Nutritional Risks Among Female Athletes

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Abstract

Background: Limited research studies have been conducted on nutritional risks among female athletes. Therefore, this literature review focuses on rigorously designed studies that examined nutritional risks among female athletes with further recommendations for athletes, coaches, parents, and health professionals, which would help improve the health of female athletes.

Methods: This review evaluates the most recent research on nutritional risk among female athletes. Inclusion criteria included peer-reviewed studies of original research on human subjects 13 years of age or older; sample size of $N \geq 19$; and studies with a thorough description of their sample and methods. A systematic search of the databases PubMed and Cochrane for published studies (from year 2000 to year 2019) was conducted to identify articles that met inclusion criteria. Bibliographies of identified articles were also searched for relevant articles.

Results: Of the 11 studies that met our inclusion criteria, most were mainly cross-sectional in design with few rigorous controls. Findings reveal that strategies to enhance nutrition patterns among female athletes may be important to avoid risks of disordered eating, eating disorders, low energy availability, and symptoms of relative energy deficiency in sports. In addition, general nutrition knowledge is lacking among athletes, sports teams, and coaches.

Conclusions: This review highlights the scarcity of evidence-based, rigorous studies examining nutritional risks among female athletes. Findings suggest that interdisciplinary working groups, comprising physicians, sports dietitians, and other supportive health professionals, would be beneficial for female athletes in helping to improve their overall diet, performance, and health.

Keywords: female athlete, nutrition, disordered eating, eating disorders, dietary patterns

Introduction

NUTRITION PLAYS A vital role in the female athlete's health and performance. An athlete's diet should be optimal in both food quality and quantity to replenish their energy reserves and avoid fatigue or inadequate nutrition. Individual macronutrient and micronutrient needs will vary based on a number of factors, including the type of competitive sport played, sex, and age, but, in general, adequate caloric intake from a variety of foods in the form of a well-balanced diet is favored in promoting athlete health and performance.¹

Studies have shown that female athletes are often insufficient in meeting nutritional and energy needs (both macro-

nutrients and micronutrients), leading to medical-related issues, poor performance and health, and low energy availability (EA).² For example, female athletes often do not meet their high energy intake needs (~ 2000 – 5000 kcal/day depending on the sport) to match their high level of energy expenditure, referred to as low EA, which can negatively influence their bone health and reproductive function.^{3,4} Some female athletes may purposefully restrict their calorie intake for performance or aesthetic reasons, while others may unintentionally have low EA due to unforeseen reasons such as increased training load and lack of education on how to properly fuel for their sport/exercise demands.²

In addition, the general knowledge of nutrition among athletes, coaches, and other sports team specialists (e.g.,

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athletic trainer [AT]) is lacking.⁵ Access to evidence-based nutrition information may be lacking for athletes, especially when a dietitian or nutritionist, a licensed expert, is not available or part of the interdisciplinary team for athletes. Of the few studies that have examined nutrition knowledge among athletes, coaches, and other sports team specialists,^{6–8} they commonly find that inadequate nutrition knowledge is present. Therefore, the purpose of this review was to identify nutritional behaviors in female athletes, which may lead to medical risks.

Given the importance of nutrition among female athletes, the key questions of this review include the following: (1) are there rigorous studies, meeting our criteria, that identify the nutritional risks of female athletes?; (2) of the studies identified, what are the nutritional behaviors of athletes that may affect medical health or performance?; and; (3) what specific recommendations for female athletes, coaches, and support professionals are provided in the literature, which would aid to improve an athlete's nutrition, health, and performance? The overall framework of this review is to examine recent research on this important topic of nutritional risks among female athletes and provide further discussion on how coaches, parents, and health professionals can play a role at improving the diets of female athletes.

Methods

A systematic search of the databases PubMed and Cochrane was conducted to identify original, peer-reviewed articles published between 2000 and May 1, 2019, which examined medical aspects of nutrition in the female athlete. Only English-language, peer-reviewed articles that met our defined search criteria were selected. Inclusion criteria for selected articles were the following: female athletes 13 years of age or older, an adequate sample size ($N \geq 19$), thorough description of study sample and methods, and specific focus on nutritional behaviors associated with medical risks. Search terms included “female athletes,” “nutrition,” “adverse medical outcomes,” and “eating disorders.” Bibliographies of identified articles were also searched for relevant articles, including one meta-analysis. Studies that included both female and male athletes were considered well.

Results

A total of 11 studies met our inclusion criteria that included nutritional behaviors and medical conditions for our discussion. Table 1 includes the studies that met our criteria, including pretest/post-test studies ($n = 1$), and cross-sectional studies ($n = 9$) with diet records, surveys, questionnaires, or interviews, along with considering one meta-analysis study. There were many reviews, consensus statements, position statements, and recommendations from governmental agencies and health and athletic organizations geared to female collegiate and professional female athletes; so some of these were included as support for the discussion provided below. Overall, results from our literature review suggest that strategies to enhance nutritional patterns in female athletes are necessary due to the potential risk of disordered eating and low EA, including the effects on bodily function/performance, along with lack of accurate sports nutrition knowledge.

Discussion

A brief summary of the 11 studies found in Table 1 that met our criteria follows.

Cross-sectional studies ($n = 9$)

A majority of the studies found in our literature review search were cross-sectional in design and survey based. A handful of the studies reviewed examined nutrition knowledge and behaviors of athletes and their health care providers such as ATs and coaches.^{9,10} For instance, Raymond Barker et al.⁹ used the General Nutritional Knowledge Questionnaire and the Eating Attitudes Test (EAT 26) in a cross-sectional survey to assess nutritional knowledge and susceptibility of the Female Athlete Triad among 48 regional endurance athletes, 11 trampoline gymnasts, and 32 untrained controls. Nutrition knowledge of female endurance athletes was significantly higher compared to nonathlete controls, but there were no significant differences in the nutrition knowledge scores in athletes classified as “at risk” compared to those classified as “not at risk” for the Female Athlete Triad. In addition, a higher percentage of athletes scored at or above the cutoff of 20 of the EAT-26 test compared to controls, suggesting a higher prevalence of disordered eating. Only one study reviewed examined nutrition knowledge among athlete health care providers. For instance, a cross-sectional survey,⁵ comprising 579 athletes, coaches, ATs, and strength and conditioning specialists (SCSs), assessed their nutrition knowledge and found that ATs and SCSs had adequate nutrition knowledge, but athletes and coaches did not.

Most of the cross-sectional studies reviewed examined disordered eating and eating disorder (ED) prevalence among athletes in determining whether athletes are at greater risk compared to the general population of nonathletes. For instance, a cross sectional survey, developed by Torstveit et al.,¹¹ assessed training or physical activity patterns, eating behaviors, body dissatisfaction (BD), and medical conditions among 1,838 female elite athletes and nonathletes ($n = 900$) in Norway. A higher percentage of athletes competing in leanness sports (70.1%) were classified as being at risk for the Female Athlete Triad compared to athletes competing in nonleanness sports (53.3%). Interestingly, a higher percentage of nonathlete controls ($n = 900$) reported significantly ($p < 0.001$) greater use of pathogenic weight control methods and had greater BD compared to female elite athletes. Although this cross-sectional study had one randomly selected control group (nonathletes), they were not matched for specific characteristics (*e.g.*, age and weight status) to the female athletes. However, in 2008, the same researchers¹¹ performed a cross-sectional study of female elite athletes with age group-matched controls in Norway¹² to assess the prevalence of disordered eating and clinical EDs. This later study found a higher prevalence of clinical EDs among female athletes competing in leanness sports (46.7%) compared with both athletes competing in nonleanness sports (19.8%) and controls (21.4%). Sundgot-Borgen et al.¹³ also examined ED prevalence among 1620 elite athletes (male and females) and controls (nonathletes) using clinical interviews, a gold standard measurement tool for assessing EDs. Findings suggest that more athletes (13.5%) than controls (4.6%) had sub-clinical or clinical EDs. In addition, athletes in leanness-dependent sports had a higher prevalence of clinical EDs

TABLE 1. STUDIES INVESTIGATING NUTRITION BEHAVIORS AMONG FEMALE ATHLETES

Reference	Design	Sample	Results	Limitations
1. Baker (2012) ¹⁷	This prestudy/poststudy measured body composition of female athletes from five sports teams using the Bod Pod [®] . Anthropometric measurements pertaining to height, weight, and waist circumference; and the Block Dietary Data Systems 2005 Food Questionnaire, and eating disorder symptomology (EDI-3)	N = 75 Female collegiate athletes	Participants in all five sports (basketball, gymnastics, soccer, and swimming and diving) were not found to change significantly ($p < 0.05$) in total body mass, fat mass, fat free mass, percent body fat, or body mass index from the preseason period to the postseason period. There were significant variations among team members on several variables.	Used multiple research assistants for data collection, which may have led to discrepancies in data collection. Measurements were taken of athletes only if coaches selected the BODPOD measurements.
2. Torres-McGehee et al. (2012) ⁵	Cross-sectional survey assessed nutrition knowledge of athletes, coaches, athletic trainers (ATs), and strength and conditioning specialists (SCSs).	N = 579 participants consisted of athletes ($n = 185$), coaches ($n = 131$), athletic trainers (ATs) ($n = 192$), and SCSs ($n = 71$).	ATs (77%) and SCSs (81.6%) have adequate nutrition knowledge, whereas coaches and athletes do not.	There were problems in the mailings of the surveys. Some coaches may not have wanted to participate.
3. Torstveit and Sundgot Borgen (2005) ¹¹	Cross-sectional survey with randomly selected controls. Participants completed a questionnaire that assessed training and/or physical activity patterns, menstrual history, oral contraceptive use, weight history, eating patterns, dietary history, and the body dissatisfaction (BD) and drive for thinness (DT) subscales of the Eating Disorder Inventory (EDI).	N = 1838 Female elite athletes in Norway representing the national teams at the junior or senior level, 13–39 years of age ($n = 938$), and nonathlete controls in the same age group ($n = 900$). More athletes reported menstrual dysfunction and stress fractures compared with controls	A higher percentage of controls (69.2%) than athletes (60.4%) were classified as being at risk for the Female Athlete Triad ($p < 0.01$). A higher percentage of nonathlete controls than athletes reported use of pathogenic weight control methods and had high BD ($p < 0.001$). A higher percentage of athletes competing in leanness sports (70.1%) and the nonathlete control group (69.2%) were classified as being at risk of the Female Athlete Triad compared to athletes competing in nonleanness sports (55.3%) ($p < 0.001$).	While the nonathlete controls were randomly selected, they were not matched to the athletes because the study included the total population in Norway. Causal inferences cannot be implied due to the nature of the study design.
4. Torstveit et al. (2008) ¹²	Cross-sectional study comprised a clinical interview and body composition measurements.	The total population of female elite athletes in Norway, 13–39 years of age ($n = 669$), and nonathletic subjects in the same age group ($n = 609$) participated in part 1 of the study. A random selection of elite athletes ($n = 186$) and controls ($n = 145$), 13–39 years of age, participated in part 2 of the study where clinical interviews and body composition measurements were taken. Results showed that more athletes in leanness sports (46.7%) had clinical EDs than athletes in nonleanness sports (19.8%) and controls (21.4%) ($p < 0.001$).	A higher prevalence of clinical eating disorders was found among female athletic participants competing in leanness sports compared with both athletes competing in nonleanness sports and controls.	Self-selection, inadequate sampling methods, and a volunteer effect.

(continued)

TABLE 1. (CONTINUED)

Reference	Design	Sample	Results	Limitations
5. Lenka et al. (2016) ¹⁴	Cross-sectional survey explored the prevalence of disordered eating (DE) and the differences between weight-sensitive and less weight-sensitive sports in a sample of female college athletes. The Eating Attitudes Test (EAT-26), Minnesota Eating Behavior Survey (MEBS), and the Difficulties in Emotional Regulation Scale (DERS) were used.	N = 151 college female students	The incidence of DE was not significantly different by sport type. However, greater emotional regulation difficulties ($\beta = 0.174$, $t = 2.191$, $p = 0.03$) and BD ($\beta = 0.276$, $t = 2.878$, $p = 0.005$) were significant predictors of disordered eating.	No nonathlete controls in the sample. Geographical, cultural, ethnic, and other differences were not accounted for in the analyses. Some eligible athletes may have left the study because they had a known eating disorder.
6. Markou et al. (2004) ¹⁵	Cross-sectional study with questionnaires and noninvasive clinical and laboratory data that assessed the influence of intensive physical exercise on bone acquisition in adolescent elite gymnasts.	N = 262 athletes (169 females, 93 males, 13–23 years of age) from 44 European countries participated in the 24th European Championship held in Greece.	The growth chart of bone mineral density (BMD) followed a normal pattern when estimated according to bone age rather than chronological age. BMD for females was positively correlated with bone age, chronological age, height, body weight, body mass index, body fat, lean body mass, and age of onset of training, and negatively with duration of exercise and intensity of training (p values ranged from <0.05 to <0.0001).	Survey responses were fixed, which leaves less scope for respondents to supply answers that reflect their true feelings on a topic.
7. Sundgot-Borgen et al. (2004) ¹³	A cross-sectional self-reported questionnaire and clinical interviews were used to assess the prevalence of anorexia nervosa (AN), bulimia nervosa (BN), anorexia athletica (AA), and eating disorders (EDs) not otherwise specified (ED-NOS) in both male and female Norwegian elite athletes and a representative sample from the general Norwegian population.	Total N = 1620 The total population of elite athletes (males and females) representing the Norwegian national teams organized by the Norwegian Confederation of Sports in 1997 (1620 athletes: 660 females and 960 males) received the initial screening questionnaire	Study reported the prevalence of eating disorders was found to be higher in athletes than in controls; higher in female athletes than in male athletes; and more common among those competing in leanness-dependent and weight-dependent sports than in other sports. More athletes (13.5%) than controls (4.6%; $p < 0.001$) had subclinical or clinical EDs. The prevalence of EDs among female athletes competing in aesthetic sports (42%) was higher than that observed in endurance (24%), technical (17%), and ball game sports (16%).	Questionnaires alone have limitations, and clinical interviews are needed to obtain accurate prevalence data.

(continued)

TABLE 1. (CONTINUED)

<i>Reference</i>	<i>Design</i>	<i>Sample</i>	<i>Results</i>	<i>Limitations</i>
8. Raymond-Barker et al. (2007) ⁹	Cross-sectional survey of female athletes and control group. The General Nutritional Knowledge Questionnaire (GNKQ) and the Eating Attitude Test (EAT-26) were used by athletes and untrained controls to assess nutritional knowledge of female athletes.	48 regional endurance athletes, 11 trampoline gymnasts, and 32 untrained controls. The participants were placed in two groups and classified as being "at risk" or "not at risk" for the Triad; nutrition knowledge and scores were compared for the two groups.	Results showed that nutrition knowledge of female endurance athletes was significantly higher compared with their nonathlete counterparts, but no significant differences were observed in the nutrition knowledge scores attained by those athletes classified "at risk" compared to those classified "not at risk".	The study was considered "explorative" because a large percentage of respondents were self-selected—leading to the conclusion that the athletes may not have been "elite."
9. Smolak et al. (2000) ¹⁸	A meta-analysis of 34 studies assessed the relationship between athletic participation and eating problems.	Female athletes (high school and college aged) were compared to female nonathletes.	The study suggested that sports participation by women constitutes a risk factor for certain elements of eating problems. However, athletic participation may be protective against eating problems. Athletes had a low body fat ($13.8\% \pm 2.7\%$) and high fat-free mass to height ratios (33.0 ± 2.0 kg/m). Average nutrient intakes were $>67\%$ for all nutrients, excepting vitamin E. At least 50% of the athletes took vitamin supplements and watched their water intake. Iron status was normal for 15 of the 19 athletes.	Studies selected for the meta-analysis did not always have information on the specific sports.
10. Mullins et al. (2001) ¹⁰	Using 4-day diet records and dietary questionnaires, this cross-sectional study observed the dietary composition, dietary nutrient intake, dietary practices, and iron status in elite female athletes.	$N = 19$ female athletes during training season aged 26 ± 3 SD years).	Female gymnasts' body height and weight fell below the 12th percentile for adolescent women. In comparison to chronological age (13.6 ± 1.0 years), bone age (11.9 ± 1.5 years) was retarded on average by 1.7 years. Female gymnasts showed bone retardation (1.7 years), reduced height potential, minimal fat mass (4.3 ± 1.3 kg), and delayed menarche. Male gymnasts showed unchanged pubertal development due to different training regimes. Intensive physical training combined with inadequate energy intake can alter the normal pattern of pubertal development.	Small sample, no control group for comparisons. Survey responses were fixed, which may have led respondents to supply answers that do not reflect their true feelings on a topic.
11. Weimann et al. (2000) ¹⁶	Cross-sectional study evaluated high-intensity training in combination with nutritional intake effects on pubertal development.	$N = 30$ elite gymnasts (22 females with mean age of 13.6 ± 1.0 SD years). Measurements of height, body composition, and energy intake using a 3-day diet record.		Small sample, no control group for comparisons. Survey responses were fixed, which may have led respondents to supply answers that do not reflect their true feelings on a topic.

than in other sports.¹³ Finally, Lenka et al.¹⁴ surveyed 151 college female students to explore disordered eating risk among female athletes in both weight-sensitive and less weight-sensitive sports. Although disordered eating was not significantly different by sport type, greater emotional regulation and BD were significantly associated with disordered eating.¹⁴

A few of the cross-sectional studies examined the effects of bone acquisition from continuous intensive exercise in gymnasts. For instance, one of these studies included female ($n=169$) and male ($n=93$) (13–23 years of age) gymnasts participating in the 24th European championship in Greece and examined the influence of intensive physical exercise on bone acquisition.¹⁵ The growth chart of bone mineral density (BMD) followed a normal pattern, when using bone age rather than chronological age and BMD for female athletes was positively correlated with bone age, height, body weight, body mass index (BMI), body fat, lean body mass, and age onset of training. BMD showed a negative correlation with duration of exercise and intensity of training. Thus, at least in this cohort of elite female artistic gymnasts, the early onset of training coupled with continuous and intensive exercise may negatively affect bone acquisition.¹⁵ Another cross-sectional study¹⁶ examined the effects on pubertal development, including bone acquisition, from high-intensity training among 22 elite female gymnasts. Results showed that female gymnasts' body height and weight were below the 12th percentile for adolescents. Bone age in this group showed bone retardation, reduced height potential, minimal fat mass, and delayed menarche.¹⁶

Prestudy/poststudy ($n=1$)

Only one of the studies reviewed had a pretest/post-test study design.¹⁷ This prestudy/poststudy design used the Bod Pod to measure body composition of 75 female athletes from five sports teams, including basketball, gymnastics, volleyball, and soccer. Total body mass, fat mass, fat-free mass, percent body fat, fat, or BMI from the preseason period (pretest) to the postseason period (post-test) did not change significantly ($p<0.05$).¹⁷ Although there were no significant changes in body composition among athletes from pretest/post-test, authors recommended that athletes be frequently monitored for body composition changes and educated on the potential health and medical consequences of unhealthy eating.¹⁷

Meta-analysis study ($n=1$)

Only one of the studies reviewed was a meta-analysis¹⁸ that assessed the relationship between athletic participation and eating problems in female athletes compared to female nonathletes. Overall, findings suggested that, while athletic participation may be protective against eating problems, sports participation for some females may be a risk factor for certain eating problems in those more susceptible. Several of the studies in this meta-analysis recommended the importance of monitoring female athletes to avoid the risk of disordered eating and associated medical complications.

A narrative overview from our literature review findings further examines factors that may place female athletes at nutritional risk.

Relative energy deficiency in sports

Current literature suggests that diets of female athletes are often not optimal when it comes to carbohydrate, fat, and energy intake.¹⁹ Female athletes may have optimal intakes of protein, except in the cases of sports promoting leanness.^{17,19,20} Some caution is needed with interpreting reports of athletes' dietary intakes because it is common for athletes, as well as healthy populations, to underreport food intake.

A syndrome common in females as well as male athletes, related to inadequate caloric intake, is the Relative Energy Deficiency in Sports (RED-S).^{21,22} The term of RED-S was introduced by the International Olympic Committee (IOC) and includes factors of the condition known as the "Female Athlete Triad," which encompasses male athletes, as well.^{21,22} RED-S is characterized by low EA to adequately support the range of body functions involved in optimal health and performance of the athlete.^{21,22} There was a paucity of studies that measured RED-S in female athletes. In addition, while this review did not compare nutritional outcomes of male athletes and female athletes, the medical consequences of RED-S specific to the female athlete include impaired physiological function, metabolism, bone health, menstrual and reproduction function, immunity, protein synthesis, cardiovascular health, and psychological health.^{23–26} Torstveit and Sundgot-Borgen¹¹ included both subclinical and clinical presentations in their description of the Triad. In general, a higher percentage of athletes competing in leanness sports are at greater risk of the Triad compared to athletes competing in nonleanness sports.¹¹

Research shows that energy needs are often unmet in the female athlete due to low EA.^{19,20,27} Athletes in endurance, aesthetic, or weight class-based sports, or sports that promote a lean body type such as ballet, are at an increased risk of the major criteria for RED-S.^{20,22} For example, in a recent study of elite ballet dancers, 65% were classified at risk for RED-S.²⁰ Yet, it can be present in athletes from any sport. The Weiss Kelly and Hecht²⁸ report indicated that the Female Athlete Triad and inadequate EA may not be the result of an unhealthy relationship with food and can sometimes be unintentional in nature.²⁸ Inadequate EA that is unintentional can be a result of underestimated energy needs or misguided dietary practices with the intention of weight loss or improved health.²¹ Low EA in female athletes may be due to low nutritional knowledge, time management, and food availability, along with greater disordered eating risk, drive for lower body weight for sport, and/or unintended failure to meet energy needs.^{19,20}

Micronutrient deficiencies and dietary supplement usage in female athletes

In addition to inadequate macronutrient intake, insufficient micronutrient consumption such as from iron may also occur, leading to stage 1, inadequate iron status.²⁹ Inadequate dietary intakes, acute inflammation brought on by exercise, sweat, and menstrual losses, especially when heavy, further increase the risk for inadequate iron status and related deficiencies in female athletes.³⁰ Iron deficiency anemia may be even more common in females participating in intense training, like distance running, due to the potential for additional losses through hemolysis, urine, and gastrointestinal bleeding.^{1,29,31} While serum ferritin is the index of iron

stores in healthy subjects, and can vary in female athletes, a lower limit of 12 $\mu\text{g/L}$ is generally considered severe enough to indicate an iron deficiency state in active females.^{29,30} The IOC promote regular screening of iron status in athletes, but currently, only 43% of National Collegiate Athletic Association (NCAA) Division I institutions complete these screenings on a regular basis.¹⁹

Deficiencies in other micronutrients may also occur as a result of exercise-related stress and inadequate dietary intakes.³⁰ Micronutrients of concern noted in the research of female athletes include vitamin D, zinc, calcium, magnesium, and B vitamins. Calcium and vitamin D insufficiency are of particular interest due to related increased stress fracture risk.^{30,32} Recent data suggest that about 33%–42% of female athletes present with insufficient vitamin D and that 72%–90% fall short of the Adequate Intake for calcium.¹⁹ For example, female gymnasts' body height and weight were below the 12th percentile of adolescent women.¹⁶ In addition, bone age (11.9 ± 1.5 years) was delayed on average by 1.7 years and female gymnasts showed bone retardation (1.7 years), reduced height potential, and minimal fat mass (4.3 ± 1.3 kg),²² placing these females at risk for osteoporosis later in life.¹⁶ For female athletes presenting with insufficient dietary intake, amenorrhea, and/or low BMD, supplementation with 1500 mg/day of calcium is currently recommended¹⁹ as well as other dietary supplements, including vitamin D for bone health and optimal calcium absorption. Dietary supplements, such as vitamins, minerals, amino acids, herbs or botanicals, metabolites, constituents/extracts, energy drinks, calorie replacement products, creatine, vitamin C, or combinations of the above, are common in the sports world because of the held belief that they may compensate for sports performance.³³ While some studies indicate multivitamin supplements may appear to compensate for an inadequate dietary intake,^{33,34} it is suggested that supplementation be limited among young athletes and more cautionary with regard to commercial supplements.^{19,35} In general, there is a lack of research on the effect of dietary supplements in female athletes.¹⁹ Therefore, it is highly recommended that supplements be used with caution as their purity, ingredients, and effectiveness are often not well regulated or confirmed.¹⁹ Froiland et al.³⁵ recommended that athletes be monitored by a registered dietitian nutritionist (RDN) because of the extensive array of supplements that appear to be used by athletes. Thus, it is recommended that supplement ingestion be reserved for dietary gaps with only third-party tested products being considered after companies have shown the safety and effectiveness of their products.^{1,35}

Research also suggests that caffeine, when taken in doses of 3 mg/kg, may provide ergogenic benefit, especially when consumed before and/or during a high-intensity sport, such as a tennis match.³⁴ Today, Olympic athletes are allowed to use caffeine without penalties, although it is still monitored by the World Anti-Doping Agency (WADA)³⁶ to scan for patterns of caffeine overuse (doping) and by the National Collegiate Athletic Association (NCAA) to limit use at high levels, which is screened for by urine of concentrations exceeding 15 $\mu\text{g/mL}$.³⁷ One area of particular concern in athletes is doping (the use of banned supplements to enhance athletic performance). Doping has recently received widespread press, with some Olympic medals taken away from competitors by WADA due to their utilization.³⁶

Risk for disordered eating and EDs

It is important to note that EDs are diagnosed using firm clinical criteria.³⁸ Therefore, unhealthy or dangerous eating patterns are not necessarily limited to an ED diagnosis. "Disordered eating" can include various unhealthy eating behaviors, including, but not limited to chronic dieting, excessive calorie counting, food-related anxiety and use of laxatives, which could potentially result in an ED diagnosis.¹⁴ In an effort to optimize performance, some female athletes often strive to maintain or reach a low body weight, which may be achieved by chronic and/or cyclic dieting behaviors.³⁹ These behaviors, over time, may lead to potentially harmful patterns of long-term dieting, disordered eating, adverse health effects, decreased performance, and an even more serious mental health diagnosis of an ED.¹⁸

Both clinical and subclinical EDs are found to be present in female athletes. Smolak et al.¹⁸ conducted a meta-analysis of 34 studies and found female athletes to be at greater risk for EDs than nonathletes. Women participating in sports where low body weight is preferred or necessary, appear to have more clinical (EDs) (46.7%) compared to athletes in nonleanness sports (19.8%) and nonathletes (21.4%).¹²

Specific sports, such as gymnastics, distance running, diving, figure skating, and classical ballet emphasize a low body weight.¹⁴ As a result, female athletes in these sports are more likely than other athletes to restrict energy intake and exhibit an inadequate caloric intake, poor body image, disordered eating, or an ED such as anorexia nervosa or bulimia nervosa.^{7,31,32,39} However, these dietary anomalies can be present in any female athlete.²³ Weiss Kelly and Hecht²⁸ noted that previous studies found chronic dieting, weight fluctuations, changes in coaches, injury, and casual weight-related comments by coaches, parents, and friends were triggers for an ED onset.

Medical consequences & preventative measures

Diminished BMD and stress fractures are two medical outcomes that may occur in female athletes. Stress fractures are due to repetitive stress on bone during training and competition, which may also be contributed by inadequate energy intake. An important factor influencing BMD is the age of onset of training. Findings from a cross-sectional study of adolescent female elite gymnasts (13–23 years) found that the earlier the age of strenuous exercise onset, the more negative the effect on bone acquisition.¹⁵ Stress fractures, which include femoral neck, patella, anterior cortex of the tibia, medial malleolus, talus, tarsal navicular, and the fifth metatarsal, and pain in the great toe sesamoids may be seen in female athletes in any sport from inadequate calorie intake, but especially those participating in sports that favor leanness.^{40,41} The usual measure in determining low body weight is the BMI (weight to height ratio).

The National Heart, Lung, and Blood Institute notes that athletes may have a higher than normal BMI ($>25 \text{ kg/m}^2$) due to greater muscle and bone mass and decreased adiposity.⁴² Body composition in specific populations can be studied by other techniques such as bioimpedance analysis, skin-fold measurements, using the Bod Pod[®] (air displacement plethysmography). However, the recent Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic

Performance indicate that because errors are associated with body composition methods, it should not be used to calculate a specific body fat percentage goal for individual athletes and it should not be used to select athletes for teams.¹

Several studies suggest that education is essential, for both athletes and their coaches.^{5,9,43} In addition, studies indicate that athletes should be regularly screened for disordered eating and monitored for caloric and nutrient intake.⁴⁴ A cross-sectional survey of women and men participating in National Collegiate Athletic Association Division I, II, and III sports at institutions across the United States included 185 athletes, coaches, ATs and SCSs, and reported that ATs and SCSs have adequate sports nutrition knowledge, whereas most coaches and athletes have inadequate knowledge.⁵ Having a licensed sports dietitian available to provide nutrition counseling services to athletes on their specific dietary needs has been shown to be effective at improving young athletes' eating behaviors and nutrition knowledge.⁴⁵

While there are other screening tools available for measuring disordered eating, of the 11 studies reviewed, most used the EAT-26, which is one of the most widely used screening measures for disordered eating risk.⁴⁶ The EAT-26 is a measure of symptoms and concerns with characteristics related to criteria of EDs. Other tools available for screening purposes include the Periodic Health Examination, recognized by the IOC, which screens adolescent and young adult females for the Female Athlete Triad, and should be performed annually.⁴³ When screening for the Triad and/or RED-S, the presence of any one of the major consequences of EA (irregular menses, poor bone health, or low energy intake) should signal further investigation.⁴³ A promising tool known as the Brief Eating Disorder in Athletes Questionnaire (BEDA-Q), a validated screening tool, has been used to differentiate between EDs and disordered eating in high-level athletes.⁴⁷

Conclusions

Current research suggests that the nutrition status of female athletes needs to be more closely monitored because of reports of disordered eating risk, low energy availability and its effects on bodily function/performance, and lack of accurate sports nutrition knowledge. These characteristics are common in female athletes and warrant an interdisciplinary team approach in screening, counseling, and treating female athletes. The interdisciplinary team may include physicians, ATs, licensed dietitians, physical therapist, and psychologist or psychiatrist, parents, and coaches.¹⁵ Specifically, these teams of coaches, athletes, and health professionals should be educated on the negative health effects of inadequate caloric intake on both performance and long-term health. In addition, early detection of low energy availability and RED-S is essential in preventing further negative consequences.¹⁷ Diagnosed stress injuries should be considered a red flag to signal further evaluation, as part of the treatment plan.¹⁷

A list of suggested recommendations includes the following:

- (1) athletes should consider developing individualized nutrition plans with a licensed dietitian who will take into account the specificity and uniqueness of the

event, performance goals, practical challenges, food preferences, and responses to various strategies;

- (2) team nutrition education sessions held on various sports nutrition topics with individual sports teams may be beneficial;²⁶
- (3) comprehensive educational programs should be developed for coaches, practitioners, parents, and clinicians to facilitate awareness of proper sports nutrition and medical concerns in the female athlete population;
- (4) The long-term risks of dietary supplements, and banned substances, should be evaluated by health professionals.
- (5) Licensed dietitians, who are also a Certified Specialist in Sports Dietetics (CSSD), should provide nutrition education to athletic teams, individuals, and coaching staff, along with individual nutrition plans and nutrition counseling, in a safe and effective manner;^{6,37}
- (6) screening for disordered eating risk and RED-S should be implemented on a regular basis;⁴⁰
- (7) health professionals may generally inquire about nutrition and eating patterns when meeting with an athlete and make appropriate referrals within the interdisciplinary team when necessary, but the inquiries should be limited because they may not be advantageous for athletes with disordered eating tendencies.

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