The Female Athlete Triad, Relative Energy Deficiency in Sport — Learn the Research and Current Understanding of These Conditions and Treatment Recommendations
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The term “female athlete triad” (the triad) was coined in 1992 and recognized as an association of disordered eating (DE), amenorrhea, and osteoporosis in female athletes participating in sports that emphasize leanness.¹ Research has revealed much about the triad in the past 25 years, leading to an evolved definition, further recommendations for treatment, and an additional term to consider. One factor that remains the same is the dietitian’s role in identification and treatment of the subclinical symptoms and clinical endpoints associated with the triad.

This continuing education course uses published consensus statements and research on the triad and relative energy deficiency in sport (RED-S) to explain the current understanding of both conditions. The article explains the triad in detail, introduces readers to RED-S, and summarizes treatment recommendations from the literature to provide guidance for the most effective nutrition interventions.

**Current Definition**
In 2014, the Female Athlete Triad Coalition released a consensus statement to update the definition of the triad based on two international conferences held to evaluate research in the field. The new definition recognizes the following three interrelated conditions of the triad: low energy availability (EA) with or without DE, menstrual dysfunction, and low bone mineral density (BMD).² These three conditions don’t always occur at the same time nor at the same level of severity. In some athlete groups, 50% to 60% of individuals who have symptoms will experience only one or two of these components at subclinical or clinical levels; the presence of all three components at the same time is fairly uncommon.³ Due to this range of expression in individuals, the triad is often viewed as a spectrum of symptoms, from a triad-free, “healthy” end (with optimal EA, eumenorrhea, and optimal bone health), to the opposite end, where all three components are at clinically diagnosed levels of disease (low EA with or without DE, functional hypothalamic amenorrhea [FHA], and osteoporosis).²

The consensus statement shares a graphic of the spectra of the triad; it uses two separated triangles to represent optimal health on one end and clinically diagnosed components at the other. In the middle of the two triangles, reduced EA with or without DE, subclinical menstrual disorders, and low BMD are situated to illustrate that different severity of symptoms and rates of acquiring them can occur.¹ This model can be useful for visualizing the triad and educating others about it.
Causes
Although symptoms vary from person to person, it’s widely agreed that low EA is the underlying cause of the menstrual dysfunction and low BMD observed in women with the triad.\(^1\) The definition of EA is dietary energy intake minus exercise energy expenditure.\(^1\) For physically active individuals, EA is the energy remaining to support all other body functions after the energy needed for exercise is taken into account.\(^4\) When dietary intake isn’t enough to provide energy for exercise and the body’s normal functions, low EA occurs. Research has shown that symptoms of low EA begin to appear at levels of intake less than 30 kcal/kg fat-free mass per day.\(^1\) If untreated, it can lead to the development of symptoms and progression of diseases associated with the triad.\(^5\) In addition to these significant health effects, the triad may negatively affect physical performance and can prevent individuals from participating in an exercise or sport they enjoy.

Risk Factors
By definition, female athletes are at risk of the triad, but physically active female adolescents and women who exercise for personal health or enjoyment are also at risk.\(^5\) Individuals in these groups who practice strict dietary restrictions that exclude an entire food group (eg, vegetarians or vegans) are at particular risk due to potential micronutrient deficiencies. There are also sport-specific risk factors that affect certain athletes, including participation in sports that emphasize leanness or involve frequent weight regulation, early start of sport specific training, overtraining, and coaching behaviors that encourage unhealthful habits.\(^6\)

Health Complications
The components of the triad, if left untreated, can lead to various health complications.

Low BMD is of particular concern because it can lead to clinically diagnosed osteoporosis and other bone injuries such as breaks or stress fractures. Bone issues arise in individuals with the triad due to a combination of factors including inadequate ingestion of nutrients such as calcium and vitamin D, and hormonal disruption such as low estrogen.\(^2,7\) Low BMD in premenopausal women is identified as 2 to 2.5 standard deviations below the mean.\(^8\) Athletes generally have BMDs that are 5% to 15% higher than nonathletes, so levels greater than 1 standard deviation below the mean may indicate poor bone health in this population.\(^8\)

Amenorrhea is the clinical endpoint of menstrual dysfunction. There are different types of amenorrhea with different causes, including low energy intake, medications, pregnancy, and genetic abnormalities. FHA is a specific type of amenorrhea associated with the triad. It’s characterized by three or more consecutive months without a menstrual cycle and abnormal gonadotropin-releasing hormone pulsatility.\(^9\) FHA can have a negative impact on musculoskeletal and cardiovascular health among other issues such as infertility, contributing to the interrelated health complications of the triad. It’s necessary to rule out other medical conditions that can lead to amenorrhea before diagnosing FHA. Subclinical irregularities in menstrual function, such as missed periods or changes in length of the cycle, should also be addressed to prevent clinically diagnosed FHA and the musculoskeletal and cardiovascular health effects associated with menstrual dysfunction.\(^9\)
RED-S
In 2014, the International Olympic Committee (IOC) released a consensus statement that introduced RED-S as a broader term to describe the syndrome resulting from low EA. It defined RED-S as “impaired physiological function including, but not limited to, metabolic rate, menstrual function, bone health, immunity, protein synthesis, [and] cardiovascular health caused by relative energy deficiency.” The statement reflected a desire for a new term that also pertained to men potentially affected by the symptoms and clinical endpoints associated with low EA. After the IOC consensus statement was published, concerns were expressed that there was insufficient research to warrant the new term. The authors of the 2014 IOC consensus statement then released additions to their original statement to support their rationale for RED-S and to provide screening and treatment recommendations; these will be discussed alongside other recommendations later in this article.

In RED-S, low EA is also identified as the underlying cause that can lead to various health consequences involving numerous body functions. Bone health and menstrual function are addressed as significant concerns, but the authors have chosen to move away from the word “triad” to put equal emphasis on other health and performance consequences that can result from low EA.

The 2014 IOC paper visually presents this concept with a spoke and wheel diagram, with RED-S at the center and potential health consequences, such as cardiovascular, gastrointestinal, and metabolic, branching out on separate “spokes.” A similar diagram displays potential performance effects associated with the syndrome, such as increased injury risk, impaired judgment, and decreased muscle strength, branching out from the RED-S center. Comparing these diagrams with the Female Athlete Triad Coalition’s conceptual figure of the triad can help dietitians and health care providers fully understand the two terms and their proposed differences, as well as effectively communicate the conditions to other caregivers and patients.

Risk Factors for RED-S
The female athletes and physically active women at risk of the triad are also at risk of RED-S. The majority of scientific research on syndromes stemming from low EA has been on female athletes, so a large portion of what’s known applies specifically to this population. The authors of the IOC statement have identified emerging studies that support the need to include male athletes in the at-risk population for RED-S. In addition, athletes with non-Caucasian ethnicity and those with disabilities have been identified as populations of concern. Recommendations for further research to develop knowledge on how chronic low EA will affect the health of these individuals have been given.

Recommendations for Risk Assessment
Screening for the conditions associated with low EA include assessment of subclinical symptoms as well as clinical endpoints.

Screening for the triad or RED-S should take place as part of an annual examination given to athletes to help ensure safety for participation in their chosen sport. It’s also suggested that female athletes at the high school and collegiate level be screened annually using the triad
specific self-report questionnaire, which is composed of 11 questions addressing history of and current menstrual status, feelings about weight status, dieting, and bone health. In addition to annual evaluations, active individuals or athletes who exhibit DE or energy deficiency, weight loss, abnormal growth, endocrine dysfunction, excessive injuries and illnesses, compromised performance, or unusual mood shifts should be screened for the triad and/or RED-S.

There’s no consensus on which screening tool is most efficacious, but researchers in the field recommend certain risk assessment instruments. The Female Athlete Triad Coalition consensus statement introduced the Female Athlete Triad: Cumulative Risk Assessment and the Female Athlete Triad: Clearance and Return-to-Play Guidelines. Both utilize a point system to categorize an individual as low, moderate, or high risk of the triad based on degrees of low EA with or without DE/energy deficiency, low BMI, delayed menarche, menstrual dysfunction, low BMD, and stress fracture. The Low Energy Availability in Females Questionnaire is a completely self-reported risk assessment for the triad being researched and tested. It includes questions on variables associated with the triad, including injuries, dizziness, cold sensitivity, gastrointestinal function, menstrual dysfunction, and illness. These tools were designed specifically for females.

The RED-S Clinical Assessment Tool (CAT) was developed by the IOC to assess risk in males and females. Its goal isn’t only to provide guidance for caregiver teams but also to allow latitude for providers to use their clinical knowledge to take individuals’ variability into account. The RED-S CAT consists of a “red light (high risk), yellow light (moderate risk), green light (low risk)” risk assessment model. It also includes a “return to play” model with decision-making steps based on medical factors, sport risk modifiers, and decision modifiers, eg, external pressures on the athlete or whether their sport is in season, to determine readiness for return to play. The RED-S CAT includes a treatment contract that provides a template on which it lists members of the multidisciplinary team, required caregiver meetings, and treatment progress goals for the athlete and team physician to agree upon before the athlete can be cleared for competition. If deemed appropriate for an individual’s situation, the contract could be a helpful way to plan and organize treatment plans for an athlete or modified for use in a nonathlete with RED-S.

Diagnosing Low EA
BMI can be used as an initial analysis of EA, but it’s important to note that low EA can occur even in a state of energy balance or weight stability. In states of chronic low EA, the body can undergo physiological adaptations to restore energy balance and maintain a stable and/or “healthy” weight.

When weight status isn’t necessarily low or unhealthy but an individual is presenting other symptoms of the triad or RED-S, it may be necessary to calculate EA to help with diagnosis. The equation for EA is energy intake (kcal) minus exercise energy expenditure (kcal) divided by kilograms of fat-free mass or lean body mass. EA at or below 30 kcal/kg of fat-free mass/day has been associated with health effects that may lead to the symptoms and clinical endpoints associated with the triad and RED-S. To establish this number, researchers measured energy intake, exercise energy expenditure, and fat-free mass precisely in controlled laboratory settings. Outside of the laboratory, ways to assess the three factors...
required to calculate EA include dietary logs, 24-hour dietary recalls, food frequency questionnaires, web calculators, heart rate monitors, dual-energy X-ray absorptiometry, and skin fold measurements. Most methods have an associated degree of error, which makes it difficult to obtain entirely accurate measures. The dietitian’s role is to choose the most appropriate measure for the patient, taking into account this possible error. Once they obtain energy intake, exercise energy expenditure, and fat-free mass measures, RDs can use the Female Athlete Triad Coalition’s EA calculator, available on its website (www.femaleathletetriad.org/calculators/), to estimate EA.

**Nutrition Therapy Treatment Recommendations**

Dietitians have an opportunity to play an active and crucial role in preventing the progression of subclinical symptoms to clinical endpoints associated with low EA, as well as the treatment of these conditions with nutrition therapy. They can be an educational voice, raising awareness about the triad and RED-S among colleagues and treatment teams, which can include physicians, athletic trainers, coaches, and psychologists.

In certain cases, nutrition counseling and monitoring of dietary intake can be a sufficient intervention for athletes or physically active individuals experiencing health complications due to low EA. It’s important to make proper referrals when further medical assistance from physicians or psychotherapists may be warranted, as in cases involving eating disorders.

**Determine Cause of Low EA**

Once an individual is diagnosed with low EA, the next step is to figure out how low EA developed. Is it the result of DE or energy deficiency? Or is it the unintentional consequence of a mismanaged weight loss program? Determining this cause will enable RDs to begin developing an effective treatment plan.

The treatment plan should consider an individual’s specific goals, diet, and training practices, and any other coexisting conditions. RDs should focus their conversations on health and nutrition instead of weight, especially if DE or energy deficiency is present, and include discussion about the importance of sleep and mental health for a sustainable recovery.

As with the available information on at-risk populations, much research on the nutrition interventions to address low EA has involved females, and, therefore, has focused on recovery of menses and nutrient needs specific to women. As the body of evidence on males and low EA grows, more tailored recommendations for nutrition therapy for adolescent males and adult men likely will arise. RDs should keep this in mind when creating unique treatment plans for male athletes or physically active males.

**Initiate Weight Gain**

Recovery of energy status can occur in a few days or a few weeks and can initiate the reversal of certain negative health effects such as undesired weight loss or amenorrhea. A 5% to 10% increase in body weight or 1 to 4 kg of weight gain has been shown to restore menses in females. Authors of the Female Athlete Triad Coalition Consensus suggest that treatment goals for weight gain should target a BMI of ≥18.5 kg/m², ≥90% of ideal body weight, or return to a body weight associated with normal menses based on a patient’s reported history.
Recommendations for determining caloric needs vary but should be based on a past weight associated with a healthy medical status, should always take into account current physical activity, and should generally not fall below 2,000 kcal per day. To initiate weight gain of 0.5 kg per week, energy intake should be 20% to 30% greater than calculated baseline energy needs. An EA of >45 kcal/kg fat-free mass has been associated with improvements in health, making it an ideal EA to aim for throughout treatment.

Once energy requirements are calculated, it’s important to work with clients to develop balanced meal plans that meet energy needs, take into account individuals’ eating preferences, and provide adequate macro- and micronutrient requirements.

**Macronutrient Requirements**

Carbohydrate, protein, and fat recommendations vary per person and per sport; therefore, dietitians need to use clinical judgment to make individual dietary prescriptions that incorporate macronutrient requirements. RDs can start with general recommendations. For example, athletes or physically active individuals should consume 3 to 12 g/kg/day of carbohydrate, 1.2 to 2 g/kg body weight of protein, and no less than 20% of their total dietary intakes from dietary fat. Specific amounts within the ranges provided should be determined based on the details of individuals’ training regimens and health status.

**Micronutrients of Concern**

Individuals diagnosed with the triad or RED-S often have restricted energy intakes that can lead to low intakes of certain micronutrients. Calcium, vitamin D, and iron are consistently cited in the literature as micronutrients of concern for athletes and physically active individuals.

Calcium is required for bone health and plays an important role in the regulation of muscle contraction. To prevent bone injuries and to support muscle function in sport, healthful levels of calcium should be maintained. Individuals without restricted energy intake or amenorrhea should consume 1,000 to 1,300 mg of calcium per day. For individuals who are amenorrheic, 1,500 mg per day is recommended until menses is restored. Supplementation also may be necessary if meeting requirements via food does not seem possible, as in some cases of energy deficiency or DE. In such cases, 1,000 to 1,500 mg per day may be helpful.

Vitamin D is necessary to ensure adequate absorption of calcium, promote bone health and muscle contraction, and support anti-inflammatory actions. Recommendations for vitamin D vary depending on individuals’ current serum levels and range from 600 to 2,000 IU per day. Clients should be tested to screen for vitamin D deficiency (<20 ng/mL) and insufficiency (<32 ng/mL). Based on these results, an appropriate supplementation amount can be recommended to reach and maintain a healthy serum level of vitamin D, which falls in between 32 and 50 ng/mL. The recommended dietary allowance for healthy individuals is 600 IU per day.

Iron is required for adequate oxygen transportation and, if deficient, can negatively affect many aspects of exercise performance, including endurance and attention span. Women of childbearing age, vegetarians, vegans, and athletes tend to be at an increased risk of iron deficiency.
deficiency due to increased iron requirement, inadequate dietary intakes, or increased excretory losses. Current recommendations for daily iron intake are 15 mg/day for women aged 14 to 18 and 18 mg/day for women aged 19 to 50. Women taking birth control have a lesser recommendation of 11 to 12 mg of iron per day due to reduced menstrual blood losses. The recommendations for men aged 14 to 18 are 11 mg/day and 8 mg/day for those aged 19 to 50. Iron recommendations can be met via diet, but various factors may impair iron absorption even when adequate amounts are consumed in food. These include vitamin D deficiency as well as consumption of phosphates, phytates, calcium, and tannins. To help increase absorption of iron, RDs should advise clients to consume high-iron foods with food sources of ascorbic acid. Iron supplementation should be advised only if the client’s iron status is being monitored and a need has been identified.

**Hydration and General Sports Nutrition**

Staying hydrated is an extremely important factor in keeping physically active individuals and athletes healthy and performing well. Encouraging individuals to meet daily fluid requirements, as well as pre-, during, and postexercise hydration recommendations, is important.

Consuming carbohydrates 30 to 60 minutes before exercise as well as a mix of carbohydrates and protein within 30 minutes after exercise is another important aspect of sports recovery and injury prevention.

**Return to Play Recommendations**

Determining whether an individual is ready to return to play or exercise must be decided on a case-by-case basis. Both the IOC and the Female Triad Athlete Coalition’s return to play models aim to take into account the details that make each person’s situation unique. Patient demographics, medical history, type of sport played, and external pressures are a few of the many factors that must be considered before giving an individual full clearance, limited participation, or complete restriction to play. The Coalition’s Decision-Based Return-to-Play Model for the Female Athlete Triad and the IOC’s RED-S Return to Play Model both provide useful guidance for this major decision in treatment.

**Conclusion**

Incorporating nutrition therapy into the treatment plan for individuals diagnosed with the triad or RED-S is necessary for a successful recovery. It’s important for dietitians to understand the similarities and differences between both conditions in order to educate patients and their health care providers, as well as develop the most effective nutrition interventions for clients.

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References


Quiz

1. What is the underlying cause of both the female athlete triad (the triad) and relative energy deficiency in sport (RED-S)?
A. Eating disorders or disordered eating
B. Low energy availability (EA)
C. Overtraining
D. Dietary restrictions

2. Why is the triad visually represented as a spectrum?
A. To illustrate the range of symptoms possible, from subclinical symptoms to clinically diagnosed endpoints
B. To demonstrate that there is no range in symptoms
C. To show the difference between the triad and RED-S
D. To display the names of different symptoms associated with the triad

3. An individual must display all three components of the triad at once to be diagnosed.
A. True
B. False

4. Why was the term RED-S created?
A. To make it easier to identify female athletes with low EA
B. To reduce the recognized symptoms and clinical endpoints associated with low EA
C. To recognize low EA in nonfemale athletes
D. To expand the symptoms and clinical endpoints associated with low EA, as well as the populations at risk in addition to females

5. What factor makes it difficult to accurately calculate low EA?
A. Individuals with low EA always maintain a healthy weight.
B. Most methods used outside of laboratories to measure energy intake, exercise energy expenditure, and fat-free mass have a degree of error associated with them.
C. There is no equation to calculate EA.
D. There are no methods of measurement for the components of EA.

6. At what level of EA do symptoms of the triad or RED-S generally appear?
A. >45 kcal/kg of fat-free mass (FFM)/day
B. >30 kcal/kg of FFM/day
C. <30 kcal/kg of FFM/day
D. <20 kcal/kg of FFM/day

7. Most of the available research on the nutrition interventions to address low EA has been on females.
A. True
B. False
8. Which tool is provided in this course as a way to evaluate the risk of an athlete for RED-S and/or the triad?
   A. BMI
   B. Vitamin D serum level tests
   C. Preparticipation evaluation
   D. RED-S Clinical Assessment Tool

9. What is the first step to develop a treatment plan for RED-S or the triad?
   A. Initiate weight gain.
   B. Restore menses.
   C. Determine the cause of low EA.
   D. Increase caloric intake.

10. What micronutrients are consistently recognized to be of concern in individuals with the triad or RED-S?
    A. Calcium, iron, and vitamin D
    B. Iron, potassium, and vitamin B₁₂
    C. Fat-soluble vitamins
    D. The B vitamins