The Female Athlete Triad

A Clinical Guide

Catherine M. Gordon
Meryl S. LeBoff
Editors

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Preface

As will be discussed many times throughout this book, the Female Athlete Triad defines the interrelationship between menstrual dysfunction, low energy availability, and decreased bone mineral density. As is captured in several of the chapters, while some female athletes meet the psychiatric criteria for an eating disorder, others exhibit a milder energy deficit. However, all are at risk for premature bone loss and/or compromised attainment of peak bone mass. As co-editors, given our training and expertise in bone health across the age spectrum, we represent both providers of children, adolescents, and adults. It is important to recall that some skeletal health experts consider osteoporosis to be a "pediatric disease with geriatric consequences" given that the underpinnings of this disease occur during early to late adolescence [1]. This statement requires careful reflection when considering female athletes and the potential long-term health consequences. Physicians and health care professionals who see children and adolescents may have the opportunity to introduce strategies that augment peak bone mass, while providers of adults need to be cognizant of factors that occurred during childhood and adolescence that may compromise skeletal health during adulthood.

The organization of this book is geared towards clinicians who care for female athletes and researchers whose discoveries impact this important field, as well as translate back to clinical care. The book begins with insights on the epidemiology of the Triad and comments on the incidence of eating disorders among female athletes. Patients with these diagnoses represent the far end of the spectrum in terms of an energy deficit, which thus places them at high risk for health complications. While several of the chapters discuss bone health given our keen interest in this area as both clinicians and clinical investigators, we also try to provide an overview of other health complications. A chapter is devoted solely to stress fractures given how frequent this injury is among female athletes. Another complementary chapter discusses the musculoskeletal approach to the female athlete written from the vantage point of an orthopedic surgeon. Our authors come from a wide variety of disciplines which will hopefully broaden the applicability of the discussions captured herein. They include pediatric and adult endocrinologists, specialists in adolescent health and sports medicine, athletic trainers, gynecologists, orthopedic surgeons,

kinesiologists, dietitians, psychologists, and epidemiologists. Each of their perspectives is unique and important to consider as we think carefully about the complex issues that a female athlete faces.

We end the book outlining a research agenda and speculating on advances that will move this field forward and advance care for our patients. Challenges arise in understanding the most accurate way to evaluate bone health, both for the growing adolescent athlete, as well as for the active adult woman. New technologies are enabling us, for the first time, to catch a glimpse of bone structure and microarchitecture and assess skeletal strength as is discussed within this book. These new examinations are affording enhanced insight into fracture risk, the ultimate outcome of interest for athletes, for it is fractures that leave athletes sidelined and away from the activities they enjoy.

In closing, we wish to acknowledge and thank our wonderful families, whose support has made this book and all aspects of our work possible. Our husbands, Robert Bagley and Mark Williams; our parents, John and Sylvia Gordon and Gerald and Phyllis LeBoff; and last but not least, our children, Benny and Jack, and Jeremy and Avery. We gratefully dedicate this book to each of you.

Providence, RI, USA Catherine M. Gordon
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About the Editors

Drs. Catherine Gordon and Meryl S. LeBoff have been collaborators in the bone health field since 1994.

Dr. LeBoff, an adult endocrinologist, is the Chief of the Calcium and Bone Section in the Endocrinology, Diabetes and Hypertension Division in the Department of Medicine at Brigham and Women's Hospital (BWH). She founded and directs the Skeletal Health and Osteoporosis Center and Bone Density Unit in Endocrinology, Diabetes, and Hypertension Division. She is a Professor of Medicine at Harvard Medical School and the BWH, Distinguished Chair in Skeletal Health and Osteoporosis.

Working in close collaboration with Dr. LeBoff, Dr. Gordon, a pediatric endocrinologist and adolescent medicine specialist, founded the Bone Health Program at Boston Children's Hospital in 2000. Dr. Gordon is Director, Division of Adolescent Medicine at Hasbro Children's Hospital, and Professor and Vice-Chair for Clinical Research in the Department of Pediatrics, Warren J. Alpert Medical School of Brown University.

Drs. Gordon and LeBoff have collaborated on numerous studies in the area of skeletal losses in adolescents with anorexia nervosa and have received funding for their collaborative efforts from the National Institutes of Health, Department of Defense, and private foundations. Each is strongly committed to identifying factors that compromise bone health in adolescent girls and young women to optimize their acquisition of peak bone mass and skeletal health as adults. Their work encompasses the entire lifespan and represents a mission to understand ways to promote healthy bones and active lifestyles from young adulthood to older age.

Chapter 1
Definition and Epidemiology of the Female Athlete Triad

Emily Kroshus and S. Bryn Austin

Introduction

More women and girls than ever are participating in competitive sports [1]. In US high schools alone more than three million girls participate in interscholastic sports on an annual basis [2]. This is a largely positive development due to the many physical, mental, and social benefits of exercise, competition, and teamwork [3]. However, sport participation is not without health risks. In certain categories of sport, inadequate energy intake relative to energy expenditure, often out of a concern for weight and shape related to competitive and normative pressures, may put athletes at risk for the Female Athlete Triad. Sports typically classified as placing athletes at the greatest risk are those that are aesthetically judged (e.g., figure skating, artistic gymnastics, diving and synchronized swimming), have gravitational demands (e.g., distance running, cross-country skiing, cycling, and ski jumping) or in which there are weight classes (e.g., wrestling, boxing, judo, taekwondo, lightweight rowing, and weight lifting); we will refer to these as weight-sensitive sports [4].

The most recent position stand of the American College of Sports Medicine (ACSM) defines the Female Athlete Triad as resulting from the interrelationship among energy availability, menstrual function, and bone mineral density (BMD) [5].

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These three components of the Triad have been conceptualized as being on continua to reinforce the idea that graded negative health outcomes can occur at varying levels of each component; these continua range from optimal health on one end to pathology and disease on the other end. In 2014 the International Olympic Committee (IOC) released a consensus statement naming a new syndrome, Relative Energy Deficiency in Sport (RED-S) [6]. This syndrome highlights the role of energy deficiency in disrupting multiple dimensions of physiologic functioning (including but not limited to menstrual function and bone health) and is an extension of the concept of the Female Athlete Triad.

Energy Availability

Energy availability has been defined as the difference between daily dietary energy intake and exercise energy expenditure; daily calculations of energy availability are typically normalized to fat-free mass and expressed in kilocalories or kilojoules per kilogram of fat-free (or lean) mass [5]. The spectrum of energy availability ranges from high, meaning that the athlete consistently balances her dietary energy intake and energy expenditure, to low, where dietary energy intake is consistently less than exercise energy expenditure. For some athletes, low energy availability may occur because they have a clinically diagnosable eating disorder such as anorexia nervosa or bulimia nervosa [7]. However, individuals do not need to meet the diagnostic criteria for an eating disorder to be engaging in purging or restrictive behaviors that can alter metabolic and reproductive hormones and compromise BMD [5]. Individuals may be engaging in subclinical disordered eating behaviors, or they may be in an energy deficit due to other reasons such as not knowing how they should adjust their energy intake to compensate for an increased training load [8].

A gold standard measure of the construct of energy availability requires calculating energy expenditure through exercise and other physical activities and dietary intake, normalized for fat-free body mass. The recent position statement of the International Olympic Committee Medical Commission's Ad Hoc Research Working Group on Body Composition, Health and Performance [4] highlights the importance of considering issues of reliability, validity, and participant burden when selecting how to measure energy intake and energy expenditure. In addition to measuring energy intake and expenditure, these calculations require reliable and valid measures of body mass indices and body composition, accounting for factors such as hydration status [4]. Best-practice recommendations for assessing energy intake include recording intake on 3–7 training days and using multiple methods such as prospective dietary records and 24-h recall. Recommendations for assessing energy expenditures include accounting for the individual's energy expenditure at rest and completing (non-training) daily activities and training activities, with energy expenditure at rest ideally accounting for non-exercise adaptive thermogenesis or spontaneous physical activity.

If feasible, Sundgot-Borgen and colleagues [4] recommend using an objective method of assessment that does not rely on self-report, such as measuring oxygen consumption. Assessment of eating pathology using a validated measurement tool is one additional component of understanding whether an individual may be in energy imbalance, but should not be considered sufficient in isolation given the expanded conceptual definition of this component of the Triad [5]. Chapter 2 includes a detailed summary of "Sports Nutrition."

Menstrual Function

The spectrum of menstrual function has been defined as ranging from eumenorrhea to amenorrhea. Eumenorrhea is classified as having menstrual cycles lasting within one standard deviation of the mean length for young adult women (28 ± 7 days) [9]. Amenorrhea is classified by the absence of a menstrual cycle over a 3-month period [9]. Secondary amenorrhea refers to amenorrhea occurring after menarche, while primary amenorrhea refers to a delay in menarche past the age of 15 years [9]. On the spectrum between eumenorrhea and amenorrhea is oligomenorrhea, which is classified as having menstrual cycles lasting longer than one standard deviation past the mean cycle length for young women (>35 days).

Operationalization of the construct of menstrual function requires understanding current menstrual function and menstrual history, including age of menarche. Units of measurement are typically duration of menstrual cycles, calculated based on the self-reported number of menstrual cycles over a specified period of time. Stager et al. [10] have cautioned against the use of retrospective survey methods to assess age of menarche; however, this method may often be unavoidable without access to the individual's pediatric medical records, should these records even exist and be accurate with respect to menarche. Ideally, after pregnancy is excluded, measurement would include a draw of serum hormones to objectively assess estradiol and testosterone levels and to rule out other explanations for menstrual dysfunction, such as pituitary tumors and ovarian cysts [4]. Assessing whether or not respondents are taking some form of hormonal contraception is also a critical aspect of evaluation of menstrual function as hormonal contraceptives may regulate the presence of menses. Close to one-third of all sexually active US women who practice contraception use a hormonal method, such as a pill or vaginal ring containing estrogen and a progestin [11]. Additionally, female athletes with menstrual dysfunction are sometimes prescribed hormonal contraception based on conflicting evidence that this action may help maintenance of BMD, even though the balance of evidence weighs against its efficacy [12]. Consequently, if hormonal contraceptive use is not assessed, then any information about the frequency of menstrual cycles or the level of relevant hormones such as serum estradiol may reflect values that are exogenously maintained and independent of energy availability.

Bone Mineral Density

The spectrum of BMD refers to the range from optimal bone health to osteoporosis [5]. The National Institutes of Health Consensus Development Panel (2001) defines osteoporosis as "a skeletal disorder characterized by compromised bone strength predisposing a person to an increased risk of fracture." BMD is not the only component of bone strength, and fractures occur at different levels of BMD in different individuals. Nonetheless, BMD level is used in part to diagnose osteoporosis among young women, with a diagnosis of osteoporosis reflecting BMD below a level at which the risk of fracture is deemed "unacceptable" [5]. Previously, epidemiologic data from postmenopausal white women were used to predict risk of osteoporotic fracture from BMD in all populations. However this approach was criticized for not accurately representing age-specific risk in premenopausal populations [12]. The 2007 ACSM position statement [5] adopts the recommendation of the International Society for Clinical Densitometry (ISCD) [13] that BMD be expressed as a *Z*-score, with comparisons made to age- and sex-specific distributions of BMD. The 2007 ACSM position statement [5] defines osteoporosis as having BMD two or more standard deviations below the mean of the comparison group, along with other secondary clinical risk factors for bone fracture such as a history of nutritional deficiencies, hypoestrogenism or stress fractures. Since the release of the 2007 ACSM guidelines, the ISCD has released an updated position statement specifying that the terms "low bone mass or bone mineral density" rather than "osteoporosis" be used in the absence of history of clinically significant fractures [14]. Individuals can have compromised BMD without meeting the diagnostic criteria for osteoporosis; evidence of skeletal fragility must first be confirmed. Previously, the term "osteopenia" was used to refer to bone density measures that fall between a healthy BMD and osteoporosis. The most recent position statement of the ACSM [5] instead uses the term low BMD to refer to a bone density measure that is one to two standard deviations below the mean for age and sex, along with other secondary clinical risk factors for bone fracture. According to Sundgot-Borgen et al. [4] and the ISCD [14, 15], the gold standard method for measuring BMD is dual-energy X-ray Absorpiometry (DXA). The ISCD [14] states that the most appropriate skeletal sites for assessing BMD in children and adolescents tend to be the posterior-anterior spine and total body less head.

Prevalence

Estimates of the prevalence of the Female Athlete Triad or of individual components of the Triad have ranged from 1 % to over 50 % [16]. Reasons for this large range include variation in how components of the Triad are conceptualized and operationalized and differences in the age, sport, and level of competition of the populations sampled. The 2007 position statement of the ACSM on the Female Athlete Triad [5] provides the most commonly used conceptual definition for the components of the

Triad. Consequently, studies conducted prior to 2007 and using the previous iteration of the ACSM definition will necessarily be subject to misclassification according to the 2007 standard. For example, in 2007, ACSM replaced disordered eating with energy availability as one component of the Triad. Studies that measure eating pathology, but not energy availability, may misclassify individuals who are fueling themselves inadequately relative to their energy expenditure either inadvertently or intentionally, but do not report certain types of eating pathology [5].

Gibbs and colleagues [16] recently conducted a comprehensive review of the prevalence of the Female Athlete Triad, including the prevalence of its clinical and subclinical components, as reported in studies published between 1975 and 2011. We build on the work of Gibbs et al. [16] by using their search criteria and classification guidelines to update prevalence estimates. We include both studies that they review (1975–2011) and all English-language peer-reviewed papers published between January 2012 and 2014 assessing the prevalence of at least one Triad condition among premenopausal exercising women using self-report and/or objective measures. Included in the updated review are studies that report the prevalence of at least one clinical and/or subclinical disorder of the Triad. We draw particular attention to the small number of studies that have been conducted since the release of the 2007 ACSM Triad position stand using the updated conceptual definition for the Triad components, validated measurement tools, and reporting simultaneous prevalence of the three components of the Triad.

A total of ten studies published since 1975 have assessed the prevalence of all three components of the Triad [16, 17], with prevalence estimates for all three components ranging from 0 % in a sample of 82 physically active females (mean age 31 years, standard deviation (SD) = 7) [18], and 0 % in a sample of 15 women on a club triathlon team (mean age = 35, SD = 6) [19] to 15.9 % in a sample of 44 elite female endurance athletes [20]. However, only four studies assessing prevalence of all three Triad components have been conducted since the 2007 ACSM update [17, 19–21], and even then they did not all operationalize the constructs of the Triad according to the 2007 ACSM standard (see Table 1.1). One of these four studies, conducted by Schtscherbyna et al. [21] in a sample of 78 elite female swimmers (mean age = 14.6 years, SD = 2.0 years), did not incorporate the concept of energy availability into the measurement of prevalence, assessing only disordered eating using three validated written measures of disordered eating risk. Nearly half (44.9 %) of the sample met the threshold set by the authors for disordered eating for at least one of three self-report measures of eating pathology (Eating Attitudes Test [EAT-26], Bulimia Investigatory Test Edinburgh [BITE], Body Shape Questionnaire [BSQ]). No athletes were classified as having primary or secondary amenorrhea, and 19.2 % were classified as having oligomenorrhea. Athletes using hormonal contraceptives were excluded from the study; however, no information was given about the number of individuals excluded based on this criteria. Low BMD, as measured using DXA and classified by a *Z*-score of below −1, was present in 15.4 % of the athletes. According to this study's operationalization of Triad, 15.4 % of the sample had clinical levels of at least two components of the Triad, and 1.3 % meet criteria for all three components.

Table 1.1 Characteristics of the studies published after 2007 of the prevalence of all three components of the Female Athlete Triad

Study	Sample	Energy availability: measurement (EA)	Energy availability: prevalence (%)	Menstrual function: measure	Menstrual function: prevalence (%)	Bone mineral density: measurement (BMD *Z*-score)	Bone mineral density: prevalence (%)	Three-way prevalence[a]
Hoch et al. (2009)	Sport: High school varsity sports (all teams)	EA ≤ 45 kcal/kg LBM	36	Primary amenorrhea, secondary amenorrhea or oligomenorrhea	54	$-1.9 < z \leq -1.0$	13	1.0 %
	Mean age: 16.5 years, SD = 1.0, *n*: 8	EA ≤ 30 kcal/kg LBM	6					
	Country: USA	EAT-26 ≥ 15	4	Secondary amenorrhea	30	$z \leq -2.0$	3	
Schtscherbyna et al. (2009)	Sport: Swimming	EA	Not measured	Primary or secondary amenorrhea	0	$z \leq -1.0$	15.4	1.3 %
	Mean age: 14.6, SD = 2.0, *n*: 8	Positive screen for one of three self-report measures (EAT-26, BITE or BSQ)	44.9	Oligomenorrhea	19.2			
	Country: Brazil							
Pollock et al. (2010)	Sport: Endurance running	EA	Not measured	Secondary amenorrhea or oligomenorrhea	52.3	$-1.9 < z \leq -1.0$	4.9–34.2	15.9 %
	Mean age: 22.9, SD = 6.0, *n*: 44	Upper quartile on any of the three subscales	Not reported			$z \leq 2.0$	0–33.3	
	Country: UK							
Coehla et al. (2013)	Sport: Tennis	Stage I: EA ≤ 45 kcal/kg LBM	87.5	Stage I = primary amenorrhea, secondary amenorrhea or oligomenorrhea	33.3	Stage I: $z \leq -1.0$	25.0	Stage I: 4.2 %
	Mean age: 14.8, SD = 10.6, *n*: 24	EA ≤ 30 kcal/kg LBM	33.3	Stage II = primary amenorrhea or secondary amenorrhea	8.3	Stage II: $z \leq -2.0$	0	Stage II: 0 %
	Country: Brazil	Stage II: EAT-26 > 20 or BSQ > 80 or BITE > 10	50.0					

EAT-26 Eating Attitudes Test-26 score, *BITE* Bulimic Inventory Test Edinburgh score, *BSQ* Body Shape Questionnaire score, *TFEQ* Three Factor Eating Questionnaire score, *DXA* Dual X-Ray Absorptiometry, *LBM* lean body mass

[a]Three-way prevalence refers to simultaneous prevalence of all three components of the Triad

In line with the updated definition, Hoch et al. [19] assessed the prevalence of all three Triad components in a sample of 80 female high school varsity athletes across multiple sports. Around one third (36 %) of the athletes were classified as having low daily energy availability (≤45 kcal/kg of lean body mass), with 6 % having energy availability of less than 30 kcal/kg of lean body mass. In addition to the gold standard of energy availability, eating pathology was also measured, with only 4 % of athletes classified as at risk of disordered eating based on having EAT-26 scores of greater than or equal to 15. Over half of athletes (54 %) reported menstrual dysfunction, with 30 % reporting secondary amenorrhea and 15 % reporting oligomenorrhea, both operationalized using the 2007 ACSM definition [5]. Hormonal contraception was assessed and reported, but results were not stratified by use. Serum hormones were also assessed to eliminate other endocrinologic or gynecologic causes of menstrual dysfunction. BMD was assessed using the 2007 ACSM [5] definitions and using DXA technology: 3 % of athletes had *Z*-scores of less than −2, and 13 % had *Z*-scores between −1 and −1.9. Overall, the authors found that 1 % of the sample had all three Triad conditions, between 4 and 18 % had any two Triad conditions, and between 16 and 54 % had any one Triad condition.

Pollock et al. [20] assessed the prevalence of the conditions of the Triad in a sample of 44 elite female endurance runners (mean age 22.9 years, SD = 6.0 years). BMD was measured at several locations on the body, with *Z*-scores varying by location. Low BMD, as measured by *Z*-scores of between −1 and −2, was characteristic of 34.2 % of the sample at the lumbar spine, 13.8 % at the femoral neck, 29.6 % at the radius, and 4.9 % for the total body. *Z*-scores below −2 were characteristic of 7.3 % of the sample at the lumbar spine, 33.3 % at the radius, and 0 % at the femoral neck and for the total body. Energy availability was not assessed. Rather, disordered eating was assessed using the Three-Factor Eating Questionnaire (TFEQ), a self-report measure of disordered eating cognitions, including cognitive restraint. Athletes scoring in the upper quartile for this sample on any of the three TFEQ subscales were classified as engaging in disordered eating. Secondary amenorrhea or oligomenorrhea, assessed using a self-report questionnaire, were present in 52.3 % of the sample. While information on hormonal contraceptive use was reported, results were not stratified by its use. Considering the sample as a whole, 15.9 % were classified as having all three components of the Triad, with menstrual dysfunction, disordered eating and low BMD.

Coehla et al. [17] also used the 2007 Triad definition to assess prevalence of the Triad in a sample of 24 adolescent female tennis players. Although the participants were from only one sport and the sample size was small—thus producing imprecise estimates with wide confidence intervals—this study is notable because it is the first and only study to date to estimate the prevalence of the Triad using the spectrum concept. The authors divided the Triad into Stage I and Stage II to reflect graded severity. Stage I was considered to be "moderately severe" and was operationally defined as having daily energy intake of less than or equal to 45 kcal/kg of lean body mass, presence of primary or secondary amenorrhea or oligomenorrhea, and a BMD *Z*-score of less than or equal to −1.0. Stage II was considered to be "severe" and was operationally defined as meeting a clinical threshold for at least one of three