexia, and the duration of the anorexia [19].

To a certain extent, low estrogen levels may also adversely affect the density and structure of bone mineral content. In patients affected by estrogen deficiency, osteoclasts live longer and more bone is resorbed. As this process continues, there is a loss in the density and structure of bone minerals, resulting in greater susceptibility to fractures in athletes, especially those whose bones are under increased mechanical stress [20]. A link between elevated fasting peptide (PYY) and decreased BMD has also been observed. Concentrations of PYY are negatively associated with bone turnover, indicating that PYY may contribute to detrimental bone pathology [21].

Endothelial Dysfunction

The “standard” components of the triad are long established, but, in the past two decades, researchers have identified another possible component of the triad, potentially transforming it into a tetrad. Endothelial dysfunction is a critical element in the pathogenesis of atherosclerosis and heart failure. The endothelium is the inner lining of blood vessels. When functioning normally, it controls the amount of fluid, electrolytes, and other materials that pass from the blood vessels into tissues; helps control blood clotting; forms new blood vessels; repairs damaged or diseased organs; and governs the dilation and constriction of blood vessels. Estrogen receptors on the endothelium of coronary and peripheral blood vessels regulate vascular function by stimulating the production of nitric oxide (NO) which, in turn, leads to the widening of blood vessels known as vasodilation. Nitric oxide is a strong vasodilator that helps to inhibit platelet aggregation, leukocyte adhesion, low-density

lipoprotein, vascular smooth muscle proliferation and migration, and other atherosclerotic processes [22]. Dysfunction of the endothelium causes hypertension and thrombosis and can lead to impaired heart function, reduced blood flow to muscles, and the development of cardiovascular disease—the leading cause of female deaths in the United States [23].

Evidence shows that there may be a link between endothelial dysfunction, amenorrhea, and low estrogen bonds. Research by Hoch et al. demonstrates that female runners with athletic amenorrhea experience a significant reduction in endothelial-dependent arterial vasodilation [22]. Because amenorrheic females are known to have hormone profiles similar to those of postmenopausal women, Lancer et al. suggest that low estrogen levels will theoretically impair endothelial cell function and arterial dilation [24].

Screening and Diagnosis

According to the American College of Sports Medicine 2007 Position Stand, screening for the triad requires a thorough knowledge of the relationship among the individual components, the spectrum covered by each component, and rates of movement along the spectrum. Ideally, this screening should occur at the time of the preparticipation physical evaluation (PPE) and annual checkups. Athletes who experience one component of the triad should be examined for the others. Early detection of at-risk athletes is critical in preventing or delaying the progress of the triad [1].

Preparticipation physical evaluations (PPEs) cover a wide range of issues that may threaten the health and safety of athletes, ranging from heart and lung problems to cultural factors such as the expectations and behavior of athletes, parents, and coaches. The first step is generally a self-report questionnaire which now exists in several formats. In 2008, the Female Athlete Triad Coalition, consisting of member universities and organizations ranging from the ACSM and the International Olympic Committee to the American Academy of Orthopedic Surgeons and the American Academy of Pediatrics, drew up a questionnaire including eight questions on eating disorders, three on menstrual dysfunction, and one on bone health to be used as the primary screening for the triad (Table 2) [25]. Simple "yes"/"no" answers were requested [18].

Mencias et al. used these questions as a base measure in examining the PPEs used by 257 NCAA Division 1 universities. They found that 25 universities (9%) included 9 of the 12 recommended items, whereas 127 universities (44%) included only four or fewer items. Although all 257 universities required a PPE for incoming athletes, only 83 required PPEs for returning athletes [26].

Supported by six leading medical societies, the Fourth Edition PPE Evaluation Form (PPE-4, 2010) covers athletes from middle school through college and includes 8 of the 12 coalition-recommended questions. If widely adopted, it could improve the effectiveness of this tool by providing standardized criteria. However, in a 2015 study of PPE administrative policies in all 50 states and Washington,

Table 2 Female athlete triad screening questionnaire (2008)

Eating disorders	Do you worry about your weight or body composition?
	Do you limit or carefully control the food that you eat?
	Do you try to lose weight to meet weight or image appearance requirements in your sport?
	Does your weight affect the way you feel about yourself?
	Do you worry that you have lost control over how much you eat?
	Do you make yourself vomit or use diuretics or laxatives after you eat?
	Do you ever eat in secret?
Menstrual history	What age was your first menstrual period?
	Do you have monthly menstrual cycles?
	How many menstrual cycles have you had in the last year?
Bone health	Have you ever had a stress fracture?

Source: Adapted from Female Athlete Triad Coalition: An International Consortium [25]

D.C., Caswell et al. show that most states have been slow in adopting PPE-4 recommendations; they advocate adoption of a nationwide standardized PPE form and the use of an electronic PPE process to improve adherence and create a national database [27].

Low Energy Availability/Eating Disorders

Multiple factors including physical symptoms as well as psychological and behavioral characteristics must be taken into account in screening for energy availability. Physical symptoms encompass a wide range of cardiovascular, endocrine, gastrointestinal, and renal factors; psychological and behavioral issues include anxiety over weight gain, binging and purging behaviors, self-induced vomiting, use of laxatives and diet pills, extreme dieting, and excessive exercise. More than 50 % of the PPE forms examined in the Mencias study omitted questions relating to eating disorders.

Many physicians regard the Eating Disorder Examination (EDE) interview or Eating Disorder Examination Questionnaire (EDE-Q) as a more effective screening tool, but the interview is time consuming and requires training for those who administer it. The EDE-Q is a self-report with ratings for four subscales: restraint, eating concern, shape concern, and weight concern. Aardoom et al. demonstrate that it is highly accurate in discriminating between those with an ED and those without and find that it is a valid technique to assess a general level of ED psychopathology [28]. Often used in primary care settings, the SCOFF questionnaire, incorporating five questions concerning eating behavior, dieting, and a compulsion with food, is helpful in identifying anorexia nervosa and bulimia.

More recently, a new instrument, the Low Energy Availability in Female Questionnaire (LEAF-Q) has been developed to assess athletes at risk for the triad. Consisting of 25 questions about injuries, illness, dizziness, and gastronomical and

reproductive functions, it was submitted by Melin et al. to 84 Swedish and Danish athletes aged 18–39 years who trained ≤5 times/week. Triad-associated disorders were common in this cohort, despite a normal BMI range. The results indicated that LEAF-Q is brief and easy to administer, has a specificity rate of 90 %, and may be successfully used to complement existing ED questionnaires [29].

In terms of diagnosing eating disorders, the *Diagnostic and Statistical Manual of Mental Disorders V* (DSM-V-2013) is regarded as the principal source book for clinicians. Anorexia nervosa (AN) is defined as a serious, potentially life-threatening psychiatric illness characterized by (1) persistent restriction of energy intake leading to significant low body weight in terms of what is minimally expected for age, sex, development, and physical health; (2) intense fear of gaining weight or persistent behavior that interferes with weight gain; and (3) distorted body image and lack of recognition of the seriousness of the low body weight [30]. Although not included in the DSM-V, the concept of anorexia athletica (sports anorexia) is often related to a triad diagnosis; in this condition, excessive exercise and the drive for thinness and high performance outweigh the body-image distortions seen with anorexia nervosa [31]. The DSM-V definition of bulimia nervosa incorporates (1) recurrent episodes of binge eating and (2) recurrent compensatory behaviors to prevent weight gain, including vomiting, diuretics, fasting, and excessive exercise. Both must occur, on average, at least once a week for three months. In DSM-V, binge eating disorder (BED) has been assigned a category unto itself. Occurring at least once a week over three months, it is marked by recurring episodes of eating large quantities of food, without purging; lack of control over eating; eating until uncomfortably full; and secretive eating.

Previously referred to as "Eating Disorders Not Otherwise Specified (EDNOS)," a fourth level, now titled "Feeding or Eating Disorders Not Elsewhere Classified (NEC)," is the most common eating disorder category, keeping in mind that eating disorder studies rely heavily on self-reports that may be inaccurate. NECs include less serious manifestations of the disorders specifically mentioned above, for example, atypical anorexia nervosa (all criteria for AN are met but weight is within or above normal range) and purging disorder (recurrent purging behavior in the absence of binge eating). It is anticipated that orthorexia, an obsession with healthy or rigorous eating, will be the next disorder added to this fourth category. Whereas the former EDNOS was highly diffuse, the NEC has been reorganized to achieve greater specificity, thereby providing new research opportunities as well as useful guidelines for clinical practice [32].

A physical exam, incorporating a PPE and the diagnostic guidelines set forth in DSM-V, is critical in identifying eating disorders. It should begin with basic height, weight, and vital signs and focus on specific physical factors specifically bradycardia and hypotension (cardiovascular); hair loss, lanugo hair, hand calluses or abrasions; dental enamel erosions (dermatological/dental); swollen parotid glands; constipation/diarrhea (gastrointestinal) and dehydration; electrolyte disturbances, edema (renal), as well as low body mass, significant weight loss, and frequent weight fluctuations. Laboratory tests should include a complete blood count, erythrocyte sedimentation rate, thyroid function tests, and urinalysis [18]. A psychologist should

be consulted to examine contributing psychological and behavioral factors such as anxiety, obsessive–compulsive disorder, and perfectionism as well as low self-esteem and the need for self-control.

Menstrual Dysfunction

As in the case of eating disorders, a physical exam and thorough medical history are the essential first steps in identifying menstrual dysfunction. Females with functional hypothalamic amenorrhea may have a normal physical exam, but a pelvic exam may reveal signs of hypoestrogenism with vaginal atrophy. In general, their gonadotropins are low or normal, estradiol is low, and prolactin and thyroid-stimulating hormone are in normal range. In cases of primary/secondary amenorrhea, a pregnancy test should be administered, and endocrinopathies should be ruled out. Endocrinopathies include five primary areas of dysfunction, as described below [33]:

- Thyroid dysfunction
- Hyperprolactinemia
- Primary ovarian insufficiency
- Hypothalamic and pituitary disorder
- Hypoandrogenic conditions including polycystic ovary syndrome and virilizing ovarian insufficiency

Evaluation of menstrual dysfunction requires gonadotropin (follicle-stimulating hormone (FSH) and luteinizing hormone (LH) measurements to eliminate ovarian failure as a cause and to check for the increased FSH/LH ratios observed in polycystic ovary syndrome. In addition, workup should include a prolactin test to assess for a lactotropic-secreting tumor, and a thyroid-stimulating hormone test for thyroid disease. If the physical exam reveals evidence of androgen excess, further laboratory testing to diagnose polycystic ovary syndrome or congenital adrenal hyperplasia and a progesterone challenge test to assess the degree of hypoestrogen should be undertaken. Primary physicians may want to consult with endocrinologists in making this diagnosis [1].

Low Bone Mineral Density

Ultimately, low BMD is the result of a combination of low energy availability and menstrual dysfunction as well as genetics and hormonal functions. Initial studies of decreased BMD focused on the lumbar spine, but subsequent research indicates that the deficit occurs throughout the skeleton. A major consequence of this condition is the risk for fractures during an athlete's competitive years, leading to reduced performance and training time and resulting in chronic pain,

delayed recovery, and disability, Moreover, fractures that occur in adolescence can predict fractures later in life [10]. Athletes with a high incidence of stress fractures, specifically endurance runners and dancers, generally exhibit high levels of dietary restraint and/or an extended history of anorexia or bulimia. Other studies show an association between fractures and amenorrhea [34]. In recent years, research has confirmed a relation between the components of the triad and musculoskeletal injuries in female high school athletes. Rauh et al. found that injured athletes had both higher EDE-Q scores and lower lumbar spine BMD, pointing to both menstrual dysfunction and low BMD as predictors of injury [35]. In the absence of more extensive research, it is difficult to assess the relative importance of one or the other triad components in determining the cause of injury. All three have a negative, long-term effect on bone.

A history of hypoestrogenism, eating disorders for 6 months or more, and stress fractures or fractures with minimal trauma warrant BMD assessment. Dual-energy x-ray absorptiometry (DXA) is regarded as the "gold standard" for evaluating BMD because of its speed, precision, safety, low cost, and widespread availability. It measures bone mass and areal BMD for the entire body as well for specific sites such as lumbar spine, hip, and distal radius [16]. Attention should be focused on the lumbar spine and forearm; they are rich in trabecular bone which is sensitive to changes in the hormonal environment and, thus, susceptible to poor bone quantity (mass) and bone quality (structure), leading to a risk of fracture [36]. In populations considered to be at risk for the triad, the prevalence of low BMD ranges from 1.4 % to 50 %.

The results of a DXA are reported as *T*-scores and *Z*-scores. The *T*-score, used for patients 20 years and older, is the number of standard deviations (SDs) by which a person's BMD differs from that of healthy adults of the same sex. The *Z*-score, reported for all ages, is the number of SDs by which a person's BMD differs from that of individuals of the same age and gender who have no fragility fractures. *Z*-scores are used to assess bone density in adolescent or premenopausal women because adolescents are still growing and have not achieved the BMD of women outside their age group [16]. Guidelines issued by the International Society for Clinical Densitometry stipulate a *Z*-score of −2.0 as "below the expected range for age," while a *Z*-score above −2.0 is "within the expected range of age." The diagnosis of osteoporosis is indicated by the presence of both a clinically significant fracture history and a *Z*-score of ≤−2.0. The posterior–anterior spine and total body minus the head are the preferred sites for performing BMD measurements; the hip should be avoided due to variability in skeletal development. If symptoms persist, the DXA test should be repeated every 12 months, using the same equipment to ensure an accurate comparison [37].

Impaired bone microarchitecture should also be considered in assessing bone structure and fragility. Since DXA calculates BMD using an area measurement (DXA BMD is also known as areal bone mineral density), it cannot accurately measure volumetric BMD which incorporates a depth value. Other imaging technologies including axial quantitative computer tomography (QCT) and peripheral QCT

(pQCT) are needed to measure bone mass and volumetric BMD as it occurs in both trabecular and cortical bone. DNA, QCT, and pQCT measure the inorganic element of the bone matrix; techniques to measure the organic component, primarily collagen, are yet to be perfected [38].

As Ducher et al. point out, diagnosing bone health in adolescents presents significant challenges given constant changes in bone mass, size, and shape. Bone growth can be compromised by childhood diseases as well as by LEA and hypoestrogenism, resulting in deficits in limb and spine dimensions as well as in volumetric BMD. Given these conditions, careful monitoring of young athletes is critical to ensure optimal skeletal development and peak bone mass. The distal forearm is a useful testing site for adolescents up to the age of 19 because it is a common site of fracture and is not loaded in activities such as running. Full recovery of bone strength may never be achieved because bone mineralization in young adults usually results in increased BMD, but not increased bone size [38].

Endothelial Dysfunction

The most common technique for evaluating endothelial function involves the use of a noninvasive, high-resolution ultrasound to examine the diameter of the brachial artery (a major blood vessel in the forearm) and to produce a brachial artery flow-mediated-dependent (FMD) vasodilation measurement. The diameter of the brachial artery and flow velocity are recorded at baseline and again following forearm occlusion with a blood pressure cuff. Deflating the cuff induces increased blood flow that stimulates an endothelium-dependent vasodilation of the brachial artery. The brachial artery FMD can be used successfully to study the early stages of atherosclerosis in children and young adults, thereby ensuring adequate time for prevention [39].

Using this technique, Hoch et al. tested the hypothesis that young female runners with athletic amenorrhea and oligomenorrhea show signs of early cardiovascular disease as manifested by decreased endothelium-dependent dilation of the brachial artery. Their results demonstrated that loss of FMD in conduit arteries compromises exercise-induced dilation of vessels and limits exercise capacity by restricting blood flow to muscles and that chronic impairment of endothelial function may accelerate the development of cardiovascular events [22].

Further studies show a positive relationship between brachial artery endothelial dysfunction and coronary artery endothelial dysfunction. For example, Schachinger et al. found that endothelial dysfunction in the brachial artery predicts atherosclerotic disease as well as cardiovascular events including heart attacks, strokes, and mortality [40]. Further research by Rickenlund et al. found a significantly decreased FMD in amenorrheic athletes as well as an unfavorable lipid profile with significantly higher total cholesterol and low-density lipoprotein [41]. A reasonable

amount of exercise is cardioprotective, but the excessive exercise characteristic of amenorrhea can be counterproductive and instead increase the risk of cardiovascular events. Although the brachial artery FMD technique has been adopted widely, there remains significant variability regarding the protocols and methods of analysis used as well as the interpretation of results. Larger studies with improved and more consistent methodologies are needed to confirm the link between endothelial dysfunction and athletic amenorrhea and the possible extension of the female athlete into a tetrad.

General Approaches to Treatment

The first step in treating and preventing the female athlete triad is greater awareness of the syndrome on the part of healthcare professionals, trainers, physical therapists, coaches, and psychologists. The first "awareness" study on the triad, published in 2006, found that 48 % of physicians were able to identify all three components, but only 9 % were comfortable in treating them. The greatest recognition was among physical medicine and rehabilitation physicians at 69 % and orthopedic physicians at 63 % [42]. A 2013 study surveying 931 physicians at three academic medical centers identified only 37 % of the physicians as having heard about the triad, with the highest level of awareness among orthopedic surgeons (80.3 %) and the lowest level among psychiatrists (11.1 %) [43]. These findings underline the need for greater knowledge of the clinical guidelines for identifying the syndrome; they can be accessed at the website of the Female Athlete Coalition [44], an international advocacy group which serves as a clearing house for education and research about the triad.

There is a general consensus that only a multidisciplinary team ranging from primary care physicians and sports specialists including nutritionists, orthopedists, and psychotherapists to coaches, trainers, family, friends, and teammates can effectively treat the triad. Updated knowledge of both nonpharmacologic and pharmacologic therapy is essential, with pharmacologic treatment of secondary importance. The treatment goal is threefold: increase overall energy availability, restore normal menstrual cycle, and enhance BMD. Consideration should also be given to the role of endothelial dysfunction.

Behavioral Treatment

An understanding of psychological factors such as depression, anxiety, poor self-esteem, and poor self-image in addition to such personality traits as perfectionism and obsessiveness is critical in treating the consequences of the triad. The goals of behavioral treatment include restoring healthy eating habits, overcoming the compulsion to diet, ameliorating poor body image, and establishing

greater control over thoughts and actions [1, 45]. There are a number of empirically based treatment options, described below, that can help reverse the effects of the triad.

Cognitive Behavioral Therapy (CBT)/Behavioral Contracting/ Treatment Plan Adherence

Backed by strong research support, the most widely used treatment for the triad is cognitive behavioral therapy or CBT. Based on the concept that emotions, behaviors, and thoughts are interconnected, this form of treatment consists of identifying distorted cognitions and views of the world along with maladaptive behaviors [46]. Treatment can provide those who suffer from the triad with information about how negative behaviors and attitudes are counterproductive to the goals of performance and how the development of appropriate strategies and skills can lead to increased self-esteem and self-worth. A key component of CBT is "behavioral contracting" which entails keeping a daily "diary" to document the athlete's negative thoughts and behavior patterns and to identify alternatives for better outcomes [1]. Treatment plan adherence focuses on personal methods of altering behavior and cognitions to reach performance goals, as well as on the individual's potential for nutritional education and counseling.

Cognitive Dissonance-Based Prevention (DBP)

The concept of cognitive dissonance centers on the mental distress that occurs when one or more feelings or behaviors contradict one or more thoughts (cognitions). In the triad, this would apply to athletes who restrict calories (behavior) yet recognize that energy availability is reduced for optimum performance (thoughts). In his seminal work, Festinger explains that human beings are driven to maintain internal consistency, meaning that thoughts, values, beliefs, and actions are in harmony [47]. Within a DBP program, female athletes are encouraged to utilize this framework when considering the thin ideal in terms of the dissonance related to performance and self-worth [48].

ATHENA Therapy and Athlete-Modified Health Weight Intervention (AM-HWI-Coach and Peer-Led Approaches)

ATHENA, an 8-week school-based and team-centered approach designed for middle and high school female athletes, has shown promising results. It focuses on identification and modification of disordered behaviors and uses cognitive

restructuring to address risk factors for diet pill use. Depression, self-esteem, steroid-use, and societal and cultural pressures are key concerns. Participants engage in role-playing to practice "refusal skills"—saying "no" to dangerous situations—in cases of eating disorders and substance abuse. Peers and healthy athletes acting as mentors provide validation and encouragement, while the community component of the program offers an increased level of support for the athletes involved. ATHENA can also be a prevention program aimed at those who have not yet engaged in unhealthy behaviors [49]. In the Athlete-Modified Health Weight Intervention (AM-HWI) program, athletes are encouraged to make small, behavioral changes to address eating disorders. Often peer-led, it seeks to reduce thin-ideal internalization, body dissatisfaction, and the negativism that results from anorexic or bulimic behavior [48].

Mindfulness-Based Stress Reduction (MBSR)

Originating in Buddhist thought and practices, mindfulness training has received increasing attention as an intervention treatment for a variety of physiological and psychological problems, including eating disorders. One of the most popular and frequently cited examples of this approach is the mindfulness-based stress reduction (MBSR) program, developed by Jon Kabat-Zinn at the University of Massachusetts. Designed as an 8–10 week course in a group setting, it is based on teaching mindfulness by incorporating psychoeducation on stress reduction, coping, and pain control, together with instruction, discussion, and practice in mindfulness meditation skills and relaxation exercises [50].

"Seven attitudinal factors," espoused by Kabat-Zinn [51] are essential to mindfulness meditation (Table 3): (1) *non-judging*, (2) *patience*, (3) *beginner's mind*, (4)

Table 3 Seven attitudinal factors that are essential to mindfulness meditation

(1) Non-judging	Freeing your mind from judgmental thoughts and opinions
(2) Patience	Accepting the fact that events must occur in their own time and cannot be rushed
(3) Beginner's mind	A willingness to look at things with an open mind, always receptive to new possibilities
(4) Trust	Developing a better understanding of one's self, one's intuition, and one's actions, even if a mistake is made
(5) Non-striving	Seeking no other goal than to be yourself
(6) Acceptance	Understanding the world in the present moment and coming to terms with things as they actually are
(7) Letting go	Allowing experiences and thoughts to be what they are without disputing them

Source: F Kabat-Zinn [51]

trust, (5) *non-striving*, (6) *acceptance*, and (7) *letting go*. When considered as treatment for the triad, the MBSR clinic approach centers on (1) focusing attention on awareness and acceptance of the present moment and, in the case of the triad, on one's sport, (2) suspending judgment and developing an openness to new ideas, and (3) creating a sense of responsibility on the part of the individual for improved health and well-being [52].

How then does mindfulness work? It is proposed that stress and anxiety can be reduced through desensitization, self-exposure, and monitoring of thoughts; physiological impacts may also be involved as manifested by a change in the levels of neurotransmitters and cerebral blood flow, including an increase in dopamine during the meditative process [53]. However, physiological research on the mindfulness response to mind–body outcomes has not been studied extensively.

Mindfulness-Based Cognitive Therapy

Based on Kabat-Zinn MBSR program, mindfulness-based cognitive therapy (MBCT) is a manualized approach to "attentional" thought control that centers on accepting thoughts as what they are, simply thoughts. Focusing on anxiety and depression, it is designed to help prevent a relapse in major depression [54] by developing a detached view of one's thoughts, and, in a cognitive fashion, learning that thoughts are not facts and that they do not determine who a person is—a concept that is helpful for the treatment of the triad. Cognitive exercises such as hatha yoga, which are used in Kabat-Zinn's program, are emphasized and may be helpful for the treatment [55]. Through this approach, patients strengthen their relaxation responses, coping strategies, self-efficacy, insights, and self-determination. At the same time, it should be noted that CBT without mindfulness procedures is also effective in addressing anxiety and depression.

Dialectical Behavior Therapy (DBT)

Dialectical behavior therapy, a mindfulness approach developed by Marsha Linehan [56], encourages patients to change their behaviors and thought processes to build better lives. Participants are taught that the relationship between acceptance of one's situation and a motivation to change is the most profound dialectic. Mindfulness is a key component of DBT, because it allows the patient to observe and allow experiences to happen without suppressing or fighting them. Problem-solving approaches, such as explaining that the person's whole is greater than the

sum of his or her parts, that parts are related, and that change involves incorporating all parts (emotions, behaviors, thoughts) in the process of change constitute the foundation of DBT [57].

Acceptance and Commitment Therapy

Developed by Steven Hayes at the University of Nevada, acceptance and commitment therapy (ACT, said as a word, not as an acronym) incorporates mindfulness techniques to assist patients in reducing their defensiveness so they may experience events as they really are. Instead of thought or emotional suppression, ACT's goal is to accept, experience, and deal with averse thoughts fully, to understand the actual words used to describe them, and then to defuse, rather than to avoid, them [58]. This approach suggests that much of psychopathology is due to maladaptive thoughts and that these thoughts, exacerbated by attempts to avoid then, result in movement away from goals—a common thought process for patients with the triad. ACT seeks to improve flexibility in six different psychological "realms": contact with the present moment, values, committed action, self as context, diffusion, and acceptance. Controlling these realms could enable triad patients to deal more effectively with their behavior [59].

Cognitive Behavioral Therapy and Mindfulness: Similarities and Differences

They are similar in that both help patients to recognize and change negative thought patterns and gain greater control over thoughts and feelings; both have been proved successful in treating depression and anxiety. They are different in that CBT focuses on actively pushing negative thoughts out of consciousness, whereas mindfulness advocates acceptance of thoughts without judgment, acknowledging their impermanence and letting them go [50, 60].

Family-Based and Coaching-Based Therapies

The above mentioned therapies center on individual or group treatment of the triad. It is important to note that influences from family and parents as well as coaches should not be overlooked. Family therapy can assist in identifying any external pressure or expectations from family members; in addition, coaching behavior and beliefs emphasizing the athlete's health rather than performance can often highly influence the approach to triad treatment.

Pharmacologic Treatment

Low Energy Availability and Eating Disorders

Increased energy availability is the key to reversing the female athlete triad: the longer the duration of low weight, the greater the risk of irreversible osteoporosis. For this component of the triad, few pharmacologic interventions have proved effective and those that demonstrate benefits are generally used in association with psychotherapy. However, antidepressant medications—including selective serotonin reuptake inhibitors (SSRIs, including the best known fluoxetine-Prozac), selective serotonin–norepinephrine reuptake inhibitors (SNRIs), and norepinephrine dopamine reuptake inhibitors (NDRIs)—may be helpful in treating LEA, secondary to chronic eating disorders, in athletes who experience concomitant depression, anxiety, and obsessive–compulsive behavior. These medications enable neurotransmitters to remain in neuron synapses for extended periods, thereby leading to a greater sense of well-being and a potential reduction in depressed mood. Moreover, they have few side effects and are well tolerated by most patients [61]. The American Psychiatric Association cites little evidence to warrant the use of medications in treating anorexia nervosa, but bulimia and binge eating have been found to respond to a combination of antidepressants and cognitive behavioral therapy [62]. Proper management and evaluation by a medical professional trained in administering these medications is essential, because frequent monitoring and feedback are needed to obtain the best results [33].

Menstrual Dysfunction

In 1989, the American Academy of Pediatrics recommended the use of oral contraceptive pills (OCPs) for young females with primary amenorrhea at age 15 or 16 and with secondary amenorrhea three months post menarche. However, studies of their efficacy are inconclusive, and some even demonstrate negative effects. For example, early investigations proposed that exogenous estrogen replacement could lead to premature growth plate closure in young athletes [18]. As Temme and Hoch point out, contraceptive therapy in the form of OCPs combining estrogen and progestin does not restore spontaneous menses, because it does not address the underlying metabolic changes that result in menstrual dysfunction [2]; specifically it does not normalize metabolic factors that impair bone formation and general health. Moreover, it does not address the fluctuations of such hormones as leptin, ghrelin, insulin-like growth factor-1 (IGF-1), follicle-stimulating hormone, and luteinizing hormone. Indeed, using OCPs to regulate menstrual cycles may produce a false sense of improvement when induced withdrawal bleeding occurs without a change

in EA and can also deflect attention from proven efforts to restore EA through caloric intake [2]. A further disadvantage of OCP therapy is its suppression of the IGF-1, a major regulator of muscle mass and bone formation during development and a factor that is already at a low level in athletes with the triad.

Low Bone Mineral Density

Research on the efficacy of pharmacologic treatment in athletes with low BMD, stress fractures, and impaired bone accrual is also inconclusive as are studies that focus on whether such treatment prevents fracture or improves healing time and recovery from fractures already sustained. The 2014 Female Athlete Triad Coalition Consensus Statement states that the decision to use pharmacologic therapies should not depend solely on BMD *Z*-scores but should also take into account such risk factors as fracture history, genetic predisposition, triad conditions precipitating low BMD, bone stress injuries, and rate of bone loss with nonpharmacologic intervention [33]. OCP treatment does not increase BMD and may, in fact, further compromise bone health by lowering IGF-1.

However, it is recommended in the case of athletes who refuse to either follow dietary recommendations or reduce their exercise programs or who, despite nutrition or exercise counseling, fail to achieve restored menses after a 6-month period. OCP is not suggested for athletes under the age of 16 due to lack of research on this age group and concern for premature growth plate closure coupled with the knowledge that athletes oppose OCP because of a fear of weight gain [38]. Transdermal estradiol treatment with cyclic progesterone is being studied as an alternative to OCP therapy. Unlike OCP, it does not suppress IGF-1 and has been found to increase spine and hip BMD in young females with anorexia nervosa [63].

Bisphosphonates, which are commonly used to treat postmenopausal osteoporosis, are not generally recommended for young athletes. They act by inhibiting bone resorption and the difference in their effect in adults versus adolescents may relate to increased bone resorption in adults as compared with reduced bone resorption in adolescents. Because they remain active in the bone for as many as 10 years, bisphosphonates raise concerns about harm to the fetus during a subsequent pregnancy, specifically in the form of possible malformations and other defects in newborns. According to the Female Triad Coalition, they should be used only after consultation with an endocrinologist or a specialist in metabolic bone disease, with a decision made on a case-by-case basis [33].

Calcium and vitamin D supplements are recommended to improve bone health in athletes with the triad. According to the 2011 Institute of Medicine (IOM) guidelines, calcium intake for children ages 9–18 is 1,300 mg daily and for women 19–30, 1,000 mg; with 2,500 mg daily as the upper limit of safety, daily intake must be divided into multiple doses. As Ackerman and Misra point out, this recommended calcium intake is not sufficient to optimize bone density in athletes with amenorrhea

[64]. Some studies indicate that calcium supplementation may contribute to stress fracture prevention; further research is needed to make a definitive assessment but, in any case, calcium intake at the IOM level is safe.

Vitamin D is known to reduce the risk of stress fractures and impaired muscle function, yet vitamin D levels are often found to be low in the American population in general and particularly in adolescents. The IOM guidelines for adolescents and premenopausal women call for a daily intake of 600 IU, but a 2012 study proposes that patients receive 800–1,000 IU and perhaps as much as 2,000 IU daily of vitamin D3 because it is a safe treatment with a high therapeutic index [65].

With endothelial dysfunction now being considered as a possible fourth component of the triad, research on alleviating its effects is underway, producing some significant findings. Using a low-dose combined OCP in amenorrheic athletes with decreased FMD at baseline, Rickenlund et al. demonstrated a significant increase in FMD after nine months of treatment, indicating that OCP can improve endothelial function through estrogen's effect in increasing nitric acid's bioavailability. However, hormone replacement treatment in postmenopausal women reveals an increased risk of cardiovascular events and breast cancer, indicating a potential risk for younger women [24].

Given its known cardiovascular benefits, folic acid, which upgrades the production of nitric oxide, has recently been proposed as a treatment for decreased FMD. In studies of amenorrheic runners and ballet dancers, Hoch et al. found an increase in FMD following the administration of 10 mg of folic acid for four weeks; indeed the runners' vasodilator response rose from $3.0 \pm 2.3\,\%$ to $7.7 \pm 4.5\,\%$ [24]. Folic acid, a water-soluble vitamin regularly eliminated in urine, is well tolerated at a low dosage of 10 mg and appears to be a safe, effective treatment for the endothelial dysfunction that occurs in the triad.

Prevention and Early Intervention

Recognition of the components of the female athlete triad is the first step in preventing the serious consequences of the triad that cannot be alleviated through nonpharmacologic, pharmacologic, or a combination of both types of treatments. Ideally the multidisciplinary approach recommended for treatment should be in place to identify the symptoms of the triad and intervene before irreversible damage occurs, particularly with respect to bone density and the potential for osteoporosis. Barbara Drinkwater, one of the first researchers to coin the term "female athlete triad," was also among the first to study the effect of athletic amenorrhea on BMD. She found that following resumption of normal menses, amenorrheic athletes regained a small amount of bone density, but never returned to normal levels. Subsequent studies confirmed that the bone density of formerly amenorrheic athletes remained 15 % less than that of athletes who were never amenorrheic. These results underline the need for early intervention to avoid devastating consequences for younger athletes in the short and long term [66].

Lack of awareness coupled with the failure or unwillingness to admit that they are susceptible to the triad must also be overcome. A 2014 study of female collegiate cross-country runners at risk of osteoporosis illustrates this danger. Results showed that this group had minimal concern for osteoporosis; specifically, they did not perceive themselves as highly susceptible to the disease nor did they believe it was a serious disease even if they were afflicted with it [67].

The multidisciplinary team that is so critical in treating elements of the triad may be even more important in implementing prevention and intervention efforts. In the case of adolescents, parents who are knowledgeable about their children's general health and about the warning signs of the syndrome should intervene. More likely, it is team physicians or independent individual coaches who are in a position to observe destructive eating habits and irrational behavioral patterns. Simple recognition of the term "female athletic triad" is not sufficient; these individuals must be fully aware of the components and consequences of the syndrome if they are to address the perceptions and misunderstandings that surround it. A 2006 study of collegiate coaches reported that 64 % of the 91 respondents had heard of the triad but only 48 % thought they could identify its components; moreover, 24 % believed that irregular or absent menstruation was a "normal" consequence of intensive exercise. In contrast, knowledgeable coaches were in a position to welcome and even to coordinate a multidisciplinary assessment that could lead to informed judgments about effective treatment and prevention strategies and on when or whether athletes should "return to play." Perhaps most important, they were more interested in adopting strategies to educate the athletes themselves as well as instilling in them a personal sense of responsibility for actions that could have repercussions over a lifetime [68].

The question of whether preventative strategies and more informed judgments can overcome compulsive personality traits and the societal pressure to be thin admits of no easy answer. In-depth knowledge, increased awareness, and deliberate action on the part of a multidisciplinary team are all needed to meet the challenges of the female athlete triad and its devastating end point, osteoporosis.

References

1. Nattiv A, Loucks AB, Manore MM, Sanborn CF, Sundgot-Borgen J, Warren MP. American College of Sports Medicine position stand. The female athlete triad. Med Sci Sports Exerc. 2007;39(10):1867–82.
2. Temme KE, Hoch AZ. Recognition and rehabilitation of the female athlete triad/tetrad: a multidisciplinary approach. Curr Sports Med Rep. 2013;12(3):190–9. doi:10.1249/JSR.0b013e318296190b.
3. Otis CL, Drinkwater B, Johnson M, Loucks A, Wilmore J. American College of Sports Medicine position stand: the female athlete triad. Med Sci Sports Exerc. 1997;29(5):i–ix.
4. Ferguson CJ, Muñoz ME, Garza A, Galindo M. Concurrent and prospective analyses of peer, television, and social media influences of body dissatisfaction, eating disorder symptoms and life satisfaction in adolescent girls. J Youth Adolesc. 2014;43(1):1–4. doi:10.1007/s10964-012-9898-9.

5. Gibbs JC, Williams NI, De Souza MJ. Prevalence of individual and combined components of the female athlete triad. Med Sci Sports Exerc. 2013;45(5):985–96. doi:10.1249/MSS.0b013e31827e1bdc.
6. Thein-Nissenbaum JM, Carr KE. Female athlete triad symptoms in the high school athlete. Phys Ther Sport. 2011;12(3):108–16. doi:10.1016/j.ptsp.2011.04.002.
7. Hoch AZ, Papanek P, Szabo A, Widlansky ME, Schimke JE, Gutterman DD. Association between the female athlete triad and endothelial dysfunction in dancers. Clin J Sport Med. 2011;21(2):119–25. doi:10.1097/JSM.0b013e3182042a9a.
8. Marguez S, Molinero O. Energy availability, menstrual dysfunction and bone health in sports; an overview of the female athlete triad. Nutr Hosp. 2013;28(4):1010–7. doi:10.3305/nh.2013.28.4.6542.
9. Patton GC, Selzer R, Coffrey C, Carlin JB, Wolfe R. Onset of adolescent eating disorders: population passed cohort study over 3 years. BMJ. 1999;318(7186):765–8.
10. George CA, Leonard JP, Hutchinson MR. The female athlete triad: a current concepts review. S Afr J Sports Med. 2011;23(2):50–7.
11. Fedorowicz VJ, Falissard B, Foulon C, Dardennes R, Divac SM, Guelfi JD, et al. Factors associated with suicidal behaviors in a large French sample of inpatients with eating disorders. Int J Eat Disord. 2007;40(7):589–95.
12. Keel PK, Klump KL. Are eating disorders culture- bound syndromes? Implications for conceptualizing their etiology. Psychol Bull. 2003;129(5):747–69.
13. Siegfried N, Bartlett M. Anorexia and suicide. Eating for life alliance. www.eatingforlife.org, http://www.eating-disorders-research.com/. Accessed 25 Jan 2015.
14. Steinhausen HC. The outcome of anorexia nervosa in the 20th century. Am J Psychiatry. 2002;159(8):1284–93.
15. Loucks AB, Thuma JR. Luteinizing hormone pulsatility is disrupted at a threshold of energy availability in regularly menstruating women. J Clin Endocrinol Metab. 2003;88(1):297–311.
16. Nazem TG, Ackerman KE. The female athlete triad. Sports Health. 2012;4(4):302–11.
17. Oleson CV, Busconi BD, Baran DT. Bone density in competitive figure skaters. Arch Phys Med Rehabil. 2002;83(1):122–8.
18. Chu SM, Gustafson KE, Leiszler M. Female athlete triad: clinical evaluation and treatment. Am J Lifestyle Med. 2013;7(6):87–94.
19. Zanaker CL. Osteoporosis in eating disorders, March 2011. www.feast-ed.org.
20. Idris AI, van't Hof RJ, Greig IR, Ridge SA, Baker D, Ross RA, et al. Regulation of bone mass, bone loss and osteoclast activity by cannabinoid receptors. Nat Med. 2005;11(7):774–9.
21. Scheid JL, Toombs RJ, Ducher G, Gibbs JC, Williams NI, De Souza MJ. Estrogen and peptide YY are associated with bone mineral density in premenopausal exercising women. Bone. 2011;49(2):194–201. doi:10.1016/j.bone.2011.04.011.
22. Zeni Hoch A, Dempsey RL, Carrera GF, Wilson CR, Chen EH, Barnabei VM, et al. Is there an association between athletic amenorrhea and endothelial cell dysfunction? Med Sci Sports Exerc. 2003;35(3):377–83.
23. Reed J, editor. Eating disorders: an encyclopedia of causes, treatment and prevention. Santa Barbara: ABC-CLIO; 2012. Accessed 25 Jan 2015.
24. Lanser EM, Zach KN, Hoch AZ. The female athlete triad and endothelial dysfunction. PM&R. 2011;3(5):458–65. doi:10.1016/j.pmrj.2010.12.024.
25. Female Athlete Triad Coalition: An International Consortium. Introduction: female athlete triad pre participation evaluation. 2002. http://www.femaleathletetriad.org/~triad/wp-content/uploads/2008/11/ppe_for_website.pdf. Accessed 15 Apr 2015.
26. Mencias T, Noon M, Hoch AZ. Female athlete triad screening in national collegiate athletic association division 1 athletes: is the preparticipation evaluation form effective? Clin J Sport Med. 2012;22:122–5. doi:10.1097/JSM.0b013e3182425aee.
27. Caswell SV, Cortes N, Chabolla M, Ambegaonkar JP, Caswell AM, Brenner JS. State-specific differences in school sports preparticipation physical evaluation policies. Pediatrics. 2015;135(1):26–32. doi:10.1542/peds.2014-1451.

28. Aardoom JJ, Dingemans AE, Slop Op't Landt MC, Van Furth EF. Norms and discriminative validity of the Eating Disorder Examination Questionnaire (EDE-Q). Eat Behav. 2012;13(4):305–9. doi:10.1016/j.eatbeh.2012.09.002.
29. Melin A, Tornberg AB, Skouby S, Faber J, Ritz C, Sjödin A, et al. The LEAF questionnaire: a screening tool for the identification of female athletes at risk for the female athlete triad. Br J Sports Med. 2014;48(7):540–5. doi:10.1136/bjsports-2013-093240.
30. American Psychiatric Association. Feeding and eating disorders. DSM-V. 2013. http://www.dsm5.org/documents/eating%20disorders%20fact%20sheet.pdf. Accessed 15 Apr 2015.
31. National Eating Disorder Information Centre (NEDIC). 2014. http://medic.ca/know-facts/definitions. Accessed 13 Feb 2015.
32. Brown TA, Keel PK, Striegel RH. Feeding and eating conditions not elsewhere classified (NEC) in DSM-V. Psychiatr Ann. 2012;42(11):421–5.
33. De Souza MJ, Nattiv A, Joy E, Misra M, Williams NI, Mallinson RJ, et al. Female athlete triad coalition consensus statement on treatment and return to play of the female athlete triad: 1st International Conference San Francisco, California, May 2012 and 2nd International Conference held in Indianapolis, Indiana, May 2013. Br J Sports Med. 2014;48(4):289. doi:10.1136/bjsports-2013-093218.
34. Barrack MT, Ackerman KE, Gibbs JG. Update on the female athlete triad. Curr Rev Musculoskelet Med. 2013;6(2):195–204. doi:10.1007/s12178-013-9168-9.
35. Rauch MJ, Nichols JF, Barrack MT. Relationships among injury and disordered eating, menstrual dysfunction, and low bone mineral density in high school athletes: a prospective study. J Athl Train. 2010;45(3):243–52. doi:10.4085/1062-6050-45.3.243.
36. Mallinson RJ, DeSouza MJ. Current perspectives on the etiology and manifestation of the "silent" component of the female athlete triad. Int J Women's Health. 2014;6:451–67. doi:10.2147/IJWH.S38603.
37. Gordon CM, Leonard MB, Zemel BS. 2013 pediatric position development conference: executive summary and reflections. J Clin Densitom. 2014;17:219–24.
38. Ducher G, Turner AI, Kukuljan S, Pantano KJ, Carlson JL, Williams NI, et al. Obstacles in the optimization of bone health outcomes in the female athlete triad. Sports Med. 2011;41(7):587–607. doi:10.2165/11588770-000000000-00000.
39. Hoch AZ, Lal S, Jurva JW, Gutterman DD. The female athlete triad and cardiovascular dysfunction. Phys Med Rehabil Clin N Am. 2007;18(3):385–400. doi:10.1016/j.pmr.2007.05.001.
40. Schächinger V, Britten MB, Zehler AM. Prognostic impact of coronary vasodilator dysfunction on adverse long-term outcome of coronary heart disease. Circulation. 2000;101:1899–906.
41. Rickenlund A, Eriksson MJ, Schenck-Gustafson K, Hirschberg AL. Amenorrhea in female athletes is associated with endothelial dysfunction and unfavorable lip profile. J Clin Endocrinol Metab. 2005;90:1354–9.
42. Troy K, Hoch AZ, Stavikos JE. Awareness and comfort in treating the female athlete triad: are we failing our athletes? WMJ. 2006;105:21–4.
43. Curry EJ, Matzkin E. The female athlete triad: who falls under the umbrella? American Academy of Orthopaedic Surgeons, *AOOS Now*. 2013. http://www.aaos.org/new/aaosnow/nov13/clinical10.
44. Female Athlete Triad Coalition: an international consortium. 2002. http://www.femaleathletetriad.org/for-professionals/information-for-physicians/. Accessed 20 Feb 2015.
45. Nattiv A, Loucks AB, Manore MM, Sanborn CF, Sundgot-Borgen J, Warren MP. The female athlete triad: position stand. MSSE. 2007. doi:10.1249/mss.0b013e318149f111.
46. Beck JS. Cognitive behavior therapy: basics and beyond, vol. 2. New York: Guilford Press; 2011.
47. Festinger L. A theory of cognitive dissonance. Stanford: Stanford University Press; 1957.

48. Becker CB, McDaniel L, Bull S, Powell M, McIntyre K. Can we reduce eating disorder risk factors in female college athletes? A randomized exploratory investigation of two peer-lead interventions. Body Image. 2012;9:31–42.
49. Randy KW, Aiken LS, Mackinnon DP, Elliot DL, Moe EL, McGinnis W, et al. A mediation analysis of the ATHENA intervention for female athletes: prevention of athletic-enhancing substance use and unhealthy weight loss behaviors. J Pediatr Psychol. 2009;34:1069–83.
50. Baer RA. Mindfulness training as a clinical intervention: a conceptual and empirical review. Clin Psychol Sci Pract. 2003;10:125–43.
51. Kabat-Zinn J. Full catastrophe living: using the wisdom of your body and mind to face stress and pain. New York: Random House; 1990.
52. Kabat-Zinn J. Mindfulness-based interventions in context: past, present and future. Clin Psychol Sci Pract. 2003;10:144–56.
53. Marlette GA, Witkiewitz K, Dillworth TM, et al. Vipassana meditation as a treatment for alcohol and drug use. In: Hayes SC, Follette VM, Linehan MM, editors. Mindfulness and acceptance: expanding the cognitive-behavioral tradition. New York: Guilford Press; 2004. p. 261–87.
54. Segal Z, Teasdale JD, Williams JM. Mindfulness-based cognitive therapy: theoretical rational and empirical status. In: Hayes SC, Follette VM, Linehan MM, editors. Mindfulness and acceptance: expanding the cognitive-behavioral tradition. New York: Guilford Press; 2004. p. 46–65.
55. Teasdale JD, Segal Z, Williams JM. How does cognitive therapy prevent depressive relapse and why should attentional control (mindfulness) training help? Behav Res Ther. 1995;33:25–39.
56. Linehan MM. Cognitive-behavioral treatment of borderline personality disorder. 1st ed. New York: Guilford Press; 1993.
57. Robins CJ, Schmidt H, Linehan MM. Dialectical behavior therapy: synthesizing radical acceptance with skillful means. In: Hayes SC, Follette VM, Linehan MM, editors. Mindfulness and acceptance: expanding the cognitive-behavioral tradition. New York: Guilford Press; 2004. p. 30–44.
58. Blackledge JT, Hayes SC. Emotion regulation in acceptance and commitment therapy. J Clin Psychol. 2001;57:243–55.
59. Hayes SC. Acceptance and commitment therapy and the new behavior therapies: mindfulness, acceptance and relationship. In: Hayes SC, Follette VM, Linehan MM, editors. Mindfulness and acceptance: expanding the cognitive-behavioral tradition. New York: Guilford Press; 2004. p. 1–29.
60. Harley therapy, CCBT vs MBCT-what is the difference. *Harley therapy counselling blog*. http://www.harleytherapy.co.uk/counselling/cbt-mbet-differences.htm.
61. Marks H. How medication treats eating disorders, Everyday health. www.everydayhealth.com/eating-disorders/,medication-to-=treat-eatingdisorders.
62. Aigner M, Treasure J, Kaye W, Kasper S. WFSBP task force on eating disorders. World Federation of Societies of Biological Psychiatry (WFSBP) guidelines for the pharmacological treatment of eating disorders. World J Biol Psychiatry. 2011;12:400–43. doi:10.3109/15622975.2011.602720.
63. Misra M, Katzman D, Miller KK, Mendes N, Snelgrove D, Russell M, et al. Physiologic estrogen replacement increases bone density in adolescent girls with anorexia nervosa. J Bone Miner Res. 2011;26(10):2430–8. doi:10.1002/jbmr.447.
64. Ackerman KE, Misra M. Bone health and the female athlete triad in adolescent athletes. Phys Sportsmed. 2011;39(1):131–41. doi:10.3810/psm.2011.02.1871.
65. McCabe MP, Smyth MP, Richardson DR. Current concept review: vitamin D and stress fractures. Foot Ankle Int. 2012;33(6):526–33. doi:10.3113/FAI.2012.0526.

66. Quinn E. Amenorrhea in athletes. http://sportsmedicine.about.com/od/women/a/Amerorrhea.htm.
67. Nguyen VH, Wang Z, Okamura SM. Osteoporosis health beliefs in women with increased risk of the female athlete triad. J Osteoporos. 2014;2014:676304. doi:10.1155/2014/676304.
68. Pantano K. Current knowledge, perceptions and interventions used by collegiate coaches in the U.S. regarding the prevention and treatment of the female athlete triad. N Am J Sports Phys Ther. 2006;1(4):195–207.