

Management of Low Bone Mass in Female Athletes

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As female athletic participation has increased, the positive effects of exercise on health have become evident. However, with this growth in sports activity, a set of health problems unique to the female athlete has emerged. The female athlete triad and its components can occur in females of all ages in every sport. The Female Athlete Triad poses serious health risks, both short and long term, to the overall well-being of affected individuals. Sustained low energy availability can impair health, causing many medical complications within the skeletal, endocrine, cardiovascular, reproductive, and central nervous systems. With the surge of females participating in athletics within the past 10 to 15 years, it is both conceivable and likely that the prevalence of this syndrome will continue to grow. Therefore, it is imperative that appropriate screening and diagnostic measures are enacted by a multidisciplinary team of health care providers, counselors, teachers, and dietitians in order to provide the proper care to affected athletes. Initial awareness should take place within the educational confines of elementary and high schools. Screening for female athletes exhibiting risk factors for the triad should also take place at the time of sports physicals. If one component of the triad is identified, the clinician should take the time to effectively workup the other. Treatment for each component of the triad includes both pharmacological and nonpharmacological measures, with emphasis placed upon increased energy availability and overall improved nutritional health. Using this all-encompassing type of approach, sports medicine practitioners should feel empowered to continue to promote the lifelong well-being of female athletes in the years to come.

Key Words: Female Athlete Triad, Low bone mass, Menstrual dysfunction

Along with the notable health benefits of exercise, unique physiologic and behavioral responses of women to athletic activity are now known.¹ Increasing numbers of female athletes with eating disorders, amenorrhea, or nontraumatic stress fractures were reported for several years after enactment of Title IX, but it was not until 1997 that these conditions were first described as being interrelated and the term female athlete triad was coined by the American College of Sports Medicine (ACSM).²

Although the estimated prevalence of the triad is low, individual components of the female athlete triad are common in athletes at all competitive levels and ages.³

The triad is best understood as a continuum ranging from health to disease of each disorder: energy availability, menstrual function, and bone mineral density. Therefore, an athlete's condition can fall anywhere along the spectrum of optimal energy availability to an eating disorder; menstrual regularity to subclinical menstrual disorders, orthorexia, or athletic amenorrhea; and low bone mineral density (BMD) to frank osteoporosis (Fig. 1).⁴ Energy availability is often considered an imbalance between energy intake, which is the total caloric intake of a person per day, and energy expenditure, which includes both the resting energy expenditure (REE) and the exercise energy expenditure (EEE). Energy availability is best

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Received: March 14, 2014
Revised: March 14, 2014
Accepted: March 17, 2014

conceptualized as energy remaining from the energy intake after EEE has occurred. Therefore, energy availability should ideally match, if not slightly exceed, REE in order to allow physiologic processes of the body to continue.⁴ At any one time, affected athletes move between the points at varying rates according to their individual experience.⁵ Because of the dire consequences associated with both the physical and mental health of the athlete affected by the triad, preventative measures are crucial to curbing the progression of this multifaceted syndrome.

ETIOLOGY

It has been theorized that the root of this syndrome begins with low energy availability.⁶ The female athlete, seeking an improved body image to enhance athletic prowess, begins to restrict caloric intake. This restrictive dieting behavior then progresses, eventually predisposing the athlete to menstrual irregularity and decreased BMD.⁷ Often, energy availability fluctuates daily, with direct and/or indirect effects on menstrual function and BMD that are realized months to years later.⁸

The etiology of this third triad component can be attributed in large part to the female's hypoestrogenic

state. Within this framework, the female athlete demonstrates accelerated bone resorption due to the lack of the suppressive effect of estrogen on osteoclast activity. It is believed that other factors including low energy availability also play a significant role in the development of low BMD in female athletes.

RISK FACTORS

Athletes at greatest risk for developing the Female Athlete Triad are those who restrict caloric intake, exercise for extended periods, and have vegetarian diets.⁹ Specifically, athletes who develop abnormal eating behaviors may be predisposed based upon various social and/or environmental factors including psychological issues, low self-esteem, abuse, genetics, and family dysfunction.^{8,10} Injury and an earlier commitment to sport-specific training are additional risk factors for the development of low energy

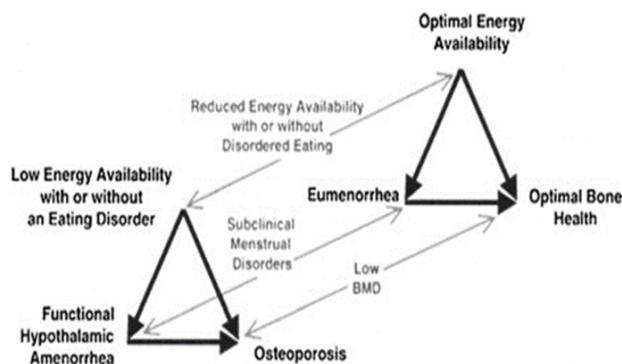


Fig. 1. The female athlete triad.

Table 1. Risk Factors and Warning Signs of the Female

Athlete Triad Athletes at risk for eating disorders
Restriction of dietary energy intake or vegetarianism
Psychosocial pressures to achieve thinness
Low self-esteem or poor family dynamics
Initiation of training at young age or increase in training intensity
Participation in lean/aesthetic sports
Athletes at risk for menstrual dysfunction
Low body mass index
Participation in lean/aesthetic sports
Athletes at risk for stress fractures
Low bone mineral density or history of stress fractures
Menstrual disturbances
Delayed menarche
Dietary insufficiency
Errors in training
Warning signs
Decline in performance
Weight loss
Mood changes
Frequent illness or injury
Fractures
Dissatisfaction with appearance

availability.¹¹ Specifically, risk factors associated with development of stress fractures within this population include low BMD, menstrual dysfunction, dietary insufficiency, and genetic inheritance, among others.¹²

Several dietary, exercise-related, and psychosocial behaviors are associated with increased risk of the triad.¹³⁻²⁰ Warning signs may include decline in performance, mood changes, frequent illness or injury, fractures, or dissatisfaction with body size (Table 1).

THE TRIAD LOW ENERGY AVAILABILITY

Energy restriction is common in female athletes, ranging from an inadvertent decrease in energy intake or failure to increase caloric consumption for exercise to pathologic restrictive behaviors in the context of eating disorders. Ways in which energy intake is decreased involve purging, fasting, use of diet pills, laxatives, and diuretics. Determining the prevalence of disordered eating in athletes is challenging because of the lack of standardized assessment tools and consistent criteria.²¹ Female athletes can consume 30% less energy per unit of body weight than male athletes, particularly in lean sports.^{1,22} The prevalence of disordered eating ranges from 1% to 62% in female athletes depending on type of sport, with higher rates in sports reliant on weight categories or lean build.²¹ The prevalence of eating disorders such as AN or bulimia nervosa in elite athletes is higher than in nonathletes (13.5% vs 3.1%)²³ and even higher in lean and aesthetic sports.^{24,25}

Research suggests that there is ideally no single cause regarding the development of eating disorders among athletes. Instead, its presence is most likely

multi-factorial, with various environmental, physiological, and cultural components. The idea that the intense pressure associated with various athletic activities may incite the development of an eating disorder in athletes who are psychologically vulnerable is a continued topic of conversation.²⁶

MENSTRUAL DYSFUNCTION

From delaying the onset of menarche²⁷ to causing subclinical menstrual disorders, oligomenorrhea, and amenorrhea,²⁸ exercise can impact menstrual function in several ways. Oligomenorrhea is defined as menstrual cycles occurring at intervals longer than 35 days, and secondary amenorrhea is defined as the absence of menstrual cycles for more than 3 months in a previously menstruating individual.²⁹ These disorders occur in 12% to 79% of female athletes and are even more prevalent in participants in lean sports such as ballet.³⁰ Diagnosing menstrual irregularities in adolescents is challenging because oligomenorrhea is present in 65% of girls during the first year after menarche.³⁰ Primary amenorrhea refers to lack of menstruation by age 15 years³¹ and does affect athletes.³² In a study of 425 collegiate athletes in 15 sports, 7.4% overall and 22.2% in aesthetic sports (cheerleading, diving, and gymnastics) had not menstruated by age 16 years,³³ as opposed to 1% in the general population.³⁴ Regardless of type of sport, up to a quarter of active women, including recreational exercisers, experience menstrual dysfunction.³⁵ In runners, training duration correlates with menstrual dysfunction, with amenorrhea increasing from 3% to 60% as training mileage increases from less than 8 to more than 70 miles per week.^{4,36}

As often the initiating factor of the triad, low energy

availability induces a hypometabolic state. Strenuous training alone has not been shown to alter menstrual cycles; it is necessary for dietary restriction to occur.³⁷ In a study by Loucks and Thuma,³⁸ it was decided that the energy threshold at which menstrual dysfunction is likely to occur is approximately 30 kcal/kg lean body mass per day. This “energy deficit” theory describes the induction of menstrual irregularities secondary to an imbalance in the body’s natural neuroendocrine function, specifically the impact on the hypothalamic–pituitary–adrenal axis. Disruption of the body’s normal homeostatic mechanisms leads to the development of significant health consequences, including infertility, decreased immune function, and decreased BMD.

LOW BMD

The last component of the triad is also best described as a spectrum encompassing optimum bone health, low bone density, and osteoporosis. Currently, bone strength is measured with dual-energy x-ray absorptiometry (DEXA), which specifically looks at one bone strength component—BMD. Other components play important roles when defining bone strength, specifically bone quality and bone mineral content. Bone tissue undergoes constant remodeling orchestrated by osteoclasts (which resorb formed bone) and osteoblasts (which form new bone) under the regulation of several polypeptides, growth factors, and gonadal and thyroid hormones.³⁹ Both low energy availability and hypoestrogenism have independent and cumulative effects on bone health. Previously, low BMD was speculated to be solely a function of hypoestrogenism through lack of inhibition of osteoclasts, as seen in women with AN, but it is now

recognized that energy deficits cause changes in the metabolic milieu such as decreasing insulin-like growth factor 1 and leptin levels and deficiencies in nutrients such as calcium that adversely affect bones, independent of menstrual status.^{40–42} Lending credence to this assumption are reports of weight gain having favorable effects on BMD but lack of complete recovery of BMD with oral contraceptive pills in patients with AN or exercise-induced amenorrhea.² Further, low BMD has been reported in athletes who have eating disorders but regular menstruation.¹³

The incremental effects of low energy availability on bone health were reported in a landmark study by Ihle and Loucks,⁴³ which established that bone formation is impaired within 5 days of the onset of low energy availability in healthy sedentary women and that extreme energy restriction (10 kcal/kg per day of FFM) causes the uncoupling of bone remodeling to become more pronounced as resorption increases.

Caloric restriction and weight fluctuations have been associated with bone loss in humans,^{13,40,41} with a 10% decrease in weight resulting in a 1% to 2% loss in BMD.^{44,45} Increasing duration of amenorrhea causes further decline in BMD and negates the benefits of exercise on skeletal health, as reported in studies comparing BMD and bone microarchitecture among amenorrheic athletes, eumenorrheic athletes, and nonathletes.^{46–50}

Adolescence constitutes a critical period for bone mass accrual, with 26% of adult bone mineral content acquired during the 2 years when peak height growth velocity occurs and almost all attained by the third decade of life.⁵¹ In young amenorrheic athletes, a bone mass loss of 2% to 6% per year may occur instead of bone mass accrual, resulting in a 3-fold higher risk of stress fractures.⁵² Biological potential for peak bone

mass may not be reached in these individuals, even with restoration of menstrual cycles.^{3,53}

A female athlete's BMD is best described as a single snapshot of her cumulative bone health at any point in time based on many interrelated variables, namely energy availability, menstrual function, and genetic influence.⁵⁴ It is important for an athlete's BMD to be charted over time, so that she is informed of her trend and can attempt to make necessary changes as deviations arise. Since the majority of peak bone mass is accrued in childhood and adolescence, it is vital that at-risk athletes be identified in an attempt to prevent chronic poor bone health.⁵ In fact, it is possible for premenopausal women who become amenorrheic, oligomenorrheic, or postmenopausal to lose approximately 2% of their BMD per year.

The prevalence of low bone density in athletes also is highly variable due to variations in definable parameters and the cost associated with diagnostic modalities. The presence of osteopenia in female athletes ranges from 22% to 50%.⁵⁵ However, female athletes in weight-bearing sports such as basketball and volleyball have a nearly 15% higher BMD than

nonathletes. A recent study looking at average BMD in collegiate athletes across a number of sports found that runners had the lowest BMD of all sports investigated (Fig. 2).⁵⁶

The protective effect of weight bearing can be eliminated in athletes affected by other components of the triad. The development of stress fractures in athletes diagnosed with low BMD and menstrual dysfunction may approach a rate of 17%.⁵⁷ Cobb and colleagues analyzed the interaction of disordered eating, menstrual irregularity, and BMD among 91 competitive long-distance runners (ages 18 to 25) and discovered 6% of the amenorrheic group had spine BMD values termed "osteoporotic" with another 48% classified as "osteopenic".⁵⁵

EVALUATION

Appropriate screening in at-risk athletes should take place during preparticipation exams or during annual health check-ups. Any long distance runner with recurrent leg pain, or under high suspicion for a stress fracture, should also undergo similar evaluation. The physician should have a firm understanding of all components of the triad, their unique interrelationships, and the entire spectrum from health to illness each component embodies.⁵⁴ It is both prudent and recommended to test an athlete for all triad components if she presents with a diagnosis of one.

Trainers, coaches, and parents are often the first to witness an athlete's abnormal psychological and behavioral characteristics. Examples include increased anxiety, unnecessary dieting, being "too critical," compulsiveness regarding exercise, social withdrawal, binge eating, substance abuse, and increased agitation.

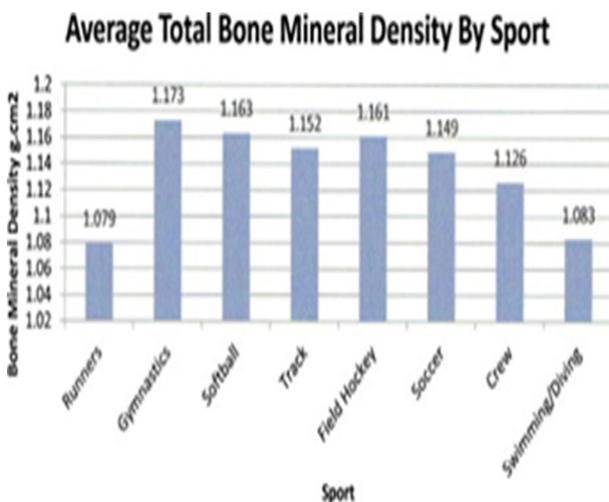


Fig. 2. Average bone mineral density among collegiate female athletes by sport.

Therefore, a high index of suspicion must exist on the physician's part when dealing with athletes presenting with altered eating habits/behaviors or multiple physical complaints.⁵ Even in the absence of a clinical diagnosis of anorexia or bulimia, the concern regarding abnormal types of eating behaviors remains heightened as this scenario can lead to low energy availability.

Pertinent components of the medical history include energy intake, dietary practices, weight fluctuations, and eating habits. The physician should also elicit a complete menstrual history including onset of menarche and current menstrual status. Sport-specific inquiries should include the number of training hours per day, number of sports played, and prior history of stress fracture/injury. An athlete with a history of disordered eating should be referred to a mental health practitioner for further workup.

Each visit should include a set of vitals (height, weight, blood pressure) along with BMI calculation and current menstrual status.⁵⁴ Physical exam findings that may be apparent in a patient effected by this triad include parotid gland enlargement, lanugo hair, acrocyanosis of the hands/feet, and bradycardia. Sexual maturity should be documented with Tanner staging. Pelvic examination may reveal vaginal atrophy if hypoestrogenism is present.⁵⁸

A standard battery of laboratory tests should be obtained if clinical suspicion of one component of the triad is present. Specifically, a complete blood count with differential, complete metabolic panel, erythrocyte sedimentation rate, thyroid function tests, and urinalysis should be a part of the standard assessment.²⁶ Other more advanced tests include urine electrolytes (which may be low from recurrent vomiting), salivary amylase (which may be increased

from vomiting), stool guaic (in cases of laxative abuse), and an electrocardiogram (assess for arrhythmias and prolonged QT interval).

Athletic amenorrhea can be evaluated further by a gynecologist or endocrinologist because it is a diagnosis of exclusion, and appropriate testing to rule out other causes should be undertaken including a pregnancy test and measurement of follicle-stimulating hormone, luteinizing hormone, prolactin, and thyrotropin levels.⁵⁹ If acne or hirsutism is present, evaluation for polycystic ovarian syndrome should also be performed.⁶⁰

The ACSM recommends a baseline DEXA test should occur in an athlete with evidence of greater than 6 months of amenorrhea, oligomenorrhea, and/or disordered eating. A history of stress fractures should also prompt the physician to order a DEXA test. A diagnosis of low BMD or osteoporosis is formulated from the lowest Z-score from the spine or hip.

PREVENTION AND TREATMENT

Optimum treatment for those athletes diagnosed with the Female Athlete Triad must include a multi-disciplinary team approach to maximize therapeutic effectiveness. This specialist-oriented team should consist of the following individuals: health care providers, mental-health practitioners, dieticians, coaches, parents, athletic trainers, exercise physiologist, etc. Although the primary emphasis is on prevention, each of the above individuals has the ability to impact the treatment plan of an affected athlete. Education originating within the school system on triad-specific components is critical to establishing a healthy awareness of the Female Athlete Triad. Young athletes should be alerted to the significant

health risks of low BMD, menstrual dysfunction, and poor overall energy availability. Within the competitive arena, coaches should emphasize the benefits of proper nutrition in relation to the attainment of athletic achievements.

After a comprehensive treatment plan has been formulated, it is necessary for the treating physician along with the multidisciplinary team to determine whether an athlete may continue to train and participate in sport competitively. The athlete must comply with all treatment strategies, be closely monitored by a physician, place importance on treatment over training, and take steps to modify training (intensity, duration, type). If the athlete chooses to not accept treatment, breaks the contract, or does not show steady progression in weight gain, then the athlete must be removed from competition.⁵⁴

The first aim of therapy focuses on energy availability. Specifically, it is essential to create an “energy positive” dietary environment by increasing intake, reducing energy expenditure, or a combination of the 2.⁵⁴ This increase in energy availability then translates into increased BMD and restoration of menstrual function.⁵⁸ For example, increases in BMD of nearly 5% per year have correlated with increases in body weight in amenorrheic athletes.⁵⁵

The ACSM has outlined nutritional guidelines for athletes.⁶¹ The recommended energy intake for sedentary women is 1,800 to 2,000 kcal/d, and an additional 500 to 1,000 kcal/d is advised for active women.^{62,63} Any athlete presenting with signs and symptoms of disordered eating should be referred to nutritional counseling. The dietitian should estimate an athlete’s daily energy availability through the use of a food diary. Bone-building supplements (vitamin D, calcium) should be administered.

The overall treatment goals for athletes presenting with disordered eating remain the following: improve nutritional status, modify unhealthy thoughts, and normalize eating behavior. Treatment success is intimately linked with the development of trustworthy relationships between athlete and care provider. Other forms of nonpharmacological therapy include individual psychotherapy, cognitive-behavioral therapy, and group therapy.⁵⁴

Pharmacological therapy may help to serve as a useful adjunct in affected patients. Antidepressants are often prescribed by mental-health practitioners in patients exhibiting certain mental disorders and/or abnormal eating behaviors (ie, bulimia, anorexia). However, health practitioners must realize that hormone therapy (HT) and/or oral contraceptives (OC) do not address the underlying pathological mechanisms of bone formation and health. Therefore, pharmacological treatment alone will not serve to restore age-appropriate BMD.⁵⁵ OC agents are recommended in athletes older than 16 years with continued BMD decline in an effort to minimize further bone loss. Bisphosphonates, while approved for treatment of postmenopausal osteoporosis, are not recommended in the young athlete due to an overall lack of proven efficacy in this population, as well as concerns for potential harmful fetal effects.

CONCLUSIONS

Screening for female athletes exhibiting risk factors for the triad should take place at the time of sports physicals. If one component of the triad is identified, the clinician should take the time to effectively workup the other. Treatment for each component of the triad includes both pharmacological and non-

pharmacological measures, with emphasis placed upon increased energy availability and overall improved nutritional health. Using this all-encompassing type of approach, sports medicine practitioners should feel empowered to continue to promote the lifelong well-being of female athletes in the years to come.

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Peer Reviewers' Commentary

The triad is best understood as a continuum ranging from health to disease of each disorder: energy availability, menstrual function, and bone mineral density. Energy availability is best conceptualized as energy remaining from the energy intake after EEE has occurred. Therefore, energy availability should ideally match, if not slightly exceed, REE in order to allow physiologic processes of the body to continue. In this review, management methods of low bone mass in female athletes to make it easier to understand the summary and, in the early screening in clinical practice is thought to be very helpful.

(Comment: Editorial Committee)