Risk of Low Energy Availability, Disordered Eating, Eating Disorders, and Bone Stress Injuries in United States Female Track and Field

Original Research

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Abstract

Introduction: Female track and field athletes have increased risk of low energy availability (LEA), disordered eating (DE), and eating disorders (ED), which are associated with health and performance consequences. This study explored LEA, DE, and ED risk among United States female track and field athletes and assessed differences in proportions between risk and competition level and bone stress injury (BSI) risk.

Methods: Female track and field athletes (n = 392, aged 18-68 years) completed an online survey including the Low Energy Availability in Females Questionnaire (LEAF-Q), Eating Disorder Examination Questionnaire (EDE-Q), and Female Athlete Screening Tool (FAST), and self-reported BSIs. Chi-square tests of homogeneity assessed differences in proportions between competition level and BSI and LEA, DE, and ED risk.

Results: 49%, 48%, and 22% of participants had high risk for LEA, DE, and ED, respectively; and concurrent risk of LEA, DE, and ED was 27%. There was a significant difference in proportions between competition level and LEA risk (X^2 (3, 387) = 11.93, p = 0.008, Φ= 0.176) and ED/DE risk (X^2 (3, 387) = 11.65, p = 0.007, Φ= 0.213); and BSI and LEA risk (X^2 (2, 392) = 8.58, p = 0.014, Φ= 0.148).

Conclusions: This study demonstrated a considerable portion of US female track and field athletes had high risk of LEA, DE, and ED.

Key Words: runners, nutrition, injury

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Introduction

Eating behaviors can be described on a continuum ranging from optimal eating habits for adequate energy availability, to disordered eating (DE), and further to, clinical eating disorders (EDs)[1–3]. Among this continuum, individuals may experience variability in energy intake as a by-product of pathological eating behaviors, such as low energy availability (LEA) and consequently Relative Energy Deficiency in Sport (REDs). LEA occurs when energy intake is insufficient compared to exercise energy expenditure to meet the body's total energy needs to support essential physiological functions[3]. LEA is the underlying cause of REDs, which is a syndrome associated with adverse health and performance outcomes, including impaired energy metabolism, reproductive dysfunction, poor bone health, and compromised immune function[3]. While LEA, REDs, DE, and ED can occur in isolation, they can also present together, and the combination of these conditions may further suppress physiological function[1,2]. Relatedly, the health consequences of LEA, REDs, DE, and ED can individually or synergistically lead to impaired psychological well-being, increased injury risk, and/or decreased sport performance[3].

Female athletes are less likely to meet their energy needs compared to male athletes and female non-athletes[3–5]. The estimated prevalence of LEA/REDs indicators is 23%–79.5% in female athletes and 15%–70% in male athletes[3]. Additionally, one in five athletes are at risk of EDs, and risk is highest in female athletes[6]. LEA, DE, and ED risk is particularly high in female track and field athletes and may be due to high metabolic and physiological demands of specific event types, poor nutritional knowledge, or misguided intentions to achieve a discipline-specific physique to optimize performance[7]. Additionally, a critical consequence of LEA and REDs in track and field athletes is impaired bone health[3,7]. Individuals with impaired bone health can develop bone stress injuries (BSIs), and this cascade of clinical events can prompt screening for LEA/REDs[8,9]. Common risk factors for BSIs include high training volume or intensity of weight-bearing exercise, low bone mineral density, and menstrual cycle irregularities[2,3,7,10,11]. Women's cross-country and track and field teams experience the first and third highest rate of BSIs per year, respectively, across all collegiate sports[12]. As such, female track and field athletes are an at-risk group for LEA/REDs, and therefore, impaired bone health.

The current methods for calculating energy availability status tend to be difficult to accurately and precisely measure[13]. Additionally, clinically diagnosing ED is not a practical approach for larger, population-based settings as it is time-consuming and requires specialized professional expertise[3,13–15]. Instead, self-reported questionnaires, which can easily be administered to large populations, have been used to assess the symptoms, thoughts, and behaviors related to eating and exercise habits[8,9,16]. Despite the risk of bias commonly associated with self-report methods[16], these questionnaires can be used to screen individuals for LEA while minimizing the logistical and financial challenges, participant burden, and measurement errors[8,13]. The International Olympic Committee currently recommends a three-step process, outlined in the REDs Clinical Assessment Tool V2.0 (REDs CAT2), including: 1) REDs screening using population-based questionnaires, 2) REDs severity/risk assessment evaluated using objective, clinical markers, and 3) REDs clinical diagnosis and treatment plan[8]. Thus, screening for LEA, DE, and ED in female athletes via self-reported methods may aid in early identification and lead to more effective treatment strategies[9].

Previous prevalence studies in female track and field athletes have focused on event-specific populations (e.g., endurance runners), distinct competition levels (e.g., elite female sprinters, Norwegian Olympic athletes), or in other nations outside of the United States (e.g., Spain, United Kingdom)[17–27]. However, the prevalence of LEA, DE, and ED in female track and field athletes, across all event disciplines, in the United States has yet to be established. Therefore, the purpose of this study was to assess the risk of LEA, DE, and ED, and the risk for and number of BSIs, among female track and field athletes in the United States.

Methods

Participants

Female athletes, aged 18 years of age or older, participating in track and field and eligible to compete for the United States, were recruited via email, social media, word of mouth, and at in-person competitions. Data collection was performed online from June 5, 2023, to October 7, 2023. The Institutional Review Board approved this study, and informed consent was obtained online from all participants

Protocol

Participants were invited to complete an anonymous online survey (Qualtrics XM, Provo, UT) consisting of validated screening instruments: the Low Energy Availability in Females Questionnaire (LEAF-Q), the Eating Disorder Examination Questionnaire (EDE-Q 6.0), and the Female Athlete Screening Tool (FAST). Demographic information was self-reported and included age, height, weight, sex, race/ethnicity, birth control use, competition level, primary event, national championship participation, and training history. Body mass index was calculated using self-reported height and weight. Competition level was determined based on their present level of competition: high school, collegiate (i.e., NCAA, NAIA), recreational (i.e., regularly trains with the intent to compete at local level), elite/sub-elite (i.e., highly skilled athlete who competes at a regional or national level), and professional (i.e., signed contract above minimum wage). Participants also reported the number of years spent participating in their primary sport and at their current level of sport participation. To account for different event disciplines, all participants were asked to report current and peak running mileage (number of miles per week) and current and peak active training hours (hours per week), such as lifting and conditioning, during their season to describe training history.

Track and Field Event Groups

Track and field event groups were divided into eight event groups according to primary event group: sprints (100m, 100m hurdles, 200m, 400m, 400m hurdles), jumps (long jump, triple jump, high jump, pole vault), throws (shot put, hammer throw, discus, javelin), multi-event (heptathlon, or two or more different primary event groups), middle distance (800m, 1500m, 3000m, 3km steeplechase), middle distance-long distance (800-10000m), distance (5000-10000m or 5-10K road), and half-marathon/marathon (21.1 km and 42.195 km).

Low Energy Availability Risk

The LEAF-Q is a validated screening tool that identifies female athletes at risk of the physiological symptoms associated with LEA[28]. The LEAF-Q includes 25 questions arranged in three sub-sections: injuries, gastrointestinal, and reproductive function[28]. The suggested LEAF-Q cut-off scores for injury, gastrointestinal disorders, and reproductive function are ≥ 2, ≥ 2, and ≥ 4, respectively[28]. A total score of ≥ 8 out of 25 questions indicates that the participant is at risk of LEA, compared to a total score of < 8 indicates a low risk of LEA[28]. The total LEAF-Q ≥ 8 has previously produced an acceptable sensitivity of 78% and specificity of 90% in female endurance athletes for correctly classifying current energy availability, reproductive function, and/or bone health[28]. The LEAF-Q was selected as it one of the only psychometrically validated screening tools that assesses LEA-related outcomes[16,28] and is recommended for the initial screening of REDs via the REDs CAT2[8].

Eating Disorder/Disordered Eating Risk

The EDE-Q is a validated screening tool to assess DE and clinical ED [8]symptoms in recreational and elite athletes[29]. The EDE-Q V.6.0 consists of 28 items and four subscales: (1) restraint, (2) eating concern, (3) shape concern, and (4) weight concern[29]. Participants report cognitive, psychological, and behavioral DE and ED symptoms experienced in the last month on a Likert scale ranging from 0 to 6[29]. Subscale items are averaged to provide subscale scores, and the EDE-Q global score is calculated by averaging the four subscale scores[29]. An EDE-Q global score of ≥ 2.3 is the standard cut-off score used to categorize high ED risk [29]. The EDE-Q cut-off score has been established as it yielded optimal validity coefficients (sensitivity = 0.83, specificity = 0.96) in a sample of 195 young adult women[30]. The EDE-Q is widely used due to its well-established validation across populations of clinical and non-clinical female populations and its recognized use in the REDs CAT2, which considers the EDE-Q cut-off as an elevated score for EDs in female athletes[8].

The FAST identifies eating pathology and was validated in female collegiate athletes with high internal consistency (Cronbach's $\alpha = 0.87$)[31,32]. Participants rate their agreement or frequency of eating and exercise behaviors on a 4-point Likert scale based on 33 items[31]. The overall FAST score is the sum of all scored items, with items 15, 28, and 32 reverse scored. A score of 74-94 indicates a risk of subclinical DE, while scores >94 may indicate clinical DE[33]. The FAST was designed to be sensitive to the unique thoughts, behaviors, and sport-specific risk factors of eating and exercise in female athletes and was selected for its unique development to identify DE within the female athlete population[31,32].

Bone Stress Injuries

Participants reported the number, location, and date of diagnosed BSIs. The location of the BSI was used to characterize high risk (i.e., femoral neck or total hip, sacrum, pelvis) or low risk (i.e., all other BSI locations)[8]. This approach is in line with the BSI characterization utilized in the REDs CAT2[8]. Athletes who reported no BSIs were categorized with no risk.

Statistical Analysis

A priori power calculation was performed using G*Power based on standard conventions in our field (effect size w = 0.3; α err prob = 0.05; power = 0.95; Df = 3 or 4) for χ^2 goodness-of-fit tests, which determined a total sample size of 191-207 participants as sufficient to yield sufficient statistical power. Data from the Qualtrics survey were transferred to Microsoft Excel V.16.71, and statistical analyses were performed using IBM SPSS Statistics for Macintosh V.29. Descriptives and frequencies of participant demographics and characteristics were analyzed; continuous data were expressed by mean ± standard deviations (SD) and categorical variables were expressed as numbers (n) and percentages (%). Ranges are provided where necessary to aid interpretation (e.g., in groups with low sample sizes). Multiple Chi-square tests of homogeneity were performed to determine: (1) differences in proportions between the level of competition and LEAF-Q, FAST, and EDE-Q risk scores, and (2) differences in proportions between BSI risk and LEAF-Q, FAST, and EDE-Q risk scores. Bonferroni adjustments were applied for multiple Chi-squared tests. All expected counts met the criteria (> 5) for Chi-square analysis with the exception of high school athletes who were excluded from analysis. For interpretation of results from screening questionnaires, the use of cut-off scores to examine proportions based on high and low risk is recommended. However, risk scores can alternatively be evaluated continuously providing further insight into within or across group differences. As such, one-way ANOVA on level of competition and LEAF-Q, FAST, and EDE-Q scores were evaluated and Pearson's bivariate correlations for BSI number and LEAF-Q, FAST, and EDE-Q scores were performed. Alpha level for all analyses was set at 0.05, *a priori*.

Results

Participant Characteristics

Participant demographics and characteristics are displayed in **Table 1**. A total of 521 participants completed the online survey with 28 participants excluded due to age < 18 years (n = 3), not identifying as female or transgender female (n = 1), not a US citizen (n = 1), consented but did not answer any survey questions (n = 25), and participated did not complete the scored portion of the survey for the LEAF-Q, FAST, or EDE-Q (n = 99). Therefore, 392 female participants were included in the final data analysis.

Low Energy Availability, Disordered Eating, and Eating Disorder Risk

The mean LEAF-Q total score was 8.10 ± 4.1 (range: 0-22), with 48.8% of all participants having a LEAF-Q total score ≥ 8, indicating a high risk of LEA. The mean FAST score was 72.52 ± 16.14 (range: 41-115), and 47.56% of participants were characterized as at high risk of DE with 35.29% scoring between 74-94 and 12.27% scoring >94. Overall, the mean EDE-Q global score was 1.35 ± 1.22 (range: 0.0-5.6) and 22.23% of all participants had an EDE-Q global score ≥ 2.3, indicating a high risk of ED. Total and subscales scores for LEAF-Q, FAST, and EDE-Q scores are presented in **Supplementary Table S1** based on competition level.

The mean LEAF-Q scores for collegiate female track and field athletes were above the suggested cut-off scores for total LEAF-Q score (9.37 ± 4.14), and all LEAF-Q sub-scales (injury: 2.08 ± 1.60, gastrointestinal function: 2.88 ± 2.16, reproductive function: 4.41 ± 2.84), and FAST scores for collegiate athletes (76.15 ± 16.85) were also above the cut-off score. Mean EDE-Q global (1.62 ± 1.38) and EDE-Q sub-scale scores for restraint (1.26 ± 1.40), eating concern (1.34 ± 1.40), shape concern (2.01 ± 1.62), and weight concern (1.88 ± 1.57) were below the suggested cut-off score in collegiate athletes.

For recreational athletes, mean LEAF-Q total (8.04 ± 3.96) and LEAF-Q gastrointestinal function sub-scale score (2.87 ± 2.14) were above the suggested cut-off scores, but LEAF-Q sub-scales for injury (1.43 ± 1.27) and reproductive function (3.74 ± 2.71) were not. All scores for LEAF-Q total (7.65 ± 4.23) and LEAF-Q sub-scales of injury (1.67 ± 1.43) and reproductive function (3.56 ± 2.83), FAST (69.73 ± 14.33), and EDE-Q global (1.10 ± 1.05) and EDE-Q sub-scales for restraint (0.83 ± 1.12), eating concern (0.78 ± 1.09), shape concern (1.58 ± 1.36), and weight concern (1.22 ± 1.24) were below the suggested cut-off, with the exception of LEAF-Q gastrointestinal function sub-scale (2.42 ± 1.94) in sub-elite/elite athletes.

For professional athletes, mean scores for LEAF-Q total (6.39 ± 3.60) and LEAF-Q sub-scales (injury: 1.50 ± 1.10, gastrointestinal function: 1.33 ± 1.68, reproductive function: 3.56 ± 2.85), FAST (63.50 ± 14.67), and EDE-Q global (0.68 ± 0.85) and EDE-Q sub-scales (restraint: 0.50 ± 1.30, eating concern: 0.39 ± 0.87, shape concern: 0.90 ± 0.69, weight concern: 0.92 ± 0.88) were all below the suggested cut-off scores.

Results from a one-way ANOVA based on competition level and continuous risk assessment scores on the LEAF-Q, FAST, and EDE-Q, as well as Pearson's bivariate correlation for BSI number and LEAF-Q, FAST, and EDE-Q scores are provided in the Supplementary Materials. Overall, analyzing the data as categorical versus continuous does not change the general interpretation of current findings presented below.

Table 1. Participant demographics.

Characteristics	Total Sample	Collegiate	Recreational	Sub-elite/Elite	Professional
Age, M ± SD	29.03 ± 8.18	20.68 ± 1.77	32.47 ± 8.95	29.77 ± 5.29	26.94 ± 3.19
Sex, n (%)					
Female	389 (99.2%)	72 (98.6%)	182 (99.5%)	113 (100%)	18 (100%)
Non-binary	3 (0.8%)	1 (1.4%)	1 (0.5%)	0 (0%)	0 (0%)
Race/Ethnicity, n (%)					
Caucasian	345 (88.7%)	63 (87.5)	165 (90.2%)	96 (85.7%)	17 (94.4%)
African American	12 (3.1%)	5 (6.9%)	2 (1.1%)	4 (3.6%)	1 (5.6%)
Asian or Asian American	13 (3.3%)	1 (1.4%)	8 (4.4%)	4 (3.6%)	-
Hispanic or Latino	2 (2.8%)	4 (2.2%)	5 (4.5%)	-	-
Indian American	1 (0.3%)	-	1 (0.5%)	-	-
Arab	1 (0.3%)	-	1 (0.5%)		-
Mixed race	4 (1.0%)	1 (1.4%)	1 (0.5%)	2 (1.8%)	-
Prefer not to answer	2 (0.5%)	-	1 (0.5%)	1 (0.9%)	-
BSI incidence, n (%)					
High risk	49 (12.5%)	9 (12.3%)	13 (7.1%)	20 (17.7%)	7 (38.9%)
Low risk	130 (33.2%)	30 (41.1%)	55 (30.1%)	39 (34.5%)	3 (16.7%)
No risk	213 (54.3%)	34 (46.6%)	115 (62.8%)	54 (47.8%)	8 (44.4%)
Competition Level, n (%)					
Collegiate	73 (18.7%)	73 (100%)	-	-	-
Recreational	183 (46.7%)	-	183 (100%)	-	-
Sub-elite/Elite	113 (28.8%)	-	-	113 (100%)	-
Professional	18 (4.6%)	-	-	-	18 (100%)
Primary Sport, n (%)					
Throws	6 (1.5%)	4 (5.5%)	0 (0%)	2 (1.8%)	0 (0%)
Jumps	2 (0.5%)	1 (1.4%)	0 (0%)	1 (0.9%)	0 (0%)
Sprints	4 (1.0%)	4 (5.5%)	0 (0%)	0 (0%)	0 (0%)
Middle distance	25 (6.4%)	10 (13.7%)	4 (2.2%)	5 (4.4%)	5 (27.8%)
Middle distance-distance	51 (13.0%)	19 (26.0%)	11 (6.0%)	14 (12.4%)	5 (27.8%)
Distance	108 (27.6%)	30 (41.1%)	41 (22.5%)	31 (27.4%)	5 (27.8%)
Half/Full Marathon	186 (47.4%)	2 (2.7%)	123 (67.6%)	58 (51.3%)	3 (16.7%)
Multis or Combination	9 (2.3%)	3 (4.1%)	3 (1.6%)	2 (1.8%)	0 (0%)
Current Birth Control Method, n (%)					
No (or N/A)	220 (59.6%)	50 (66.0%)	92 (50.6%)	62 (54.9%)	14 (77.8%)
OCP	77 (19.7%)	14 (19.2%)	45 (24.6%)	17 (15.0%)	1 (5.6%)
IUD	32 (8.2%)	1 (1.4%)	14 (7.7%)	14 (12.4%)	3 (16.7%)
Hormonal Implant	52 (13.3%)	6 (8.2%)	27 (14.8%)	19 (16.8%)	-
Hormonal Patch	3 (0.8%)	2 (2.7%)	1 (0.5%)	-	-
Hormonal ring	2 (0.5%)	-	1 (0.5%)	1 (0.9%)	-
HRT	1 (0.3%)	-	1 (0.5%)	-	-
Years in Primary Sport, M ± SD	12.83 ± 7.26	8.31 ± 2.86	14.52 ± 8.49	13.47 ± 5.96	12.00 ± 4.37
Weight (kg), M ± SD	58.68 ± 8.92	58.31 ± 8.55	60.35 ± 8.43	56.51 ± 6.67	57.32 ± 7.64
Height (m), M ± SD	1.66 ± 0.07	1.66 ± 0.06	1.66 ± 0.07	1.65 ± 0.07	1.68 ± 0.07
BMI (kg/m^2), M ± SD	21.29 ± 2.73	21.01 ± 2.44	21.95 ± 2.67	20.58 ± 2.64	20.41 ± 3.61
Average mileage (miles/week), M ± SD	46.87 ± 19.11	48.13 ± 14.43	36.85 ± 13.65	59.91 ± 18.97	66.25 ± 19.60
Peak mileage (miles/week), M ± SD	58.15 ± 21.08	55.85 ± 14.47	49.07 ± 15.67	71.59 ± 22.24	78.22 ± 25.42
Average training hours (hours/week), M ± SD	10.43 ± 4.80	12.12 ± 5.60	8.90 ± 4.04	11.37 ± 4.76	13.69 ± 3.87
Peak training hours (hours/week), M ± SD	13.12 ± 6.13	13.83 ± 6.55	12.18 ± 6.01	13.77 ± 5.99	16.31 ± 4.97

Data are presented as M ± SD and n (%). Bone stress injury (BSI).

Chi-Squared Tests of Homogeneity Based on Risk

There was a statistically significant difference in proportions based on level of competition and LEA risk (X^2 (3, 387) = 11.93, p = 0.008, Φ= 0.176) and ED/DE risk based on the FAST (X^2 (3, 387) = 11.65, p = 0.007, Φ= 0.213) (Table 2). There were no significant differences in proportions based on competition level and ED risk, according to EDE-Q scores (X^2 (3, 387) = 6.39, p = 0.094, Φ= 0.129) (Table 2).

Table 2. Level of competition on risk for LEA and ED/DE in female track and field athletes.

Level of Competition	**LEAF-Q Low Risk** *n (% within risk)*	**LEAF-Q High Risk** *n (% within risk)*	***p*-value**
Collegiate	27 (13.6%)	46 (24.3%)	0.008
Recreational	94 (47.5%)	89 (47.1%)	
Sub-elite/Elite	63 (31.8%)	50 (26.5%)	
Professional	14 (7.1%)	4 (2.1%)	
Level of Competition	FAST Low Risk *n (% within risk)*	FAST High Risk *n (% within risk)*	*p*-value
Collegiate	30 (14.8%)	43 (23.4%)	0.007
Recreational	91 (44.8%)	92 (50.0%)	
Sub-elite/Elite	68 (33.5%)	45 (24.5%)	
Professional	14 (6.9%)	4 (2.2%)	
Level of Competition	EDE-Q Low Risk *n (% within risk)*	EDE-Q High Risk *n (% within risk)*	*p*-value
Collegiate	52 (17.3%)	21 (24.4%)	0.094
Recreational	139 (46.2%)	44 (51.2%)	
Sub-elite/Elite	93 (30.9%)	20 (23.3%)	
Professional	17 (5.6%)	1 (1.2%)	

Data are presented as n (%). High school athletes excluded. Low Energy Availability in Females Questionnaire (LEAF-Q) was used to determine low energy availability (LEA) risk; Female Athlete Screening Tool (FAST) was used to determine disordered eating (DE) risk; Eating Disorder Examination Questionnaire (EDE-Q) was used to determine eating disorder (ED) risk. High risk for LEA was defined as LEAF-Q total score ≥ 8, high risk for ED/DE based on FAST was defined as FAST > 74, and high risk for ED was defined as EDE-Q ≥ 2.3.

Based on BSI incidence, 12.5% of participants were classified as high risk, 33.2% were classified as low risk, and 54.3% were classified as no risk (Table 1). There was a statistically significant difference in proportions based on BSI risk and LEA risk (X^2 (2, 392) = 8.58, p = 0.014, Φ= 0.148), indicating that athletes with high LEA risk had significantly greater incidence of both low- and high risk BSIs compared to the athletes with low LEA risk (56.2% vs. 43.8% low risk BSI and 59.2% vs. 40.8% high risk BSI) (Table 3). There were no significant differences in proportions based on BSI risk and risk categorization according to FAST (X^2 (2, 392) = 0.891, p = 0.467. Φ= 0.095) and EDE-Q (X^2 (2, 392) = 1.77, p = 0.413, Φ= 0.067) (Table 3).

Table 3. BSI risk based on risk for LEA and ED/DE in female track and field athletes.

Measure	**No Risk BSI** *n (% within BSI risk)*	**Low Risk BSI** *n (% within BSI risk)*	**High Risk BSI** *n (% within BSI risk)*	***p*-value**
LEAF-Q				
Low Risk	123 (57.7%)	57 (43.8%)	20 (40.8%)	0.014
High Risk	90 (42.3%)	73 (56.2%)	29 (59.2%)	
FAST				
Low Risk	116 (54.5%)	64 (49.2%)	26 (53.1%)	0.467
High Risk	97 (45.5%)	66 (50.8%)	23 (46.9%)	
EDE-Q				
Low Risk	170 (79.8%)	96 (73.8%)	39 (79.6%)	0.413
High Risk	43 (20.2%)	34 (26.2%)	10 (20.4%)	

Data are presented as n (%). Bone stress injury (BSI); Low Energy Availability in Females Questionnaire (LEAF-Q) was used to determine low energy availability (LEA) risk; Low Energy Availability in Females Questionnaire (LEAF-Q) was used to determine low energy availability (LEA) risk; Female Athlete Screening Tool (FAST) was used to determine disordered eating (DE) risk; Eating Disorder Examination Questionnaire (EDE-Q) was used to determine eating disorder (ED) risk. High risk for LEA was defined as LEAF-Q total score ≥ 8, high risk for ED/DE based on FAST was defined as FAST > 74, and high risk for ED was defined as EDE-Q ≥ 2.3.

Occurrence and Coexistence of Risk of Low Energy Availability, Disordered Eating, and Eating Disorder

Across the whole sample, 260 participants (66.33%) were identified as high risk for LEA, DE, and/or ED. The percentage of athletes who were at high risk for LEA via LEAF-Q and ED/DE via FAST was 17.31% (45 out of 260 participants). The percentage of athletes who scored high risk for LEA via LEAF-Q and ED via EDE-Q was 1.54% (4 out of 260 participants). The percentage of athletes who were at risk for ED/DE via FAST and EDE-Q was 14 participants (5.38%). Sixty-nine of all at-risk participants (26.54%) had concurrent risk for LEA, DE, and ED, based on high risk scores on all three risk assessment questionnaires. The occurrence and coexistence of LEA, DE, and/or ED risk among our sample is illustrated in Figure 1.

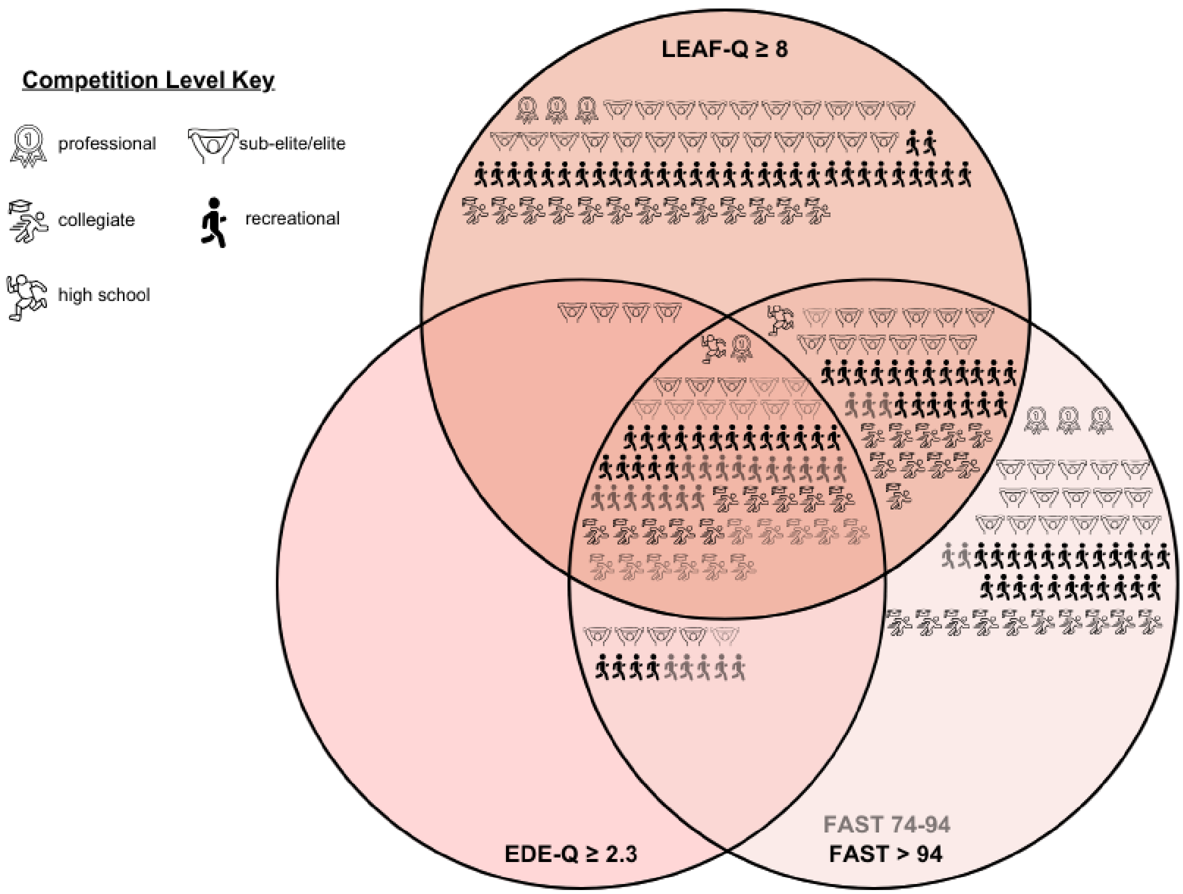

Figure 1. Occurrence and coexistence of risk of low energy availability (LEA), disordered eating (DE), and eating disorders (ED) in United States track and field athletes. Icons indicate athletes' track and field competition level: high school, recreational, collegiate, sub-elite/elite, and professional. Of all participants (n = 392), 260 participants (66.33%) screened high risk for LEA, DE, and/or ED. Of participants at high risk (n = 260), 45 participants (17.31%) were at high risk for LEA via LEAF-Q and ED/DE via FAST, 4 participants (1.54%) were at high risk for LEA via LEAF-Q and ED via EDE-Q, and 14 participants (5.38%) were at risk for ED/DE via FAST and EDE-Q. Sixty-nine of all at-risk participants (26.54%) had concurrent risk for LEA, DE, and ED, based on high risk scores on all three risk assessment questionnaires. Low Energy Availability in Females Questionnaire (LEAF-Q), Female Athlete Screening Tool (FAST), Eating Disorder Examination Questionnaire (EDE-Q).

Discussion

The present study assessed the risk of LEA, DE, and ED, as well as BSI, among female track and field athletes in the United States across a range of competition levels. Using the LEAF-Q, FAST, and EDE-Q allowed for a comprehensive approach to investigate the prevalence of these conditions (LEA, DE, and ED) concurrently. Notably, these data show that ~27% of the sample report concurrent risk for LEA, DE and ED. Findings further illustrate that LEA, DE, and ED risk, as well as BSIs are common in female track and field athletes, with collegiate athletes demonstrating highest risk.

Low Energy Availability, Disordered Eating, and Eating Disorder Risk

Previous studies have assessed LEA, DE, or ED risk in track and field populations from Norway, Canada, Spain, Netherlands, and other countries[33–38]. Specifically, high risk estimates in previous work ranged from 19–65%, 32–60%, 18–21% of athletes based on the LEAF-Q, FAST, and EDE-Q respectively[33–35,39,40]. These estimates are comparable to our current findings of LEA via LEAF-Q (49%), ED/DE via FAST (47%), and ED via EDE-Q (22%). A number of these studies have targeted a specific event groups within track and field (e.g., distance runners) but failed to consider all track and field event groups in one study design and most utilized a singular screening tool for LEA, DE, or ED[33–38,41]. Our study reported a similar risk of LEA, DE, and ED in United States female track and field athletes as previous work examining track and field athletes in event-specific disciplines, distinct competition levels, or in other populations from other countries[33–35,39,40]. Sygo et al. (2018) found that the prevalence of LEA and LEA secondary indicators in elite Canadian female sprinters was 31%, which is less than the 49% of female track and field athletes (inclusive of sprinters, throwers, jumpers, middle, and long-distance runners) at risk in the current study. The differences reported between the two studies highlight a future need to assess event group differences amongst female track and field athletes. These athletes were followed across a 5-month indoor training period and found that LEA prevalence increased to 54% in athletes. Further, of those who presented with LEA indicators at the start of the season, 75% persisted with LEA indicators at post-season[36]. Regular screening and longitudinal monitoring of LEA, DE, and ED are important strategies in maintaining optimal health and performance in female athletes.

To date, few studies have assessed the concurrent risk of LEA, DE, and ED. Karlsson et al. (2023) demonstrated that 13% of recreational active female runners had concurrent risk of LEA and ED, defined by scoring high risk on 2 or more questionnaires[7]. The current sample demonstrated a greater overlap (~27%) between LEA, DE, and ED risk, using all three measures (i.e., LEAF-Q, FAST, EDE-Q). Our sample may have demonstrated higher concurrent risk due to the inclusion of several competition levels and track and field event groups, as opposed to just recreational runners[7], which were only a subset of the total participant sample.

Risk of Bone Stress Injuries

Nearly half of the participants reported a previous history of low or high risk BSIs. This is higher than the number of BSIs previously reported in track and field athletes. However, the differences in number of BSIs may be a result of the current female-only sample and collecting lifetime prevalence of BSIs, as opposed to one year prevalence[42]. As athletes with high LEA risk had a greater incidence of BSIs, compared to athletes with low LEA risk, screening for LEA, DE, and ED should follow a BSI diagnosis, as impaired bone health and BSIs are well-known consequences of LEA.

Level of Competition

There is an ongoing discourse about whether sport participation is a protective factor or risk factor for LEA, DE, and ED across sport types[17–27]. Studies conducted in elite athletes and non-athletes demonstrate that elite athletes are generally at lower risk for LEA and ED, but the presence of LEA-related factors varies by population[19,20]. For example, elite athletes were more likely to report menstrual irregularities and BSIs than non-athlete controls[19]. In the present study of only female track and field athletes, professional athletes were at the lowest risk for LEA, DE, and ED, compared to other competition levels. Alternatively, collegiate athletes seem to be at increased risk for LEA, DE, and ED, which may be due to heightened pressure from teammates and coaches, body dissatisfaction, and demanding schedules, which was also reflected in our current sample[7,43,44]. Though not directly explored in the present study, collegiate athletes face many unique barriers and challenges to meeting sport-specific nutritional recommendations, such as financial restrictions, lack of time, poor access to food options, insufficient cooking spaces, and others, which may not need to be considered at other competition levels[45]. Recreational female runners typically have lower training loads and goals unrelated to competitive sport performance, but LEA risk remains high in the sample included here[27,46]. Studies in mixed sport cohorts have reported higher ED risk in elite athletes, compared to recreational athletes[47,48]. However, elite athletes also reported no differences in EDs and menstrual irregularities, compared to controls[21]. Interestingly, Palermo et al. (2019) illustrated a mismatch between athletic identity and competition level as a risk factor for DE[17], supporting the notion that athletes who experience pressure to improve performance are more susceptible to the development of DE. A mismatch between athletic identity and competition level may help explain the lack of uniform results across different levels of competition and should be a point of emphasis in future research.

Screening Protocols

As LEA, DE, and ED can occur in isolation or concurrently, screening should account for differences in these conditions and administration of multiple screening questionnaires should be considered, if possible, to address the spectrum of eating behaviors. The LEAF-Q appears to be the most sensitive in detecting pathological eating and exercise behaviors of the three questionnaires in this sample of female track and field athletes. Further, the FAST detected more ED/DE cases compared to the EDE-Q. As such, priority should be given to the LEAF-Q when assessing LEA risk and the FAST to detect ED/DE risk in female track and field athletes. Regardless of screening tool, it is important to decipher the underlying cause of LEA, DE, and ED in future work, as the presentation and identification of conditions can vary. Comprehensive screening protocols should address all possible causes of pathological eating and exercise behaviors and other female athlete specific health concerns[2]. Consequently, there is a need to improve screening protocols to provide support and address risk factors experienced by female athletes[3,9]. A framework for female athlete health considerations in preparticipation examinations has been proposed by Schulz et al. (2024), including essential components related to REDs, menstruation and contraception, and nutrition/eating behaviors[49].

Screening protocols are needed to assist in the recognition of signs and symptoms of LEA, DE, and ED. The REDs CAT2 aids in the evaluation of athletes suspected of LEA and REDs via a three-step model including: (1) REDs screening via risk assessment questionnaires, (2) assessment of objective REDs measures for risk stratification, and (3) clinical diagnosis and treatment of REDs. While screening questionnaires can have lower sensitivity and specificity to assess complex multifactorial conditions (i.e., LEA, DE, ED), questionnaires are inexpensive, easy to use, and allow for identification of risk in large athlete samples. However, inconsistencies in validation processes and lack of key psychometric properties explored can lead to errors in reporting and over- or under-estimation of risk. The questionnaires in the present design were selected for their validation processes in female athletes and wide use within this population and questionnaires provide support for use of cut-off in identifying at risk individual (e.g., discriminant validity)[28,30,50,51]. Selection of screening questionnaires should be determined based on the development of the original tool, the outcome of interest, and its utility in the target population.

Strengths and Limitations

A major strength of the present study was the inclusion of US female track and field athletes at multiple levels of competition and several event groups, which provided original insights into the risks of LEA, DE, and EDs among this population. However, we were unable to examine differences in event groups due to non-homogenous sample sizes across groups, and in some cases of event group, very small sample sizes, which is an important consideration for future research. Additionally, the combined approach of multiple self-reported questionnaires recommended by the REDs CAT2 provided insight into which questionnaire may be most useful in this population. While it is a strength of our study that the sample population includes United States athletes, this may also limit generalizability of study findings to track and field athletes in other nations. Future research should aim to recruit a more diverse sample of track and field athletes representing equal sample sizes across all event groups to explore event-specific risk factors of LEA, DE, or ED.

Due to the cross-sectional design of the study, it is not possible to determine causal relationships, and the results are limited to estimations of risk. There is a possibility that estimates of LEA, DE, and ED risk are over-reported due to selection bias, but also a possibility that participants under-reported due to fear of being held out of sport, inability to recognize maladaptive behaviors, and/or social desirability bias. Self-reported measures (i.e., weight, height) may have also introduced response bias to outcomes of interest. High school athletes were excluded from Chi-squared tests based on participant's level of competition, due to the small sample size (n = 4), which limits our understanding of LEA, DE, and ED risk in high school athletes. Participants had to be 18 years of age or older in order to participate in the study, which may explain the low number of high school athletes. Further exploration of the risk of LEA, DE, and ED using updated REDs screening protocols via the REDs CAT2 is warranted in this population[8]. Future work should consider development of more psychometrically robust screening questionnaires given the importance of risk assessment tools in the recognition and assessment of these conditions across various levels of competition and sport types. It is also recommended to continue to assess LEA, DE, and ED risk over time to improve screening and identification of at-risk athletes.

Conclusions

The risk of LEA, DE, and ED remains an ongoing health issue in female athletes, persisting across sport types and levels of competition and across the globe. Findings from this study suggest that risk of LEA, DE, and ED are frequent among United States female track and field athletes, across all competition levels and that collegiate athletes may be at highest risk for LEA and ED. Early detection of LEA, DE, and EDs is crucial for implementing the appropriate multidisciplinary care team, including medical, nutritional, and psychological support to assist athletes in making positive dietary behavior changes. The findings of this study highlight the important use of validated screening tools as an easy-to-administer, brief, and inexpensive method for assessing LEA, DE, and ED risk. Additional work is needed to evaluate LEA, DE, and ED risk across competitive seasons and throughout an athlete's career. Finally, national governing bodies should prioritize screening for LEA, DE, and ED for athletes to improve the recognition of signs and symptoms, which may reduce the risk of adverse health and performance outcomes in female track and field athletes.

Conflict of Interest: The authors have no conflicts of interest to report.

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Supplementary Materials

Alternative Statistical Approach

The alternative statistical approach included a one-way ANOVA based on competition level and risk assessment scores for LEAF-Q, FAST and EDE-Q and Pearson's bivariate correlation for BSI number and risk assessment scores for LEAF-Q, FAST and EDE-Q.

The one-way ANOVA on level of competition and LEAF-Q scores was significant ($F(3,383) = 3.933$, $p = 0.009$, $\eta^2 = 0.030$) (Supplementary Table 1). College athletes scored significantly higher on the LEAF-Q (9.37 ± 4.14) than sub-elite/elite athletes (7.65 ± 4.23) ($p = 0.030$), as well as professional athletes (6.39 ± 3.60) ($p = 0.033$). Similarly, the one-way ANOVA on level of competition and FAST scores was significant ($F(3,383) = 4.664$, $p = 0.003$, $\eta^2 = 0.035$). College athletes scored significantly higher on the FAST (73.64 ± 16.85) than sub-elite/elite athletes (69.73 ± 14.33) ($p = 0.037$), as well as professional athletes (63.50 ± 14.67) ($p = 0.014$). Lastly, one-way ANOVA on level of competition and EDE-Q scores was significant ($F(3,383) = 5.297$, $p = 0.001$, $\eta^2 = 0.040$). College athletes scored significantly higher on the EDE-Q (1.62 ± 1.38) than sub-elite/elite athletes (1.10 ± 1.05) ($p = 0.025$), as well as professional athletes (0.68 ± 0.85) ($p = 0.018$). Then, a bivariate correlation demonstrated that BSI number and LEAF-Q score was statistically significant ($r = 0.145$, $p = 0.002$) (Supplementary Figure 1). There were no statistically significant differences between BSI number and FAST score or EDE-Q score.

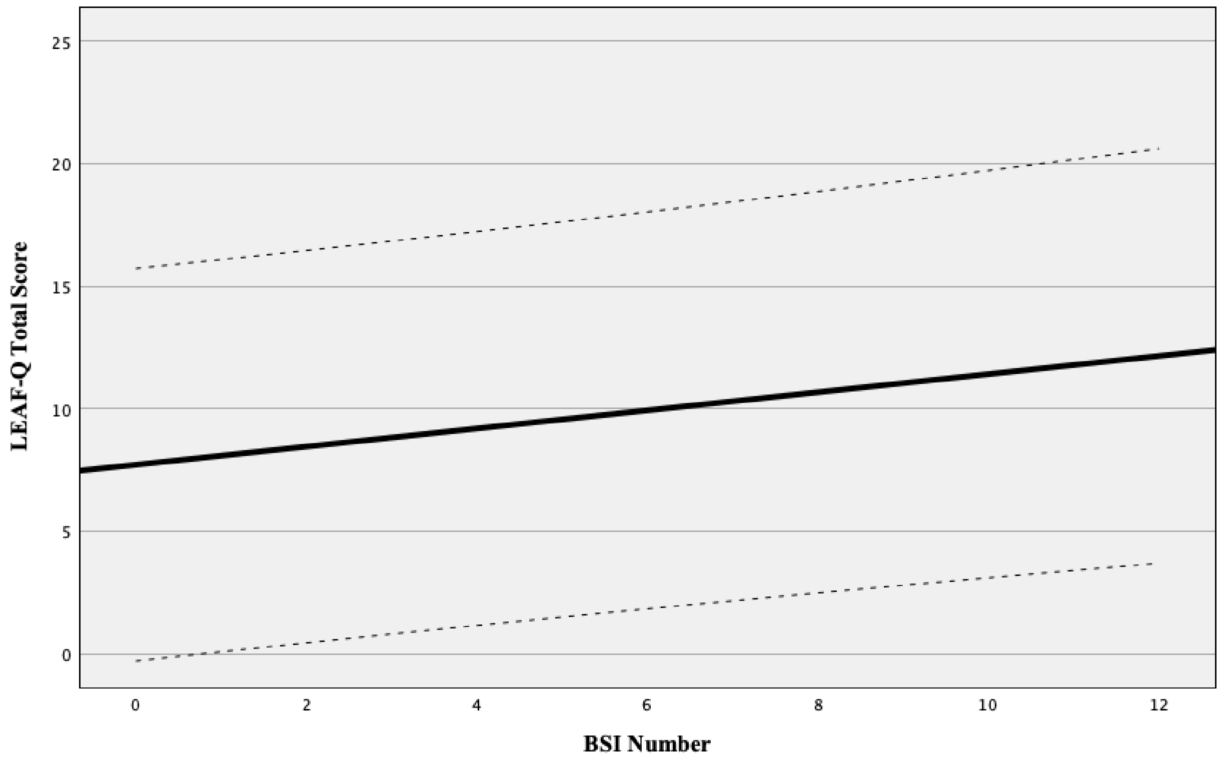
Supplementary Table 1. LEAF-Q, FAST, and EDE-Q scores based on athletes' level of competition.

Measure	Collegiate *m*(SD)	Recreational *m*(SD)	Sub-Elite/Elite *m*(SD)	Professional *m*(SD)
LEAF-Q				
Injury	2.08(1.60)*	1.43(1.27)	1.67(1.43)	1.50(1.10)
Gastrointestinal	2.88(2.16)*	2.87(2.14)*	2.42(1.94)*	1.33(1.68)
Reproductive	4.41(2.84)*	3.74(2.71)	3.56(2.83)	3.56(2.85)
Total	9.37(4.14)*	8.04(3.96)*	7.65(4.23)	6.39(3.60)
FAST	76.15(16.85)*	73.64(16.53)	69.73(14.33)	63.50(14.67)
EDE-Q				
Restraint	1.26(1.40)	1.13(1.27)	0.83(1.12)	0.50(1.30)
Eating Concern	1.34(1.40)	0.93(1.15)	0.78(1.09)	0.39(0.87)
Shape Concern	2.01(1.62)	2.02(1.59)	1.58(1.36)	0.90(0.69)
Weight Concern	1.88(1.57)	1.77(1.51)	1.22(1.24)	0.92(0.88)
Global	1.62(1.38)	1.47(1.24)	1.10(1.05)	0.68(0.85)

A one-way ANOVA was performed based on competition level and continuous scores on the LEAF-Q, FAST, and EDE-Q. Data are presented as mean (SD) for normally distributed data. *LEAF-Q, Low Energy Availability in Females Questionnaire; FAST, Female Athlete Screening Tool; EDE-Q, Eating Disorder Examination Questionnaire.*

*Score is above previously established cut-offs. The suggested LEAF-Q cut-off scores for injury, gastrointestinal function, and reproductive function are ≥ 2, ≥ 2, and ≥ 4 and LEAF-Q total ≥ 8. A suggested score of 74-94 on the FAST has been used to indicate risk of subclinical DE, while a score >94 may indicate risk of clinical DE. The suggested cut-off scores for EDE-Q sub-scales and global scores are ≥ 2.3.

Supplementary Figure 1. Association between BSI number and scores on the LEAF-Q.



Pearson's bivariate correlation between BSI number and LEAF-Q total score. Line of best (solid line), with error bars (dashed line). *LEAF-Q, Low Energy Availability in Females Questionnaire; BSI, bone stress injury.*