Prevalence of Female and Male Athlete Triad Risk Factors in Ultramarathon Runners

Tracy Beth Høeg, MD, PhD,*† Emily Miller Olson, MD,‡ Kira Skaggs, BA,‡ Kristin Sainani, PhD,§
Michael Fredericson, MD,‡ Megan Roche, MD,§ and Emily Kraus, MD‡

Abstract

Objective: To identify the prevalence of male and female athlete triad risk factors in ultramarathon runners and explore associations between sex hormones and bone mineral density (BMD). **Design:** Multiyear cross-sectional study. **Setting:** One hundred-mile ultramarathon. **Participants:** Competing runners were recruited in 2018 and 2019. **Assessment of Risk Factors:** Participants completed a survey assessing eating behaviors, menstrual history, and injury history; dual-energy x-ray absorptiometry for BMD; and laboratory evaluation of sex hormones, vitamin D, and ferritin (2019 cohort only). **Main Outcome Measure:** A Triad Cumulative Risk Assessment Score was calculated for each participant. **Results:** One hundred twenty-three runners participated (83 males and 40 females, mean age 46.2 and 41.8 years, respectively). 44.5% of men and 62.5% of women had elevated risk for disordered eating. 37.5% of women reported a history of bone stress injury (BSI) and 16.7% had BMD Z scores <-1.0. 20.5% of men had a history of BSI and 30.1% had Z-scores <-1.0. Low body mass index (BMI) (<18.5 kg/m^2) was seen in 15% of women and no men. The Triad Cumulative Risk Assessment classified 61.1% of women and 29.2% of men as moderate risk and 5.6% of both men and women as high risk. **Conclusions:** Our study is the first to measure BMD in both male and female ultramarathon runners. Our male population had a higher prevalence of low BMD than the general population; females were more likely to report history of BSI. Risk of disordered eating was elevated among our participants but was not associated with either low BMD or low BMI.

Key Words: bone stress injury, energy availability, endurance running, low BMD

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INTRODUCTION

Bone stress injury (BSI) is a common running-related injury, with about 20% of collegiate runners sustaining at least one per year.[1–3] Unlike most other running injuries, injuries related to poor bone health are associated with long-term health consequences such as osteoporosis and fragility fractures later in life.[4]

A BSI is an overuse injury resulting from the inability of bone to withstand repetitive loading. Although women are at higher risk, BSIs are also common in men[5–7] with 27% of male collegiate runners sustaining a BSI over a two-year period in one study.[5] In both men and women, participation in "leanness sports," low body mass index (BMI), and low energy availability are risk factors for poor bone health and BSI.[5,8] In women, the combination of low energy availability, menstrual irregularities, and low bone mineral density (BMD) is called the female athlete triad. The male equivalent of the triad involves low energy availability, low BMD, and sex hormone insufficiency.[9] Low energy availability can lead to reductions in sex hormone levels and BMD.[9] The female athlete triad and the male equivalent are distinct from relative energy deficiency in sport (RED-S), which is a term used to denote a broader array of physiological and performance outcomes related to low energy availability.[10]

The popularity of competitive long-distance running among postcollegiate, middle age, and older adults is growing.[11,12] Over the past 20 years, there has been an 18-fold increase in the number of ultramarathon events (races greater than 42.2 km).[13]

Few studies have examined the bone health of ultramarathon runners. One study found a self-reported cumulative annual incidence of BSIs among active ultramarathon runners of 5.5%,[14] whereas another found lower-extremity BSIs accounted for approximately 10% of running injuries incurred the year before ultramarathon participation.[15] Premenopausal ultramarathon runners with oligomenorrhea have been found to have lower BMD.[16] Another study found that middle-aged male ultramarathon runners had significantly lower BMD compared with sedentary controls.[17]

This study's primary aim was to determine the prevalence of male and female athlete triad risk factors and decreased BMD in 100-mile ultramarathon runners. Our secondary aim was to explore the associations between sex hormones (estradiol, testosterone, and free testosterone) with BMD. To the best of our knowledge, no studies have systematically investigated the prevalence of triad risk factors, low BMD, and history of BSI in both male and female ultramarathon runners. Our study is

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*From the *Department of Physical Medicine & Rehabilitation School of Medicine, University of California-Davis, Sacramento, California; †Northern California Orthopaedic Associates, Grass Valley, California; ‡Stanford Department of Orthopaedic Surgery, Stanford University, Palo Alto, California; and §Department of Epidemiology and Population Health, Stanford University, Stanford, California.*

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Corresponding Author: Emily Kraus, MD, Department of Orthopaedic Surgery, Stanford University, 300 Pasteur Drive, Edwards Bldg. R105 MC5341, Stanford, CA 94305 (ekraus@stanford.edu).

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the first to assess the relationship between sex hormone levels and bone health in ultramarathon runners.

METHODS

Subjects

The study population consisted of ultramarathon runners participating in the 2018 and 2019 Western States Endurance Run. All 738 runners who registered for the 2018 and 2019 races received a recruitment email 2 months before the race and 123 (83 males and 40 females) consented to participate. Written consent was obtained for each participant. Runners younger than 18 years of age and non-English speakers were excluded. Five athletes participated in both 2018 and 2019; only their 2019 data were included in the analyses.

Procedures and Data Collection

Institutional review board approval was obtained at UC-Davis in 2018 (#1197430-4) and Stanford in 2019 (#49492). Data were uploaded into Stanford's secure, web-based database, Research Electronic Data Capture (REDCap).

Participants were asked to complete an online questionnaire before the race using the secure program Qualtrics. All runners who agreed to participate completed a questionnaire within the 8 weeks before the race. Demographics included age, sex, height, and weight. We assessed training history and performance, including history of ultramarathon participation, preferred race distance training schedule, and lifetime history of BSIs. Participants completed a series of questions regarding diet and eating behaviors, including patterns of disordered eating and history of/current eating disorders. The questions in this survey (see **Supplemental Digital Content 1**, http://links.lww.com/JSM/A280) were derived from the Female Athlete Triad Screening Questionnaire, the Triad Consensus Panel Screening Questionnaire, and the dietary restraint and pathologic behavior sections of the Eating Disorder Examination Questionnaire,[18,19] which have been validated in other cohorts.[20] A menstrual history was also obtained from each female participant.

For both 2018 and 2019 athletes, dual-energy x-ray absorptiometry (DXA) was used to measure BMD. DXA scans were performed in the 2 days before the race using GE Lunar Prodigy Primo (GE Healthcare, Chicago, IL). Measured regions included the lumbar spine (L1-L4), femoral neck, forearm, and total hip. Results were reported as BMD in g/cm.[2] Z-scores were used, which correct for age, sex, and ethnicity. The scanner maintained a quality assurance program through BodySpec. Licensed technicians performed each DXA. Height and weight were recorded by technicians at the time of DXA measurement for BMI calculations.

The 2019 cohort underwent an additional laboratory evaluation. Fasting blood samples were collected by 2 trained phlebotomists arranged by InsideTracker (Cambridge, MA) the day before the race between 7 and 10 AM Two athletes had their blood drawn the week before the race at a Quest Diagnostics Center between 7 and 10 AM Samples were placed on ice and overnighted to a Quest Diagnostics facility (Secaucus, NJ). Laboratory tests included 25-hydroxy vitamin D (25(OH)D), ferritin, testosterone, and estradiol. Quest Diagnostics securely sent the deidentified results to InsideTracker for analysis.

Outcome Measures

Variables of interest included self-reported disordered eating behaviors, low BMI, low BMD, history of BSI, delayed age of menarche, and oligomenorrhea (for women). Each variable was quantified as low- (0 point), moderate- (1 point), or high-risk (2 points) using the Female Athlete Triad Coalition Consensus Statement Cumulative Risk Assessment tool and a modified version for male athletes that excluded late menarche and history of oligomenorrhea/amenorrhea variables (Figure 1).[5,20] Disordered eating score designation was based on responses to a validated standardized questionnaire.[18] A score of 0 was assigned for those with no significant disordered eating; 1 for those with disordered eating behaviors; and 2 for behaviors consistent with a diagnosis of a DSM-V eating disorder. Postmenopausal women and women who reported the use of hormonal contraceptives were excluded from the oligomenorrhea/amenorrhea scoring. To calculate the cumulative risk score, postmenopausal women were given an oligomenorrhea score of 2 and those on hormonal birth control were given a score of 0. Participants were not questioned about their menopausal status; however, the 5 athletes older than 50 years of age who reported absence of menstruation were considered postmenopausal.[21]

Risk Factors	Low Risk = 0 points each	Moderate Risk = 1 point each	High Risk = 2 points each
*Disordered Eating**	☐ Little to no dietary restriction	☐ Moderate restrictions reported likely consistent with disordered eating	☐ Significant restrictions reported likely consistent with DSM-V Eating Disorder
Low Body Mass Index (BMI)	☐ BMI ≥ 18.5 kg/m^2	☐ BMI 17.6-18.4 kg/m^2	☐ BMI ≤ 17.5 kg/m^2
Delayed Menarche	☐ Menarche ≤ 15 years	☐ Menarche 15 to 16 years	☐ Menarche ≥ 16 years
Oligomenorrhea and/or Amenorrhea†	☐ >9 menses in 12 months	☐ 6-9 menses in 12 months	☐ <6 menses in 12 months
Low Bone Mineral Density (BMD)	☐ BMD Z-score ≥-1	☐ BMD Z-score -1 to -2	☐ BMD Z-score ≤ -2
History of Prior Bone Stress Injury (BSI)	☐ No prior BSI	☐ 1 prior low-risk BSI	☐ Multiple BSIs or 1 moderate- or high-risk BSI‡
Cumulative Risk (Total each column, then add for total score)	0 points +	____ points +	____ points = Total Score

Figure 1. Female and male athlete cumulative risk assessment scoring. *Risk of disordered eating based on self-report of restricting or purging behaviors. †Participants were not questioned about their menopausal status; however, athletes older than 50 years of age who reported 0 menstrual cycles were considered postmenopausal.[19] To calculate the cumulative risk score, postmenopausal women were given an oligomenorrhea score of 2 and those on hormonal birth control were given a score of 0. ‡High-risk skeletal sites associated with low BMD and delay in return to play in athletes with one or more components of the triad include the femoral neck, sacrum, and pelvis. This figure was adapted from the Female Athlete Triad: Cumulative Risk Assessment.[20] DSM-5, diagnostic and statistical manual of mental disorders, fifth edition.

In cumulative risk of BSI, a score of 0 or 1 was low-risk, 2 to 3 (for men) or 2 to 5 (for women) was moderate-risk, and 4+ (for men) and 6+ (for women) was high-risk.[5,20]

Analysis

Descriptive statistics such as means, SDs, and percentages were calculated. Exploratory analyses were calculated using Spearman rank correlation coefficients between sex hormone levels (estradiol, testosterone, and free testosterone) and BMD (spine, total body, and hip) in women and men from the 2019 cohort. Testosterone values from one female were excluded due to high levels being significantly outside of the physiological normal for females. Ferritin levels were also excluded from one woman who was taking iron infusions.

ETHICAL CONSIDERATIONS

The primary ethical consideration in this project was related to the distribution of abnormal results to participants because there was no active follow-up in the study and no interaction between the participants and study team after data collection. The decision was made to return all laboratory and bone density results to the participants and strongly encourage them to review the results with a physician both for normal and abnormal results.

RESULTS

Participants

In 2018 and 2019, 738 runners (164 women and 574 men) competed in the Western States Endurance Race. A total of 123 runners (40 women and 83 men) completed the consent form and electronic questionnaire (16.7% enrollment). Of those, 108 (36 women and 72 men) completed DXAs. Of the 67 participants in 2019, 51 (19 women and 32 men) completed the serum evaluation. Enrollment was capped based on available DXA scan time slots, and all time slots were filled both years. Participation was determined by how early runners indicated they were interested in participating. Of our participants, 100/120 or 83.3% finished the entire race compared with an overall 83.7% race finish rate (618/738).

Demographic and Running Characteristics

Runners were predominantly white and from the United States (Table 1). Approximately 50% of both male and female runners self-identified as either professional or competitive runners, with 17.5% of women and 2.4% of men competing professionally. The mean age was 46.2 years for men (range: 27.2-76.2 years) and 41.8 years for women (range: 26.4-57.2 years). Women ran an average of 61.5 miles/week and had been competing for an average of 13.8 years. Men ran an average of 57.3 miles/week and had been competing for an average of 16.1 years.

TABLE 1. Participant Demographic and Running Characteristics, N (%) or Mean (SD)

	Women (n = 40)	Men (n = 83)
Age (yr)	41.8 (7.6)	46.2 (10.3)
Race/ethnicity		
White	39 (97.5%)	70 (84.3%)
Hispanic/Latino		7 (8.4%)
Other	1 (2.5%)	5 (6.1%)
Missing		1 (1.2%)
Country		
United States	37 (92.5%)	65 (78.3%)
Europe	1 (2.5%)	3 (3.6%)
Australia/NZ	1 (2.5%)	5 (6.0%)
South/Central America		5 (6.0%)
Other		5 (6.0%)
Missing	1 (2.5%)	
Running level*		
Professional	7 (17.5%)	2 (2.4%)
Competitive age group	14 (35.0%)	39 (47.0%)
Middle of pack	14 (35.0%)	39 (47.0%)
Finisher	5 (12.5%)	3 (3.6%)
Finished race		
Yes	29 (72.5%)	73 (88.0%)
DNF	10 (25.0%)	10 (12.0%)
DNS	1 (2.5%)	
Mileage (miles/week)	61.5 (16.1)	57.3 (21.1)
Running time (h/wk)	12.7 (3.2)	10 (3.1)
Years racing	16.1 (10.2)	13.8 (9.9)

*Professional runners receive some sort of income or sponsorship, competitive runners finish the race near the top of their age group, middle of the pack runners finish around the average finishing time, and finishers are often toward the last people to finish.
DNF, did not finish; DNS, did not start.

Primary Endpoints

Disordered Eating and Body Mass Index

Average BMI was 21.2 kg/m^2 for women and 6 (15%) had BMI values below 18.5 kg/m^2 (Table 2 and Figure 2). Average BMI was 22.6 kg/m^2 for men, and none had BMI values below 18.5 kg/m^2 (Table 2 and Figure 2). Twenty-five (62.5%) women and 37 (44.5%) men were classified as either moderate- or high-risk for disordered eating. In addition, about 50% of both male and female runners reported trying to lose weight for performance.

There was no association between disordered eating risk score and low BMI or low BMD. Of 23 women with an elevated risk of disordered eating, 3/23 (13.0%) had low BMD (Z score < -1) and 2/23 (8.7%) had low BMI ($<$18.5 kg/m^2) versus 3/13 (23.1%) and 4/13 (30.8%), respectively, of those classified as low-risk for disordered eating (data not shown). Of 30 men with elevated risk of disordered eating, 10 (33.3%) had low BMD versus 15/42 (37.1%) of those classified as low-risk for disordered eating.

Menstrual History

The mean age of menarche in this cohort was 13.2 years (Table 2); 12 runners (30.0%) had menarche at age 15 years or later (considered moderate-to high-risk). Almost half of the female runners (n = 19) had used hormonal contraceptives in the last year and 5 were considered postmenopausal, limiting our assessment of oligomenorrhea. Of the remaining 16 athletes, 4 (25.1%) were in the moderate- or high-risk categories for oligomenorrhea.

TABLE 2. Female Athlete Triad Cumulative Risk Assessment and a Male Equivalent

	Women (n = 40); Mean (SD) or n (%)	Men (n = 83); Mean (SD) or n (%)
BMI (kg/m^2)*	21.2 (2.1)	22.9 (2.6)
Trying to lose weight for performance	21 (52.5%)	38 (45.8%)
Periods/year†	10.9 (3.1)	—
Menarche age	13.2 (1.7)	—
Use of hormonal contraception	19 (47.5%)	—
Spine Z-score*	0.2 (1.2)	−0.2 (1.3)
Femoral Z-score*	0.5 (0.9)	0.3 (0.9)
Total hip Z-score*	0.5 (0.9)	0.0 (0.8)
History of bone stress injury	15 (37.5%)	17 (20.5%)
Cumulative risk score	Women (n = 36*)‡	Men (n = 72*)
Low risk	12 (33.3%)	47 (65.3%)
Moderate risk	22 (61.1%)	21 (29.2%)
High risk	2 (5.6%)	4 (5.6%)
Low energy availability	Women (n = 40)	Men (n = 83)
Low risk	15 (37.5%)	46 (55.4%)
Moderate risk	16 (40.0%)	29 (34.9%)
High risk	9 (22.5%)	8 (9.6%)
BSI	Women (n = 40)	Men (n = 83)
Low risk	24 (62.5%)	66 (79.5%)
Moderate risk	8 (20.0%)	9 (10.8%)
High risk	7 (17.5%)	8 (9.6%)
BMI	Women (n = 36‡)	Men (n = 72‡)
Low risk	30 (85%)	72 (100.0%)
Moderate risk	5 (12.5%)	0
High risk	1 (2.5%)	0
BMD	Women (n = 36‡)	Men (n = 72‡)
Low risk	30 (83.3%)	47 (65.3%)
Moderate risk	6 (16.7%)	20 (27.8%)
High risk	0	5 (6.9%)
Menarche	Women (n = 40)	
Low risk	28 (70.0%)	—
Moderate risk	7 (17.5%)	—
High risk	5 (12.5%)	—
Oligomenorrhea (excluding postmenopausal women and those on hormonal contraceptives, remaining n = 16)		
Low risk	12 (75.0%)	—
Moderate risk	1 (6.3%)	—
High risk	3 (18.8%)	—

BMI and femoral and total hip BMD values were only available for 36 women and 72 men; spine BMD Z scores were only available for 35 women and 72 men.
† Periods per year is based on 16 women who were not taking oral contraceptives and were not postmenopausal.
‡ To calculate the cumulative risk score, postmenopausal women were given an oligomenorrhea score of 2 and those on hormonal birth control were given a score of 0.

Bone Mineral Density and Bone Stress Injury

More than one-third of women reported a history of BSI (37.5%) (Figure 2), although only about one-sixth (16.7%) had BMD Z scores < −1 (considered moderate- to high-risk, Table 2). For men, 20.5% had a history of BSI and 30.1% had BMD Z-scores < −1. Female and male athlete triad individual risk factors are displayed in Figures 1 and 2.

Female and Male Athlete Triad Cumulative Risk Assessment Score

About twice as many women (61.1%) as men (29.2%) had moderate-risk scores on the cumulative risk assessment; 5.6% of both men and women were in the high-risk category (Table 2).

Exploratory Analyses

We found significant correlations between higher spine Z-scores and higher levels of estradiol (Spearman correlation coefficient, r = 0.52, P = 0.022), testosterone (r = 0.51, P = 0.03), and free testosterone (r = 0.58, P = 0.012) in women (Figure 3). There was also a significant correlation between higher testosterone and higher total hip Z-score in women (r = 0.71, P = 0.0011). These findings were unaffected by adjusting for hormonal contraceptive usage or for post-menopausal status. We did not identify statistically significant correlations between BMD total testosterone, free testosterone, or estradiol in men.

Additional Laboratory Analyses

Serum Evaluation (2019 cohort only):

Table 3 shows descriptive statistics related to hormone levels, ferritin levels, and vitamin D levels. Of the premenopausal women, 8 were classified as having low estradiol; however, all 8 of these athletes were using hormonal contraception (Table 3). One postmenopausal woman had low estradiol. Four men had elevated estradiol levels up to 54.9 pg/mL, and all had normal total testosterone levels. Three had elevated and 3 had low free testosterone levels.

No women and one man had low ferritin levels (<10 ng/mL). However, 12/19 women (63%) and 4/32 men (12%) had levels lower than 35 ng/mL, below the cutoff recommended for elite athletes.[22] Eleven women (58%) were identified with 25(OH)D deficiency (<30 mmol/L)[23] including 3 taking vitamin D supplements. No men had 25(OH)D deficiency.

DISCUSSION

This study is the first to describe the prevalence of all components of the female athlete triad, including low BMD in both male and female ultramarathon runners.

Low Bone Mineral Density

Over a third (35%) of our male population had low BMD, which is consistent with the 36% to 43% previously reported in male long-distance runners.[24,25] However, our female runners tended to have low BMD at a similar rate to that of the general population at 17% and lower than the 26% to 42% previously observed in collegiate female runners.[16,24,26–30] Women 30 years of age and older are more likely to have regular menstruation[31] and this may help maintain BMD in postcollegiate runners. Older athletic women may also have improved ability to maintain BMD due to continuing weight-

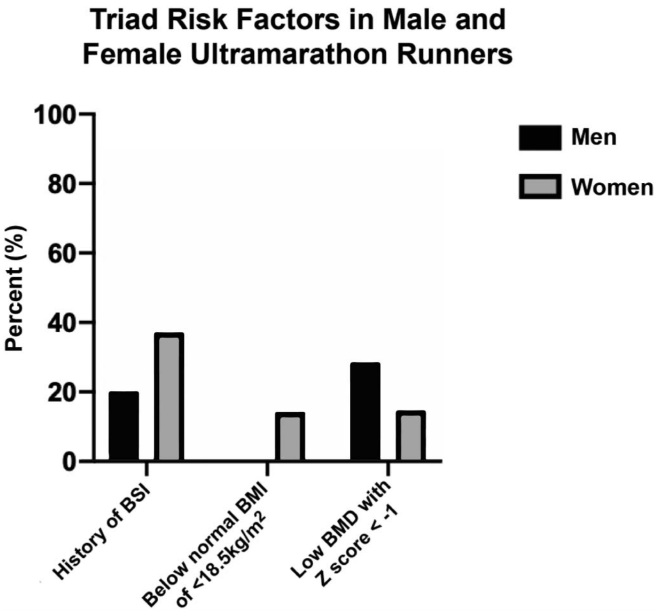

Figure 2. Prevalence of BSI history, low BMI, and low BMD by sex.

bearing activities and preserving muscle mass.[32] Societal pressures on younger female athletes to be lean to improve performance may also contribute to the difference.[33]

Bone Stress Injury

More than one-third of women in our study had sustained at least one BSI (37.5%) and about one-fifth of the men had sustained a BSI (20.5%). Our overall prevalence of BSI was similar to the 24.9% of active ultramarathon runners reporting a history of BSI in a prior investigation[15]; however, that study did not report men and women separately. Our prevalence is on par with prevalence values reported in collegiate runners, which range from 15% to 31%; however, our population had been competing longer than collegiate runners and thus has had a longer time to sustain a BSI.[5,34–36]

Disordered Eating

We found almost two-thirds of females to be moderate- or high-risk for disordered eating based on self-report. If disordered eating is coupled with low energy availability, this can have deleterious effects on reproductive and growth hormones as well as bone turnover.[37] However, disordered eating behaviors may not always correlate with low energy availability if we are instead capturing an effort to maintain health or improve performance while energy availability remains sufficient. Indeed, we did not find disordered eating risk to correlate with low BMD or BMI in our female or male population.

Nearly 45% of our male participants were considered moderate- or high-risk for disordered eating. Although there is a paucity of research in disordered eating in male ultramarathon runners, one previous study of male endurance athletes[38] reported a prevalence of eating disorders/disordered eating of just 9%. As stated above, disordered eating may not result in low energy availability, and our study failed to find a correlation in either sex. Specifically, questions regarding body dissatisfaction have been found to not correlate with the presence of an eating disorder in athletes.[39]

Menstrual Dysfunction

Four (25%) of 16 premenopausal female ultramarathon runners not on hormonal contraception were in the moderate- or high-risk categories for menstrual irregularity. In comparison, studies in collegiate and high school runners have found an oligomenorrhea prevalence range from 26% to 64%.[30,40,41] Direct comparisons are difficult, given we had few women who were not taking hormonal contraception.

Exploratory Analyses

We found a significant positive relationship between testosterone, free testosterone, estradiol, and BMD in female runners. To the best of our knowledge, ours is the first study to identify a relationship between testosterone and BMD in females. The relationship between estrogen and BMD in females has been previously demonstrated.[42] We did not identify a relationship between sex hormone levels and BMD in men, but may have been underpowered to do so. Heikura et al[37] found males with lower testosterone levels to have 4.5-fold higher rates of BSI compared with males with normal testosterone. However, another small study of long-distance middle-aged male runners also failed to find a relationship between testosterone levels and BMD.[43]

Additional Laboratory Analyses

Low ferritin is considered the first stage of iron deficiency[44] and iron deficiency may have negative effects on bone

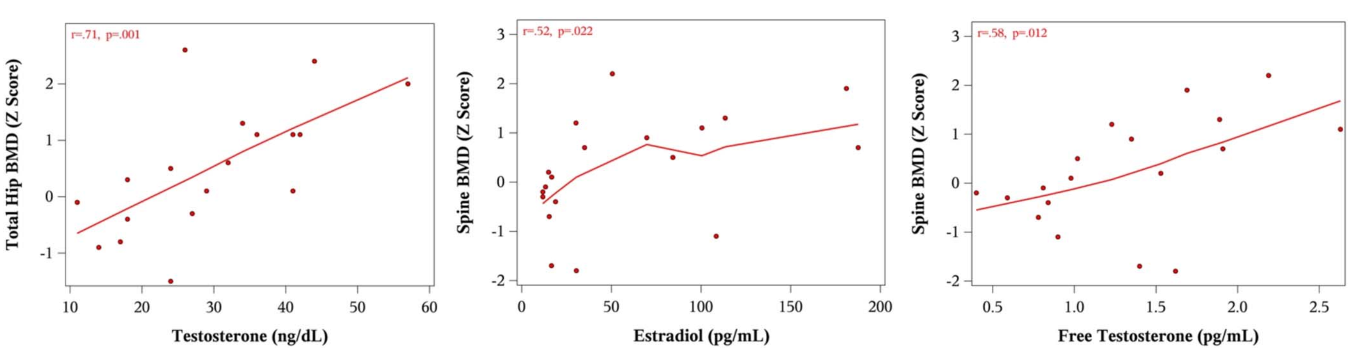

Figure 3. Correlations between sex hormone levels and female BMD.

TABLE 3. Serum Evaluation From the 2019 Cohort

	Women, N (%) or Mean (SD)	Women Normal Range*	Women, N (%) Below Normal	Women, N (%) Above Normal	Men, N (%) or Mean (SD)	Men Normal Range*	Men, N (%) Below Normal	Men, N (%), Above Normal
N	19†				32			
Estradiol pg/mL	58.5 (56.4)‡	19.5-356.7	7 (41.1%)	0 (0%)	31.4 (8.0)	0-39.8	0 (0%)	4 (12.5%)
Free testosterone pg/mL	1.3 (0.6)	0.3-3.2	0 (0%)	0 (0%)	17.1 (16.9)	8.7-54.7	3 (9.4%)	3 (9.4%)
Total testosterone ng/dL	29.7 (12.2)	7-48	0 (0%)	0 (0%)	579 (144)	87-882	0 (0%)	0 (0%)
Ferritin ng/mL	30.8 (18.4)	10-291 >35 for elite athletes*	0 (0%) 12 (66.7%)	0 (0%)	95.5 (70.5)	15-200 >35 for elite athletes	1 (3.1%) 4 (12.5%)	2 (6.2%)
25(OH)D ng/mL	31.3 (11)	"Sufficient" >30	11 (57.9%)	0 (0%)	28.9 (9.6)	"Sufficient" >30	0 (0%)	0 (0%)

*Normal laboratory values were obtained from the performing laboratory Quest Diagnostics. Recommended values for elite athletes based on prior research.[18].

† Sample size is 18 for women for ferritin, free testosterone, and total testosterone. One woman who was on iron infusions was excluded from ferritin statistics; one woman had testosterone values indicative of a pathologic process and was excluded from free testosterone and total testosterone statistics.

‡ Excludes data from 2 women who were believed to be postmenopausal.

health.[45] The female endurance running population has been consistently found to have high levels of iron deficiency, with a prevalence reported between 20% and 50%[46]; however, the definitions of "iron deficiency" varied significantly in these studies. In our study, no women had low ferritin levels (<10 ng/mL), whereas 12/19 (63%) had levels lower than 35 ng/mL (considered suboptimal in elite athletes),[22] despite 50% reporting iron supplementation.

Over half (58%) of our females and none of our males were found to have 25(OH)D insufficiency (<30 mmol/L). The relationship between 25(OH)D levels and BSI is complex, although some studies have linked supplementation with lower risk of stress fractures.[47–50]

LIMITATIONS

Our current investigation included use of self-reported questionnaires for diet, training, prior BSI, and menstrual history, which introduces possible recall bias. A large number of the female runners were on hormonal contraceptives or postmenopausal, limiting our ability to assess menstrual regularity. Our sample size was relatively small, particularly for women. In contrast to other studies in collegiate or elite runners, our cohort included runners with a wide range of ages and training levels. BMD can also be affected by additional hormones not measured in this analysis, and hormones fluctuate within an individual over the course of a week and tend to decrease with age. Finally, our study was not designed to determine correlation between running mileage, specific nutrient deficiencies, or genetic factors that may all play a role in BSI development.

CONCLUSION

Our study is the first to analyze BMD in men and women ultramarathon runners. Ours is the largest study of ultramarathon runners to examine the prevalence of female and male athlete triad risk factors. We found that over a third of our male participants had low BMD, whereas the BMD among our females was similar to the general population. One in 5 male and 1 in 3 female study participants had sustained a BSI. Nearly half of our male participants and two-thirds of our female participants were at moderate- or high-risk for disordered eating. However, these elevated risk scores for low energy availability were not associated with low BMD or low BMI. These results highlight the need for a better understanding of risk factors for BSI in this unique population of athletes.

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