Health Considerations in Female Runners

Brian Y. Kim, MD, MS\textsuperscript{a,b,*}, Aurelia Nattiv, MD\textsuperscript{a,b,c}

KEYWORDS

- Female athlete triad
- Running
- Nutrition
- Bone health
- Energy availability

KEY POINTS

- The adolescent years represent a vulnerable period because nutritional inadequacies and suboptimal bone accrual may have long-lasting consequences.
- Adequate intakes of calcium, vitamin D, and iron are of particular importance in female runners to optimize bone health and hematopoiesis.
- Female runners should strive to maintain an energy availability of 45 kcal/kg fat-free mass per day to avoid the downstream neurometabolic effects of menstrual dysfunction and low bone density.
- Recently released consensus guidelines and risk assessment tools may be helpful in stratifying individuals based on their risk of bone stress injury and other Triad-related sequelae.
- Nonpharmacologic therapy, such as nutritional intervention and activity modification, remains the mainstay of treatment of Triad-related conditions, with pharmacologic options reserved for severe or recalcitrant cases.

INTRODUCTION

The 1928 Summer Olympic Games marked the debut of female competition at the highest level of track and field. However, the historic occasion was marred by sensationalized accounts of female runners strewn across the finish line in prostration after completing the 800-m run. Such attitudes were informed by cultural norms and pseudoscience, and severely limited women’s participation in athletics well into the second half of the twentieth century. The International Olympic Committee (IOC) would not allow women to compete at distances greater than 200 m for another 32 years. A major obstacle was overcome in 1972 with the passage of Title IX, which set a precedent.

Conflicts of Interest: None.
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for the provision of equal opportunities for women and men in sport. However, major sporting bodies like the Amateur Athletic Union and the IOC were slow to offer tangible opportunities for female sports participation, particularly in distance running. Despite the slow start, female participation in running has increased greatly over the past few decades. In 2013, more than 40% of marathon finishers in the United States were female, compared with just 10% in 1980. At the 2012 Summer Olympic Games, women comprised nearly 50% of track and field athletes and outnumbered men in the marathon by 118 to 105. Girls at the youth level constitute the fastest-growing group of participants in organized sport, from 300,000 in 1972 to 3.2 million today. In terms of participation, women compare favorably with men at both the National Collegiate Athletic Association (NCAA) and high school levels (Table 1), and track and field remains the most popular sport for high school girls, with nearly 500,000 participants in 2013 to 2014. Although coeducational participation may now be the norm in many sports, the sporting worlds of women and men remain distinct. Women of all ages continue to compete with dated societal ideals of form and behavior. At the professional level, female athletes generally garner fewer accolades and less lucrative compensation in the form of contracts, prize earnings, and endorsements than male counterparts. These issues exist alongside a biological and hormonal milieu that varies markedly over different life stages, posing additional challenges for active women. With these considerations, this article offers a perspective on health considerations in female runners, focusing on the importance of nutrition and medical concerns related to the female athlete triad (Triad).

GROWTH AND DEVELOPMENT

Young female athletes face formidable challenges, including increased nutritional requirements, myths about ideal body types that may foster disordered eating (DE), and the need to reconcile advice from a variety of sources, including coaches, trainers, peers, parents, and increasingly the media. An imbalance between the demands of sport and those of normal development can be a source of stress among young athletes, and can persist into adulthood. Hence, this article initially considers the growth and maturation of active girls.

Menarche

Widely considered the central event in pubescence, menarche is heralded by the onset of pulsatile gonadotropin-releasing hormone release and its downstream mediators: luteinizing hormone (LH), follicle-stimulating hormone, and estrogen. The

<table>
<thead>
<tr>
<th>Table 1</th>
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<tbody>
<tr>
<td>Participation in running sports in the United States 2013 to 2014</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Cross-country</th>
<th>Outdoor Track</th>
<th>Indoor Track</th>
</tr>
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<tr>
<td>Female (HS)</td>
<td>218,121</td>
<td>478,885</td>
<td>66,126</td>
</tr>
<tr>
<td>Male (HS)</td>
<td>252,547</td>
<td>580,321</td>
<td>73,650</td>
</tr>
<tr>
<td>Female (NCAA)</td>
<td>15,922</td>
<td>27,752</td>
<td>25,876</td>
</tr>
<tr>
<td>Male (NCAA)</td>
<td>14,218</td>
<td>27,514</td>
<td>24,785</td>
</tr>
</tbody>
</table>

**Abbreviation:** HS, high school.

mean age at menarche in the United States has recently been reported at 12.3 to 12.4 years,\textsuperscript{5,6} and there is considerable agreement that this represents an earlier onset compared with previous reports.\textsuperscript{5–8} The mechanisms underlying this trend are not clear, but may be related to changes in relative weight, ethnic composition, chemical exposure, and insulin resistance over time.\textsuperscript{5,8,9} Although cross-sectional and retrospective studies have suggested a delayed onset of menarche in athletes, there is likely considerable bias in these observations, because late-maturing girls in sport seem to be over-represented as they pass from childhood through adolescence.\textsuperscript{4,10,11}

**Adolescent Growth Spurt**

The growth spurt in girls is an early pubertal event, occurring soon after the initiation of breast development.\textsuperscript{12} Peak height velocity (PHV) occurs at 10.8 to 11.3 years, or about 2 years earlier than in boys, but can vary significantly based on pubertal timing (ie, earlier, average, or later).\textsuperscript{13} Age at PHV is not strongly correlated with adult stature.\textsuperscript{13,14} In most cases, height velocity in girls slows dramatically by 14 or 15 years, whereas some boys grow beyond 18 years.\textsuperscript{13} Sport participation itself does not seem to have an appreciable effect on vertical growth in healthy children.\textsuperscript{15}

**Changes in Body Composition**

Sex differences in fat-free mass (FFM), fat mass (FM), and body fat percentage (BF%) during childhood become more clearly defined during adolescence. By the end of high school, girls have nearly twice the BF% of boys,\textsuperscript{16} a proportion that seems to persist even at the level of elite adult runners.\textsuperscript{17} Maximum increases in FFM occur at age 13 years in girls, preceding boys by about 2 years.\textsuperscript{18} Unlike height, body composition can be influenced by athletic training, with increases in FFM and decreases in FM seen in athletes compared with nonathletes.\textsuperscript{4} Weight is low for height in female distance runners (compared with nonrunners) at all ages, although it is difficult to separate effects of training from changes related to normal growth and maturation.\textsuperscript{19,20}

**Skeletal Maturity**

The adolescent years represent a brief but critical window of opportunity for bone accumulation.\textsuperscript{21} Puberty-associated increases in growth hormone and insulin-like growth factor-1 mediate this process, as well as the actions of hormones, such as dehydroepiandrosterone, estrogen, and leptin.\textsuperscript{22,23} Bone acquisition is maximal in the years surrounding PHV, or about 11 to 15 years of age,\textsuperscript{24} during which 33% to 46% of adult bone content is accrued.\textsuperscript{25} Healthy adolescents of normal weight engaging in impact activities, such as soccer, generally have higher bone mineral density (BMD) than swimmers and athletes engaging in non–weight-bearing sports.\textsuperscript{26} However, long-term participation in competitive endurance running may attenuate these gains in adolescent athletes,\textsuperscript{27} particularly at the spine.\textsuperscript{28} Longitudinal data show that in healthy girls bone mass accumulation declines markedly by age 16 years,\textsuperscript{24} highlighting early adolescence as a vulnerable period during which interruptions in normal bone accumulation may have far-reaching consequences.\textsuperscript{21}

**Strength and Performance Measures**

Before age 14 years, boys and girls differ marginally in their performance on a variety of motor tasks, including running speed. With puberty, dramatic differences in neuromuscular agility and explosiveness emerge, largely as a result of a plateau in the motor performance improvements of girls.\textsuperscript{29} Aerobic performance trends similarly, whereby improvements in maximal oxygen uptake (V\textsubscript{O\textsubscript{2}}\text{max}) increase linearly from age 7 years to
PHV, then plateau in girls, but not in boys. However, the magnitude of these differences seems to be mitigated in the endurance-trained population.

**Preadolescence and Adolescence: A Vulnerable Period**

The adolescent growth spurt represents a period of increased vulnerability to overuse injuries. Laboratory studies have shown that growth cartilage present during rapid phases of growth is less resistant to tensile, shear, and compressive forces than either mature bone or less mature prepubescent bone. Dissociation between bone matrix formation and bone mineralization during the growth spurt also results in diminished bone strength. Stress fractures seem to occur more frequently during the adolescent spurt as well, although prospective studies are lacking. Numerous cases of stress-related lower extremity physeal injuries involving young athletes have been reported in the literature, primarily from running-related activities. These injuries may result in leg-length discrepancy or angular malalignment of the affected leg, setting up the potential for long-term disability. The potential for catastrophic injury is highlighted by case reports of severe femoral neck stress fractures in female adolescent athletes.

**NUTRITIONAL CONSIDERATIONS**

Nutrition is of paramount importance to female runners. Low energy intake (EI) can result in menstrual dysfunction, suboptimal BMD, increased risk of illness, and prolonged recovery from illness. Guidelines for macronutrient intake in adult athletes can be found in Table 2. Of special consideration, vegetarian athletes may be at risk for low intakes of energy, protein, fat, and key micronutrients, such as iron, calcium, vitamin D, riboflavin, zinc, and vitamin B₁₂. Consultation with a sports dietitian is recommended to avoid deficiencies.

**Patterns of Intake in Female Runners**

Across a variety of sports, female athletes reportedly consume about 30% less energy and carbohydrate (CHO) per kilogram of body weight than male athletes in the same sport. Some investigators have attributed the large discrepancies between reported EI and measured energy expenditure of female endurance athletes with stable body weights to under-reporting of EI. However, under-reporting does not account for the widely observed neurometabolic effects of chronic energy deficiency in female athletes.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Recommended macronutrient intake in adult athletes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carbohydrates</strong></td>
<td></td>
</tr>
<tr>
<td>General recommendations</td>
<td>6–10 g/kg BW/d</td>
</tr>
<tr>
<td>During moderate-intensity exercise &gt;1 h</td>
<td>0.5–1.0 g/kg BW/h</td>
</tr>
<tr>
<td>After exercise</td>
<td>1–1.5 g/kg BW within 30 min and again every 2h for 4–6 h</td>
</tr>
<tr>
<td><strong>Protein</strong></td>
<td>1.2–1.7 g/kg BW/d</td>
</tr>
<tr>
<td><strong>Fat</strong></td>
<td>1–2 g/kg BW/d or 20%–35% of total EI</td>
</tr>
</tbody>
</table>

*Abbreviations: BW, body weight; EI, energy intake.*

endurance athletes. Edwards and colleagues, in a study of female endurance runners using 7-day food diaries and doubly labeled water, documented energy deficit in 9 of 9 subjects, with a mean deficit of 32%. An even greater proportion of female athletes (76%) were energy deficient in a larger heterogeneous study of endurance runners. Similar results have been found among groups of adolescent, NCAA, and elite distance runners. Deficits in protein (PRO) intake seem to be far less common.

Several investigators have related suboptimal EI in female runners with menstrual abnormalities, including luteal phase dysfunction (LPD) and amenorrhea. Amenorrheic runners have also been found to have lower resting metabolic rate (RMR) than matched, eumenorrheic counterparts, indicating an adaptive syndrome to conserve energy. Suboptimal fat intake, although less common than CHO deficiency, has been observed in runners with suboptimal EI, menstrual dysfunction, and stress fractures. In addition, suboptimal EI may be associated with certain patterns of cognitive dietary restraint.

**Defining Low Energy Availability**

The determination of energy status is an imperfect science. One preferred index of energy status, energy availability (EA), is defined as EI minus exercise energy expenditure (EEE) divided by kilograms of FFM. In controlled laboratory settings, this index has been significantly associated with changes in reproductive and metabolic hormone concentrations and markers of bone formation and resorption. Table 3 outlines methods of assessing variables in the calculation of EA. Physically active women should strive for an EA of at least 45 kcal/kg FFM/d to ensure adequate energy for normal physiologic functions. Many controlled experiments have identified 30 kcal/kg FFM/d as a critical threshold of EA, associated with detrimental changes in reproductive function and bone metabolism.

**Intentional Versus Unintentional Underfueling**

Unintentional underfueling may occur in athletes who do not realize that they need to increase their EI to match increased EEE from training activity; this commonly occurs in high school cross-country runners. These athletes typically do not have psychological reasons that interfere with their ability to comprehend the need to increase EI. In contrast, intentional underfueling occurs when athletes restrict their EI to improve

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**Table 3**

Methods of assessing variables in the calculation of EA

<table>
<thead>
<tr>
<th>EI</th>
<th>EEE</th>
<th>FFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-d food log</td>
<td>Metabolic equivalent of task</td>
<td>Dual-energy X-ray absorptiometry</td>
</tr>
<tr>
<td>4-d food log</td>
<td>Heart rate monitoring</td>
<td>Air displacement plethysmography</td>
</tr>
<tr>
<td>7-d food log</td>
<td>Accelerometry</td>
<td>Bioelectrical impedance</td>
</tr>
<tr>
<td>24-h recall</td>
<td>—</td>
<td>Skin fold caliper measurement</td>
</tr>
<tr>
<td>Food frequency</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

* EA = \( \frac{EI \text{ (kcal)} - EEE \text{ (kcal)}}{\text{kg of FFM}} \)

**Abbreviations:** EA, energy availability; EEE, exercise energy expenditure; EI, energy intake; FFM, fat-free mass.

appearance, fit preconceived ideals of body image, or enhance athletic performance; this can occur in the presence or absence of DE. In a study by Manore and colleagues, 64 62% of female athletes endorsed a desire to lose at least 2.3 kg (5 pounds), compared with 23% of male athletes. These athletes may show behaviors such as binge eating, purging, diuretic/laxative abuse, use of diet supplements, or compulsive exercise in excess of normal training. Although athletes seldom meet the criteria for a clinical eating disorder (ED), many show signs of DE and may strive to achieve extremely low weight. In runners, motivating forces typically include the desire to achieve a body type consistent with societal pressures and/or perceived sport-specific ideals. 65

**Performance Considerations**

A preponderance of research in endurance athletes has shown the short-term performance benefits of moderate-CHO to high-CHO diets, including the ability to fend off overtraining syndrome. 66–69 Regarding fueling during endurance training, the American College of Sports Medicine (ACSM) recommends ingestion of 0.7 g/kg/h of CHO during exercise in a 6% to 8% solution, particularly for events greater than 1 hour. 42 This intake translates to about 42 g of CHO, or 620 to 1000 mL (21–34 ounces) of sports beverage, per hour in a 60-kg athlete. These recommendations are supported by 2 recent meta-analyses that confirmed the performance benefits of CHO supplementation in this range for endurance performance. 70, 71 In high-level runners, an individualized nutritional strategy should be developed that is designed to deliver CHO at a rate that is commensurate with exercise intensity as well as the duration of the event. 72 After exercise, the goal is to provide adequate fluids, electrolytes, energy, and CHO to accelerate glycogen resynthesis and promote an anabolic hormone profile to hasten recovery. A CHO intake of approximately 1.0 to 1.5 g/kg body weight (BW) during the first 30 minutes, and again every 2 hours for 4 to 6 hours, seems adequate to accomplish this goal. 42, 73–75

Many runners and coaches attempt to alter body composition to improve performance. Although average body composition measures of athletes in various sports are commonly reported in the literature, these values cannot be extrapolated to individuals. Specific body composition ranges may be a useful tool for clinicians monitoring high-risk athletes, but they have little relevance to performance. A multidisciplinary team, including the athlete, coach, dietitian, and physician, should work together to optimize EA, and to recognize athletes with low body mass indices (BMIs) and/or low BWs as at risk for the Triad consequences. Although low BF% is not independently associated with menstrual dysfunction, low BMD, or stress fractures, it should be considered as a consequence of inadequate EI, and/or excessive exercise, and addressed accordingly. 61 Weight loss, if desired, should take place in the off-season or before the competitive season with the support of a sports dietitian. Findings that should raise concerns are changes in menstrual status, recurrent illness or injury, or any signs of DE. 65

**Micronutrient Intake**

Athletes who maintain a negative energy balance put themselves at risk for deficiencies in micronutrients, of which iron, calcium, and vitamin D are particularly relevant for female runners. Recommended intakes of these nutrients are summarized in Table 4.

**Iron**

Iron performs a vital role in hemoglobin synthesis and oxygen transport. Women are at greater risk of iron deficiency (ID) compared with men because of menstrual losses
and decreased iron intake. In the United States, the prevalence of iron deficiency anemia (IDA) is 3% to 5% and iron deficiency without anemia (IDNA) is 16% in women of childbearing age.79 Athletes may be at particular risk because of increased losses caused by gastrointestinal (GI) bleeding, and reduced absorption caused by subclinical inflammation.80–83 Bioavailability of iron depends on several factors, including the individual’s iron status, the form of iron consumed (heme vs nonheme), and the presence of inhibitors, such as bran, polyphenols, and antacids.65,84 Meat consumption is a strong determinant of iron status85 and good sources of heme iron include lean meat, poultry, and seafood.86 Nonheme iron, found in white beans, lentils, spinach, and iron-enriched foods, is not as readily absorbed by the body. In a study of female runners, individuals consuming a modified vegetarian diet (<100 g red meat per week) showed 30% less iron bioavailability than those consuming a regular diet.87 In general, athletes with low EI (<2000 kcal/d) have been shown to be at increased risk for poor iron status.88 Koehler and colleagues,89 in a group of elite female athletes, found a mean iron intake of 13.8 ± 4.1 mg/d, with 63% below the recommended daily amount. In another study, a group of active women had poorer indices of iron status compared with sedentary controls, despite higher dietary iron intake.82 Female distance runners, even at the elite level,90 may be at particular risk for suboptimal iron status.90–93 Iron overload, typically resulting from chronic, high-dose supplementation, has been reported in runners, but is uncommon and more commonly observed in men.94

Calcium

Adequate calcium status is important for optimal bone health. Disruptions in bone homeostasis lead to the gradual weakening of bone and may accelerate the onset of low bone mass or osteoporosis. Adequate calcium intake during childhood is paramount for peak bone mass, which is attained by about age 25 years.95 Suboptimal calcium intake is common in female athletes, especially in those for whom a drive for thinness leads to calorie restriction.96–99 Barrack and colleagues,49 in a study of female NCAA runners, reported intakes less than 1000 mg/d in 26% of subjects. Milk and milk products contribute substantially to calcium intake in the United States.

| Table 4
| Recommended intakes for iron, calcium, and vitamin D in females
<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Iron (mg/d)</th>
<th>Calcium (mg/d)</th>
<th>Vitamin D (IU/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9–13</td>
<td>8</td>
<td>1300</td>
<td>600</td>
</tr>
<tr>
<td>14–18</td>
<td>15</td>
<td>1300</td>
<td>600</td>
</tr>
<tr>
<td>19–30</td>
<td>18</td>
<td>1000</td>
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<tr>
<td>31–50</td>
<td>18</td>
<td>1000</td>
<td>600</td>
</tr>
<tr>
<td>51–70</td>
<td>8</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td>&gt;70</td>
<td>8</td>
<td>1200</td>
<td>800</td>
</tr>
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</table>

Pregnant or Lactating

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>Iron (mg/d)</th>
<th>Calcium (mg/d)</th>
<th>Vitamin D (IU/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14–18</td>
<td>27 (pregnant)</td>
<td>1300</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>10 (lactating)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19–50</td>
<td>27 (pregnant)</td>
<td>1000</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td>9 (lactating)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: IU, international unit.

* Goals for vitamin D intake are based on dietary recommendations and are independent of the individual’s sun exposure.

Data from Refs. 76–78

and decreased iron intake. In the United States, the prevalence of iron deficiency anemia (IDA) is 3% to 5% and iron deficiency without anemia (IDNA) is 16% in women of childbearing age.79 Athletes may be at particular risk because of increased losses caused by gastrointestinal (GI) bleeding, and reduced absorption caused by subclinical inflammation.80–83 Bioavailability of iron depends on several factors, including the individual’s iron status, the form of iron consumed (heme vs nonheme), and the presence of inhibitors, such as bran, polyphenols, and antacids.65,84 Meat consumption is a strong determinant of iron status85 and good sources of heme iron include lean meat, poultry, and seafood.86 Nonheme iron, found in white beans, lentils, spinach, and iron-enriched foods, is not as readily absorbed by the body. In a study of female runners, individuals consuming a modified vegetarian diet (<100 g red meat per week) showed 30% less iron bioavailability than those consuming a regular diet.87 In general, athletes with low EI (<2000 kcal/d) have been shown to be at increased risk for poor iron status.88 Koehler and colleagues,89 in a group of elite female athletes, found a mean iron intake of 13.8 ± 4.1 mg/d, with 63% below the recommended daily amount. In another study, a group of active women had poorer indices of iron status compared with sedentary controls, despite higher dietary iron intake.82 Female distance runners, even at the elite level,90 may be at particular risk for suboptimal iron status.90–93 Iron overload, typically resulting from chronic, high-dose supplementation, has been reported in runners, but is uncommon and more commonly observed in men.94

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Nieves and colleagues\textsuperscript{100} and Kelsey and colleagues\textsuperscript{101} found that, in young female runners, higher intakes of calcium, skim milk, and dairy products are associated with lower rates of stress fracture. Removing dairy products from the diet requires careful replacement with other food sources of calcium, including fortified foods.\textsuperscript{86} Although calcium supplements are widely available, recent evidence suggests a possible increased risk of cardiovascular events in postmenopausal women taking calcium supplements of 1 g/d.\textsuperscript{102,103} Until further studies examine this association, we recommend that most calcium intake should come from dietary sources.

\textbf{Vitamin D}

Adequate vitamin D status is important for health, preventing growth retardation and skeletal deformities during childhood, and decreasing the risk of osteoporosis and fracture later in life. Vitamin D deficiency causes muscle weakness.\textsuperscript{104–106} Vitamin D can be obtained from the diet, but few foods, apart from oily fish such as salmon, naturally contain vitamin D.\textsuperscript{86,107} A study of collegiate runners found that nearly 80% failed to meet recommendations for vitamin D intake,\textsuperscript{49} and those who did usually relied on supplements (Barrack MT, personal communication, 2015). Sunlight is a major contributor to vitamin D status, with 5 to 10 minutes of exposure to the arms and legs (depending on time of day, season, latitude, use of sunscreen, and skin pigmentation) resulting in the production of about 3000 international units (IU).\textsuperscript{107} Because of the angle of the sun, little or no vitamin D can be produced from November to February in areas above about 35° north latitude (eg, Los Angeles; Charlotte, NC).\textsuperscript{107} There is no consensus on optimal levels of vitamin D, although levels less than 20 ng/mL generally indicate deficiency. Levels between 20 and 29 ng/mL may indicate an insufficiency, and values greater than or equal to 30 ng/mL are generally considered adequate.\textsuperscript{108} Studies in athletes are few, but vary considerably with population, location, and the time of year.\textsuperscript{109–113} In a study of endurance runners, Willis and colleagues\textsuperscript{114} found 30% of subjects to be insufficient, although none were frankly deficient (<20 ng/mL). Low levels have been associated with stress fracture risk in female military recruits,\textsuperscript{115} although studies in athletes are lacking. More prospective studies are needed to evaluate the role of calcium and vitamin D intake in the prevention of bone stress injuries in athletes, particularly those participating in sports with greater incidences, such as distance running.\textsuperscript{116}

\textbf{THE FEMALE ATHLETE TRIAD}

The Triad encompasses 3 components: (1) low EA with or without DE, (2) menstrual dysfunction, and (3) low BMD.\textsuperscript{60,61} Over the past few decades, increased understanding of the Triad has clarified the mechanisms correlating inadequate EI with hypoestrogenemia, decreased BMD, and subsequent increased fracture risk.\textsuperscript{60,117} Although early descriptions focused on the pathologic end points of the Triad (ED, amenorrhea, and osteoporosis), recent studies have increased recognition of subclinical disorders, such as DE, subclinical menstrual disturbances,\textsuperscript{52,118} low bone density, and bone stress injuries.\textsuperscript{119,120} Other medical complications of the Triad include endocrine, GI, renal, and neuropsychiatric manifestations.\textsuperscript{60}

\textbf{Energy Availability}

Chronic energy deficit disrupts hypothalamic neuroendocrine function in women, negatively affecting menstrual function and bone turnover.\textsuperscript{57,59,121} As a result, RMR is decreased, accounting for the ability of amenorrheic athletes to maintain weight
stability. Muscular function may be negatively affected as well, because short-term energy deficit of just 5 days has been shown to reduce postabsorptive myofibrillar protein synthesis. Rates of bone formation are also suppressed within 5 days of decreasing EA from 45 to less than or equal to 30 kcal/kg FFM/d, and bone resorption may increase when EA is reduced enough to suppress estradiol. In a large sample of trained, exercising women, EA was also able to distinguish amenorrheic from eumenorrheic athletes. Hence, experts have recommended that exercising women should maintain an EA of at least 45 kcal/kg FFM/d to avoid the aforementioned clinical sequelae. Views regarding body image may be useful in the assessment of the runner, because a drive for thinness has been shown to be a proxy indicator of underlying energy deficiency. Monitoring athletes periodically during the year is prudent as well, because EA may change throughout the course of a season. It is worth noting that, contrary to popular belief, the stress of exercise itself, independent of EA, does not alter LH pulsatility in women.

**Menstrual Status**

Amenorrhea is the absence of menstrual cycles for more than 3 months and oligomenorrhea is characterized by menstrual cycles occurring at intervals longer than 35 days. Subclinical disturbances, such as LPD and anovulatory cycling, may have no perceptible symptoms. A diagnosis of functional hypothalamic amenorrhea (FHA) secondary to low EA in athletes is a diagnosis of exclusion and must follow an evaluation to rule out pregnancy and endocrinopathies. The prevalence of secondary amenorrhea, which varies widely with sport, weight, and training volume, has been reported to be as high as 65% in some studies of distance runners, compared with 2% to 5% in the general population. Amenorrhea in distance runners has been associated with increases in training mileage and decreases in BW, but not body fat per se, and seems to be less prevalent with increasing age. Subclinical menstrual disorders can be present in eumenorrheic athletes, with LPD or anovulation found in 78% of eumenorrheic recreational runners in at least 1 menstrual cycle out of 3.

**Effects on Bone**

Low BMD can be diagnosed via dual-energy X-ray absorptiometry (DXA) based on guidelines from the International Society of Clinical Densitometry and the ACSM. Exercise has beneficial effects on bone mineral accumulation during childhood and early adolescence, with 10% to 40% higher bone mass gains observed in physically active adolescents compared with sedentary individuals. However, the hypoestrogenic state that underlies menstrual dysfunction has adverse effects on bone, with lower BMD values seen in amenorrheic versus eumenorrheic athletes. DE is also associated with low BMD independently of menstrual irregularity in runners, and dietary restraint may be the DE behavior most associated with negative bone health effects in young runners. One systematic review of female athletes found the prevalence of osteopenia and osteoporosis in excess of what would be expected in a normal population distribution. In a study by Barrack and colleagues, nearly 40% of a sample of female adolescent runners had a Z-score less than −1 on DXA, which was approximately twice the proportion reported in a previous study of athletes representing multiple sports. Female adolescent runners, in particular, seem to show a suppressed bone mineral accrual pattern that may put them at risk for suboptimal peak bone mass.
and a history of fracture, were significantly more likely to have low bone mass. For adolescent boys, those with a BMI less than or equal to 17.5 kg/m² and the belief that thinness improves performance were significantly more likely to have low bone mass. In young runners who display low BMD at baseline, catch-up accrual may be difficult, highlighting the importance of adequate EA and neuroendocrine function during the adolescent years.

**Relationship to Stress Fractures**

Bone stress injury (BSI) results from chronic repetitive mechanical stress and exists on a spectrum from mild stress reaction to cortical fracture. BSIs represent a significant burden for female runners, with a reported incidence of up to 21% in competitive track athletes, and increased risk compared with male counterparts. Numerous studies have documented the relationship between amenorrhea and low bone mass and the risk for stress fractures. Bennell and colleagues, in a study of track athletes, found late age at menarche to be one of the strongest predictors of stress fracture risk. Recent findings by Barrack and colleagues, showing the cumulative risk conferred by multiple triad-related risk factors on bone health and susceptibility to fracture, have shown the important role that risk stratification may have in decreasing risk for injury. In this study, the highest risk was seen with a combination of greater than 12 h/wk of exercise, participating in a leanness sport/activity, and evidence of dietary restraint, which conferred a 46% risk of incurring a BSI (odds ratio, 8.7; 95% confidence interval, 2.7–28.3). Tenforde and colleagues also reported that the combination of late age at menarche, prior fracture, participation in dance/gymnastics, and BMI less than 19 kg/m² conferred the greatest risk of BSI in a study of adolescent runners. Female athletes diagnosed with BSI who are found to have menstrual irregularity should also be screened for DE and low BMD.

**Screening**

Screening for the Triad requires an understanding of the relationships among its components, the spectrum within each component, and rates of movement along each spectrum (Fig. 1). The preparticipation physical and annual health examinations provide optimal screening opportunities, but other occasions may present when athletes are evaluated for issues such as menstrual dysfunction, BSI, or recurrent injury or illness. Athletes who present with one component of the Triad should be assessed for the others. A recent panel recommended the use of a risk-stratification tool that incorporates evidence-based risk factors for the Triad, assigning a point value in each Triad category based on risk magnitude (Fig. 2). Of note, a prior history of certain risk factors (eg, ED, oligomenorrhea/amenorrhea, or BSI) still confers risk points, even if the condition is not currently present. In addition to risk stratification, the team physician should use clinical judgment and take into account the athlete’s unique situation in making a decision for clearance and/or return to play. Table 5 shows the assessment of risk using this tool in 2 sample runners.

Athlete A, who is determined to be at moderate risk with a score of 2, is likely to be granted provisional clearance, with routine follow-up with a dietitian and periodic risk reassessment as needed, depending on the development of any new or worsening risk factors. Special notice may be taken of the running volume/mileage at which she sustained her prior BSI. Athlete B, who is at high risk with a score of 6, may benefit from additional work-up, including laboratory assessment, DXA, and consultation with
a sports dietitian to document adequate EA, before clearance for running. If a psycho-
logical component is detected during screening, consultation with a mental health
practitioner may be prudent as well. If athlete B is able to decrease her risk, or has
a satisfactorily reassuring secondary evaluation, she may be granted either limited
or provisional clearance, with regular follow-up with a physician, dietitian, and any
other clinical team members as needed for adequate monitoring of her health.

Treatment

Treatment of Triad conditions must address low EA, the underlying cause of the Triad.
A nonpharmacologic approach involving increasing EI and/or reducing EEE, as well as
normalization of BW, is the mainstay of treatment and current best practice for suc-
cessful resumption of menses and improvement in bone health.60,61 Causal evidence
for the efficacy of increased EI for return of menses (ROM) has been supplied by Wil-
liams and colleagues'165 study in primates, which showed ROM after supplemental
caloric intake in the setting of ongoing training. Several case studies,166–168 as well
as a 5-year retrospective analysis,169 have documented the association between
weight gain and ROM following amenorrhea in exercising women. Studies in anorexics
have documented stabilization of BMD with short-term weight gain.170

Treatment strategies should depend on how the athlete developed low EA (Fig. 4).
Specific approaches are varied and depend on individual circumstances, so targets
may include reversal of recent weight loss, a return to BW associated with normal
menses, weight gain to achieve a BMI of greater than or equal to 18.5 kg/m² or
greater than or equal to 90% of predicted weight, or a minimum EI of 2000 kcal/d,
although higher intakes may be required.61 These goals can be accomplished with
a combination of increased EI and decreased EEE, depending on the demands of

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Fig. 1. Spectra of the female athlete triad. The 3 inter-related components of the Triad are
energy availability, menstrual status, and bone health. Energy availability directly affects
menstrual status, and, in turn, energy availability and menstrual status directly influence
bone health. Optimal health is indicated by optimal energy availability, eumenorrhea,
and optimal bone health, whereas, at the other end of the spectrum, the most severe pre-
sentation of the Triad is characterized by low energy availability with or without an eating
disorder, functional hypothalamic amenorrhea, and osteoporosis. An athlete’s condition
moves along each spectrum at different rates depending on her diet and exercise behaviors.
BMD, bone mineral density. (From Nattiv A, Loucks AB, Manore MM, et al. American College
2007;39:1867–82; Wolters Kluwer/Lippincott Williams & Wilkins; with permission.)
<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Low Risk = 0 points each</th>
<th>Moderate Risk = 1 point each</th>
<th>High Risk = 2 points each</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low EA with or without DE/ED</td>
<td>No dietary restriction</td>
<td>Some dietary restriction(^b); current/past history of DE;</td>
<td>Meets DSM-V criteria for ED(^b)</td>
</tr>
<tr>
<td>Low BMI</td>
<td>BMI ≥18.5 or ≥90% EW(^c) or weight stable</td>
<td>BMI 17.5 &lt;18.5 or &lt;90% EW or 5 to &lt;10% weight loss/month</td>
<td>BMI ≤17.5 or &lt;85% EW or ≥10% weight loss/month</td>
</tr>
<tr>
<td>Delayed Menarche</td>
<td>Menarche &lt;15 years</td>
<td>Menarche 15 to &lt;16 years</td>
<td>Menarche ≥16 years</td>
</tr>
<tr>
<td>Oligomenorrhea and/or Amenorrhea</td>
<td>&gt;9 menses in 12 months(^b)</td>
<td>6-9 menses in 12 months(^b)</td>
<td>&lt;6 menses in 12 months(^b)</td>
</tr>
<tr>
<td>Low BMD</td>
<td>Z-score ≥1.0</td>
<td>Z-score ≤1.0(^d) ≤−2.0</td>
<td>Z-score ≤−2.0</td>
</tr>
<tr>
<td>Stress Reaction/Fracture</td>
<td>None</td>
<td>1</td>
<td>≥2; ≥1 high risk or of trabecular bone sites(^e)</td>
</tr>
</tbody>
</table>

**Fig. 2.** Female athlete triad: cumulative risk assessment. \(^a\) Some dietary restriction as shown by self-report or low/inadequate energy intake on diet logs. \(^b\) Current or past history. \(^c\) Absolute BMI cutoffs should not be used for adolescents. \(^d\) Weight-bearing sport. \(^e\) High-risk skeletal sites associated with low BMD and delay in return to play in athletes with 1 or more components of the Triad include stress reaction/fracture of trabecular sites (femoral neck, sacrum, pelvis). BMD, bone mineral density; BMI, body mass index; DE, disordered eating; DSM-V, Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition; EA, energy availability; ED, eating disorder; EW, expected weight. (From De Souza MJ, Nattiv A, Joy E, et al. 2014 female athlete triad coalition consensus statement on treatment and return to play of the female athlete triad: 1st International Conference held in San Francisco, California, May 2012 and 2nd International Conference held in Indianapolis, Indiana, May 2013. Br J Sports Med 2014;48:289; BMJ Publishing Group Ltd; with permission.)

If EA can be accurately estimated, a goal of greater than or equal to 45 kcal/kg FFM/d should be targeted. Changes should be gradual, with the goal of increasing weight by about 0.5 kg every 7 to 10 days. **Fig. 5** shows changes that can be made to bring a 55-kg runner with a baseline intake of 2000 kcal/d into optimal EA. Calcium-rich foods should also be encouraged, targeting an intake of 1000 to 1300 mg/d, as well as a vitamin D intake of 600 IU/d. \(^61,76\) Time to ROM may vary considerably among amenorrheic athletes, \(^168–170\) and may take more than a year. \(^169\) Improvements in EA can effect positive metabolic changes within days to weeks, whereas changes in BW may take weeks to months. Improvements in BMD occur more slowly, typically trailing ROM. \(^171\) Note that although improvements in BMD can occur with ROM, improved nutrition, and weight gain, BMD may not be restored to normal levels. \(^172–174\)

**Consideration of Pharmacologic Treatment of Triad-related Medical Conditions**

Pharmacologic treatment may be warranted for the psychological treatment of ED/DE, especially if there are comorbid conditions. \(^61\) For Triad-related health consequences of amenorrhea and osteoporosis, nonpharmacologic management is the mainstay of treatment. Pharmacologic strategies for treatment of menstrual dysfunction and osteoporosis, and/or athletes with multiple fractures related to the Triad, are largely experimental and should only be considered after a suboptimal response to at least 1 year of nonpharmacologic management or if new fractures occur. \(^61\) For female athletes with FHA or prolonged oligomenorrhea, hormone replacement therapy (HRT) in the form of...
exogenous estrogen and cyclic progesterone may be indicated if there is failure of at least 1 year of nonpharmacologic management. Transdermal estrogen at a dose of 100 μg twice weekly, along with cyclic progesterone (2.5 mg daily for 10 days of every month), has been shown to improve BMD in adolescent girls with anorexia nervosa Fig. 3. Female athlete triad: clearance and return-to-play (RTP) guidelines by medical risk stratification. a Clearance/RTP status for athletes at moderate to high risk for the triad: provisional clearance/RTP, clearance determined from risk stratification at time of evaluation (with possibility for status to change over time depending on athlete’s clinical progress); limited clearance/RTP, clearance/RTP granted but with modification in training as specified by physician (with possibility for status to change depending on clinical progress and new information gathered); restricted from training/competition (provisional), athlete not cleared or able to RTP at present time, with clearance status reevaluated by physician and multidisciplinary team with clinical progress; disqualified, not safe to participate at present time and clearance status to be determined at a future date depending on clinical progress, if appropriate. (From De Souza MJ, Nattiv A, Joy E, et al. 2014 female athlete triad coalition consensus statement on treatment and return to play of the female athlete triad: 1st International Conference held in San Francisco, California, May 2012 and 2nd International Conference held in Indianapolis, Indiana, May 2013. Br J Sports Med 2014;48:289; BMJ Publishing Group Ltd; with permission.)

![Table 5 Sample Triad risk assessment in 2 female athletes](Image)

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Athlete A Comment</th>
<th>Score</th>
<th>Athlete B Comment</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low EA with or without ED/DE</td>
<td>No dietary restriction</td>
<td>0</td>
<td>Mild restriction (vegetarian)</td>
<td>1</td>
</tr>
<tr>
<td>Low BMI</td>
<td>BMI 21</td>
<td>0</td>
<td>BMI 18.1</td>
<td>1</td>
</tr>
<tr>
<td>Delayed menarche</td>
<td>Menarche age 15 y</td>
<td>1</td>
<td>Menarche age 15 y</td>
<td>1</td>
</tr>
<tr>
<td>Oligomenorrhea/amenorrhea</td>
<td>At present eumenorrheic; no past history of menstrual dysfunction</td>
<td>0</td>
<td>6 menses in the past 12 mo</td>
<td>1</td>
</tr>
<tr>
<td>Low BMD</td>
<td>No prior DXA</td>
<td>0</td>
<td>No prior DXA</td>
<td>0</td>
</tr>
<tr>
<td>BSI</td>
<td>History of second metatarsal shaft BSI</td>
<td>1</td>
<td>History of bilateral tibial BSI in high school</td>
<td>2</td>
</tr>
<tr>
<td>Total score</td>
<td>Moderate risk</td>
<td>2</td>
<td>High risk</td>
<td>6</td>
</tr>
</tbody>
</table>

**Abbreviations:** BMD, bone mineral density; BMI, body mass index; BSI, bone stress injury; EA, energy availability; ED, eating disorder; DE, disordered eating, DXA, dual-energy X-ray absorptiometry.
and is an option for HRT, although studies are currently ongoing in the female athlete population.\textsuperscript{61,175} It should be emphasized that combined hormonal contraceptives do not restore spontaneous menses and are not clearly associated with improved BMD in amenorrheic athletes.\textsuperscript{176–178}

In athletes with FHA or prolonged oligomenorrhea, and osteoporosis, who have failed nonpharmacologic therapy, pharmacologic strategies other than HRT and oral contraceptive therapy should be prescribed only after a thorough metabolic work-up by a physician experienced in treating osteoporosis and metabolic bone disease in this population.\textsuperscript{61} In these uncommon situations, osteoporosis medications, such as bisphosphonates and teriparatide, may be considered. According to De Souza and colleagues,\textsuperscript{61} these treatments may be used when estrogen is contraindicated, in compliant patients who have had a lack of response to greater than or equal to 18 to 24 months of HRT, in eumenorrheic athletes/exercisers (not hypoestrogenic) who meet the criteria for pharmacologic therapy, or in athletes with multiple debilitating fractures and significant morbidity. For a full discussion and literature review of nonpharmacologic and pharmacologic management of osteoporosis and fractures in young female athletes, the authors recommend the 2014 Triad Consensus article.\textsuperscript{61}

**Baseline Statistics**

\[ BW: 55 \text{ kg} \quad Body\ fat: 18\% \quad FFM: 45.1\text{ kg} \]

\[ EI: 2000 \text{ kcal} \]

*Daily exercise: 1 hr at 7 min/mile pace (12.3 METs)*

\[ EEE = \text{MET} \times BW \times \text{hrs of exercise} = 12.3 \text{ kcal/(kg} \times \text{h}) \times 55\text{kg} \times 1\text{h} = 676.5 \text{ kcal} \]

**Baseline EA:**

\[ EA = (EI - EEE)/FFM = (2000 - 676.5)/45.1 = 29.3 \text{ kcal/kg FFM} \]

**Goal Intake to achieve EA of 45 kcal/kg FFM:**

\[ EI = (EA \times FFM) + EEE = (45 \times 45.1) + 676.5 = 2706 \text{ kcal} \]

**EI after intervention to meet recommended intake:**

\[
\begin{align*}
8 \text{g/kg BW of CHO} &= 1760 \text{ kcal} \\
1.7 \text{g/kg BW of PRO} &= 374 \text{ kcal} \\
1 \text{g/kg BW of fat} &= 495 \text{ kcal} \\
&= 2629 \text{ kcal}
\end{align*}
\]

**Fig. 4.** Pathways to low EA and treatment recommendations. DE, disordered eating; EA, energy availability. (Modified from De Souza MJ, Nattiv A, Joy E, et al. 2014 Female Athlete Triad Coalition consensus statement on treatment and return to play of the female athlete triad: 1st International Conference held in San Francisco, California, May 2012 and 2nd International Conference held in Indianapolis, Indiana, May 2013. Br J Sports Med 2014;48:289; BMJ Publishing Group Ltd; with permission.)

**Fig. 5.** Example of increasing EA in a 55-kg female runner. BW, body weight; CHO, carbohydrate; EA, energy availability; EEE, exercise energy expenditure; EI, energy intake; FFM, fat-free mass; MET, metabolic equivalent; PRO, protein.
Clearance/Return to Running Considerations

For any runner found to be at moderate or high risk, reassessment during the season is advised, because variables related to risk, particularly EA and menstrual status, may change during a season. Ultimately, a risk-stratification tool does not supersede clinical judgment, and physicians must take into account the athlete’s unique situation in the final determination for clearance and return to play. A decision-based return-to-play model (Fig. 6) is useful in showing the complexity of issues that need to be considered. Importantly, risk modifiers in the female running population include those listed in Fig. 2, as well as age, classification as a lean-build sport, training mileage, and competitive level (high school, collegiate, elite, recreational).

IRON DEFICIENCY WITH AND WITHOUT ANEMIA

Women are at increased risk of IDA compared with men because of decreased iron intake and menstrual losses. IDA is likely more prevalent in female athletes as well. Several explanations have been proposed to account for the iron losses observed during training, including hemolysis, hematuria, sweat loss, GI bleeding, and exercise-induced inflammation through the activity of hepcidin. Vegetarians and athletes with inadequate EI seem to be at increased risk. In women, anemia is defined by a serum hemoglobin concentration less than 12 g/dL. Serum ferritin is the most commonly used marker of body iron stores, with levels less than 12 ng/mL diagnostic of ID. There is a lack of consensus on what constitutes low ferritin (or iron depletion) in the athletic population, with thresholds ranging from less than 12 ng/mL to less than 25 ng/mL, depending on the study. As an acute phase reactant, ferritin increases independently of iron status in the setting of inflammation, and day-to-day variations may be significant. Soluble transferrin receptor (sTfR), especially the sTfR/log(ferritin) index, is less variable and may more accurately reflect total body iron, with levels greater than or equal to 4.5 indicating iron depletion. This index has been useful in identifying athletes with IDNA who may be more likely to respond positively to iron supplementation. A causal link between IDA and decreased work capacity has been discussed in the literature. In endurance athletes performing submaximal exercise, this decrement is likely more related to the inability to maintain prolonged activity of iron-dependent oxidases than hemoglobin concentrations. Whether subclinical IDNA leads to decreased physical performance, and should therefore be treated with iron supplementation, remains controversial. Several placebo-controlled studies have shown performance benefits of iron supplementation in athletes with IDNA, including improved endurance times, faster time trials, and increased energetic efficiency. However, others showed no benefit despite improvements in ferritin levels. Further research is needed to clarify optimal cutoffs used to screen athletes, with the goal of identifying and treating those at risk of ID and performance decrement. Based on current evidence, female athletes at higher risk of ID (eg, prior history of ID/IDA, vegetarian, performance decrement, and increased fatigue) should be screened using hemoglobin and ferritin cutoffs of 12 g/dL and 20 ng/mL, respectively, to identify IDA or IDNA, in order to reduce the adverse effects that ID may have on training and performance.

PREGNANCY

Current knowledge on the benefits of physical activity during pregnancy is encouraging. Exercise during pregnancy may decrease odds for complications such as...
Fig. 6. Decision-based RTP model for the female athlete triad. RTP decision is determined by the primary care or team physician, and is based on a complex and comprehensive synthesis of health status, cumulative risk assessment, participation risk, sport, and decision modifiers. 25(OH) Vit D, 25-hydroxyvitamin D; BMD, bone mineral density; BMI, body mass index; BP, blood pressure; CBC, complete blood count; ECG, electrocardiogram; DXA, dual-energy X-ray absorptiometry; ED, eating disorder; OCD, obsessive-compulsive disorder; RTP, return-to-play; TFTs, thyroid function tests; TSH, thyroid-stimulating hormone. (From De Souza MJ, Nattiv A, Joy E, et al. 2014 Female Athlete Triad Coalition consensus statement on treatment and return to play of the female athlete triad: 1st International Conference held in San Francisco, California, May 2012 and 2nd International Conference held in Indianapolis, Indiana, May 2013. Br J Sports Med 2014;48:289; BMJ Publishing Group Ltd; with permission.)
gestational diabetes, preeclampsia, large for gestational age/macrosemi
a, and preterm delivery. Clapp showed that offspring of women who exercised throughout pregnancy were significantly lighter and leaner at age 5 years compared with offspring of women who stopped exercising during pregnancy. Most guidelines recommend that healthy women with uncomplicated pregnancies accumulate at least 150 minutes of moderate intensity aerobic activity per week during pregnancy and the postpartum period, although specific exercise prescriptions may vary. Recommendations for calcium, vitamin D, and iron for pregnant and lactating women are listed in Table 4. Of note, iron requirements increase significantly during pregnancy and maternal anemia has been associated with an increased risk of preterm delivery. Therefore, it is imperative that women of childbearing ages, particular those with multiple pregnancies, monitor iron status carefully. The American College of Obstetricians and Gynecologists has published absolute and relative contraindications to aerobic exercise during pregnancy. Further research is needed to examine the long-term effects of exercise prescription during pregnancy on both maternal and child health.

In the postpartum period, return to physical activity has been associated with decreased risk of postpartum depression. The rate of return to activity varies from one woman to another, although some may be capable of engaging in an exercise within days of delivery. There are no published studies to indicate that, in the absence of medical complications, rapid resumption of activities will result in adverse effects for the mother or child. No known maternal complications are associated with resumption of training, and moderate weight loss while nursing is safe and does not compromise neonatal weight gain. Nursing women should consider breastfeeding their infants before exercising to avoid the discomfort of engorged breasts.

SUMMARY

With the continued popularity of running and steady increase of female participation in sport, the care of female runners will continue be an important topic of discussion. Advances in the understanding of the Triad and Triad-related conditions have largely informed the approach to the health of this population. An appreciation for the close relationship between EA and neuroendocrine function has equipped clinicians with the ability to promote optimal bone health and decrease risk factors for BSI and other bone consequences. The risks related to the Triad should not deter providers from encouraging participation in a sport that can be, by and large, a healthy and enjoyable endeavor for most participants. Looking forward, it is hoped that refinements in the assessment of risk factors related to the Triad, as well as advances in the treatment of Triad-related conditions, can help to ensure a vibrant and robust enjoyment of sport for all.

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