Journal of Women's Sports Medicine

The Association of Low Energy Availability Knowledge and Risk in Female Track and Field Athletes

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BACKGROUND: Under fueling is associated with a number of negative health and performance consequences, and strategies are needed to improve outcomes. Few studies have explored the associations among LEA knowledge and risk of low energy availability (LEA) conditions (i.e., Relative Energy Deficiency in Sport (REDs), eating disorder/disordered eating (ED/DE)). The purpose of this study was to examine associations between LEA knowledge and LEA and ED/DE risk.
METHODS: Female track and field athletes (n = 368) completed an anonymous online survey consisting of demographic information, Low Energy Availability in Females Questionnaire (LEAF-Q), Female Athlete Screening Tool (FAST), Eating Disorder Examination Questionnaire (EDE-Q)], and LEA knowledge (LEA-KQ). A one-way ANOVA examined differences between LEA-KQ scores and low- vs. high-risk groups for LEA, DE, and ED. Pearson's partial correlations, controlled for bone stress injury (BSI) and peak training mileage, were used to assess associations between LEA-KQ and LEAF-Q, FAST, and EDE-Q scores.
RESULTS: Of the total sample (n = 368; age 29 ± 8 years), 49% were at high risk for LEA based on the LEAF-Q, 35% were at subclinical DE risk and 13% were at clinical ED risk based on the FAST. Scores on the EDE-Q demonstrated 22% of the sample were at high risk for ED. There was a significant difference in mean LEA-KQ scores in athletes at risk for DE based on the FAST [F (2, 365) = 4.078, $p = 0.018$, $\eta = 0.022$]. There were no significant associations between LEA-KQ and LEAF-Q, FAST, and EDE-Q ($p = 0.534$, $p = 0.051$, and $p = 0.934$, respectively) while controlling for BSI and peak weekly mileage.
CONCLUSION: There was no significant association between LEA knowledge and risk. This warrants further exploration, as it is important to understand the direction of the relationship to employ effective education-based programs to prevent the negative health and performance consequences associated with under fueling.

INTRODUCTION

Energy intake must meet the energy demand of athletes training and competition to support the body's essential functions and maintain optimal health and performance.[1] Failure to meet energy intake requirements can result in low energy availability (LEA), a condition defined as a mismatch between energy intake and exercise energy expenditure, results in the body's total energy needs being unmet[1,2]. Conditions, such as the Female Athlete Triad (Triad) and Relative Energy Deficiency in Sport (REDs), are caused by exposure to LEA.[1,2] The Triad is a medical condition that involves LEA (with or without disordered eating (DE)), menstrual dysfunction, and low bone mineral density, while REDs is a syndrome of impaired physiological and/or psychological functioning that results in disruption to a variety of body systems (i.e., bone health, reproductive function, energy metabolism, immunity, etc.).[1,2] The level of dysfunction associated with LEA can worsen along the spectrum of eating behaviors from optimal nutrition to eating disorders (ED), with poorer physiological function being related to higher risk pathological eating behaviors.[1,3] Notably, pathological eating behaviors are more prevalent among female athletes compared to male athletes and female non-athletes.[1,4]

Interventions to reduce the risk of LEA-related conditions are of interest to the athletic community.

DOI: 10.53646/e3rijh65
Published online: September 3, 2025

A long-standing recommendation for LEA prevention is sport nutrition and REDs-related education, as highlighted in the first position statement on the Triad by the American College of Sports Medicine, and most recently in the International Olympic Committee's consensus statement on REDs.[1,2,5] To support these recommendations, the goal of primary and secondary prevention strategies is to (i) tackle inadequate knowledge of sports nutrition, (ii) advance athletes' understanding of the associated health and performance outcomes related to REDs, and (iii) improve early screening and identification of REDs in at-risk athletes.[5]

The need for widespread education on these topics has been further supported by findings suggesting that athletes with improved sports nutrition knowledge are more likely to achieve nutrition recommendations for overall energy and macronutrient intake.[6] Other work has attempted to examine the strength of the association between sports nutrition knowledge and its influence on LEA outcomes, eating behaviors and/or fueling decisions in athletes.[7–14] Results of this work are equivocal, as some studies found that that female athletes at greater risk for LEA may have higher sports nutrition knowledge, while others found that female athletes at greater risk for LEA have poorer sports nutrition knowledge, and more have shown no relationship between LEA outcomes and sports nutrition knowledge.[7-13] These contradictory findings may suggest that some female athletes at risk of LEA may seek out information related to sports nutrition due to misguided attempts to control food intake or body composition, while other female athletes at risk of LEA may be inadvertently under fueling due to a lack of sports nutrition knowledge.[15,16] Challenges in interpreting this literature may be due to the fact that a majority of these studies are cross-sectional, thus the underlying direction of the association between LEA knowledge and risk to support these findings are still needed. Previous findings has primarily focused on sports nutrition knowledge, rather than LEA knowledge, which may further influence athlete's eating behaviors and risk for LEA-related pathology.[7–12,14]

Therefore, the primary aim of this study was to assess the association between LEA knowledge and LEA risk and ED/DE risk. Based on previous work examining sports nutrition knowledge and LEA risk, we hypothesize that athletes at higher risk for LEA and ED/DE will have lower LEA-related knowledge.

METHODS

Patient Cohort

Female track and field athletes across all event groups (18-68 years) eligible to compete for the United States in international competitions were recruited via email, social media, word of mouth, and at in-person competitions. Participants were invited to complete an anonymous online survey via Qualtrics XM (Provo, UT). Participant information and LEA knowledge were collected along with responses to validated risk assessment tools: Low Energy Availability in Females Questionnaire (LEAF-Q), Female Athlete Screening Tool (FAST), and Eating Disorder Examination Questionnaire (EDE-Q 6.0).[17-19] Data collection occurred from June 5, 2023, to October 7, 2023. Online informed consent was obtained from all participants prior to study participation, and the University Institutional Review Board approved this study.

Participant Information

Participant information (e.g., sex, age, race/ethnicity, academic area of study, competition level, primary event(s), United States of America Track and Field (USATF) National championship participation) was collected via self-report. Participants reported the number of years spent in their primary event (i.e., sprints, jumps, throws, multi-event, middle distance, distance, half-marathon and marathon) and at their current competition level (i.e., high school, collegiate, recreational, sub-elite/elite, professional). USATF National championship participation was classified based on the number of indoor and outdoor track and field championships a participant had reportedly competed in. Training history was described based on current and peak training hours (hours per week) and current and peak running mileage (number of miles per week) during their season. Additionally, participants reported the number, location, and date of previously diagnosed bone stress injuries (BSIs). The REDs CAT2 categorizes BSIs as high risk (i.e., femoral neck or total hip, sacrum, pelvis) or low risk (i.e., all other bone stress injury locations) based on reported location.[20] However, in the broader sports medicine community, there are several other important high-risk sites to consider, particularly in runners, including the navicular, talus, fifth metatarsal,

DOI: 10.53646/e3rijh65
Published online: September 3, 2025

anterior tibia, medial malleolus, and sesamoid.[21] Therefore, for the purposes of this study, BSI was simply categorized as total number of BSI.

LEA Risk

The Low Energy Availability in Females Questionnaire (LEAF-Q) is a screening tool designed to assist with early detection and intervention of female athletes "at risk" of the physiological symptoms associated with LEA.[17] The LEAF-Q includes 25 questions arranged in three sub-sections: (1) injuries, (2) gastrointestinal function, and (3) reproductive function.[17] The suggested LEAF-Q subscale cut-offs for injuries, gastrointestinal function, and reproductive function are ≥ 2, ≥ 2, and ≥ 4, respectively.[17] A total LEAF-Q score of ≥ 8 out of 25 questions indicates the individual is at risk of LEA.[17] Previous work has shown that a total LEAF-Q ≥ 8 is associated with a sensitivity of 78% and specificity of 90% in female athletes for correctly classifying current EA, reproductive function, and/or bone health.[17] The LEAF-Q has reported internal consistency in elite female endurance athletes ($\alpha = 0.71$), with each subscale demonstrating internal consistency: injuries ($\alpha = 0.79$), gastrointestinal function ($\alpha = 0.75$), and reproductive function ($\alpha = 0.61$).[17]

ED/DE Risk

The Female Athlete Screening Tool (FAST) is a 33-item assessment tool designed to identify eating pathology, specifically among female athletes.[18,22] This questionnaire asks participants to rate their agreement on a 4-point Likert scale with statements related to eating pathology, exercise behaviors, and body image. Of note, items 15, 28, and 32 are reverse scored.[18,22] The total FAST score is the sum of all questionnaire items and total FAST scores between 74-94 have been used to indicate risk of subclinical DE, while scores >94 may indicate risk of clinical ED.[22,23] The FAST has high internal consistency in female athletes ($\alpha = 0.87$).[18,22]

The Eating Disorder Examination Questionnaire (EDE-Q 6.0) is 28-item screening tool that assesses ED/DE symptoms across four subscales: (1) restraint, (2) eating concern, (3) shape concern, and (4) weight concern and has been used previously in samples of recreational and elite athletes[19]. Participants are asked to self-report cognitive, psychological, and behavioral ED/DE symptoms from the last 28 days on a 0-6 Likert scale. Each of the four subscales is calculated based on the sum of individual questionnaire items: restraint (5 items), eating concern (5 items), shape concern (8 items), and weight concern (5 items), and subscale scores are averaged to calculate the EDE-Q global score. An EDE-Q global score of ≥ 2.3 is considered high risk, which is consistent with the REDs CAT2 criteria of an elevated score in females.[19,20] This score has been reported to be the optimal cut-off score in a sample of 195 adults with a specificity of 86% and a sensitivity of 92%.[24] The EDE-Q has been validated against clinical interviews and demonstrated good reliability ($\alpha = 0.93$).[25]

LEA Awareness and Knowledge

LEA awareness was categorized based on Triad and REDs awareness. Participants were asked "*Have you ever heard of the Triad [or REDs]?*". Participants responses were categorized into "Yes" and "No/I don't know" .

LEA knowledge was assessed using the Low Energy Availability Knowledge Questionnaire (LEA-KQ), an adaptation of a previously validated questionnaire.[26] The LEA-KQ consists of 35 items and includes questions related to the Triad and REDs. Responses receive one point for each correct answer, or zero points for an incorrect answer or selecting "I don't know." For questions of a "select all that apply" nature, a +/- scoring method was employed. For each "select all that apply" question, a participant will receive +1 point for each correct response and –1 for each incorrect response. The total score for a multi-select question is the sum of all positive and negative points, which is then divided by the maximum number of possible points (for example, 10/10 was 1 point, 6/10 was 0.60 points, etc.). Any negative total scores are truncated at zero. The total LEA-KQ score was the sum of all 35 items, with a range of 0-35 points. The original questionnaire (37 items) had a Cronbach's α of 0.914, and the adapted questionnaire had a Cronbach's α of 0.748, demonstrating high internal consistency.[26] No established reference values currently exist for LEA-KQ scores to classify knowledge as high or low.[26] The detailed list of questions used and possible responses for the LEA-KQ is available online (Supplementary Materials).

Statistical Analysis

Qualtrics survey data were compiled in Microsoft Excel V.16.71 and analyzed using IBM SPSS Statistics V.29 (IBM Corp., Armonk, NY). Normally distributed continuous data were expressed by mean ± standard deviations and

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Published online: September 3, 2025

categorical variables were expressed as numbers (n) and percentages (%). To determine an association between Triad awareness and REDs awareness, a Chi-squared test of independence was conducted. To assess differences in mean LEA-KQ scores based on Triad/REDs awareness, an independent samples T-test was conducted. To determine differences in mean LEA and ED/DE risk based on age group and LEA-KQ scores based on LEA and ED/DE risk, a one-way ANOVA was conducted, with Tukey's HSD post-hoc analysis. To assess the associations between LEA-KQ scores and LEAF-Q, FAST, and EDE-Q scores, while controlling for BSI and peak weekly mileage, Pearson's partial correlations were completed across the total sample and at an age group level. The Shapiro-Wilk test was used to assess normality for the independent samples T-test, ANOVA, and Pearson's partial correlations, and skewness [-2, +2] and kurtosis [-7, +7] were evaluated if Shapiro-Wilk's was violated. Levene's test for equality of variances was also evaluated. Scatterplot matrices were visually inspected to determine whether the assumption of linearity of the continuous variables were met. Normal distribution of variables were evaluated using histograms and Q-Q plots. Outliers were assessed based on the critical point of Mahalanobis distance of 18.47 in the current sample. Cases greater than the critical point were removed from final Pearson's partial correlation analysis. Pearson's partial *r* is reported to show the independent impact of each variable. The *a priori* alpha level for all analyses was set at 0.05.

RESULTS

Participant characteristics

Participant demographics are reported in Table 1 and Table 2. In total, 521 female track and field athletes consented to participate in the online study. Participants were assessed for eligibility and were excluded due to incomplete survey responses (n = 25), not female or transgender female (n = 1), not a US citizen (n = 1), and under 18 years of age (n = 3). Of the 493 participants who were eligible to participate, 125 did not complete the scored portion of the risk assessment for LEA, ED, or DE (n = 99) or the LEA-KQ survey (n = 26) and were excluded from data analysis. Thus, a total of 368 participants were included in the final analyses (Figure 1).

A majority of the sample was white (88.8%), non-Hispanic (97.0%), and held a degree in higher education (84.0%). More than half of the sample did not currently use hormonal birth control, and the most commonly used hormonal birth control were as follows: oral contraceptive pill (19.0%), intrauterine device (8.4%), hormonal implant (13.9%), with less than 1.0% of participants using hormonal patches, hormonal rings, and hormone replacement therapy . Participants competed in a variety of primary events across many different levels of competition, as reported in Table 1. Overall, the participants' average training was 10.47 ± 4.86 hours, or 47.33 ± 19.04 miles per week, and peak training averaged 13.17 ± 6.22 hours, or 58.54 ± 21.26 miles per week.

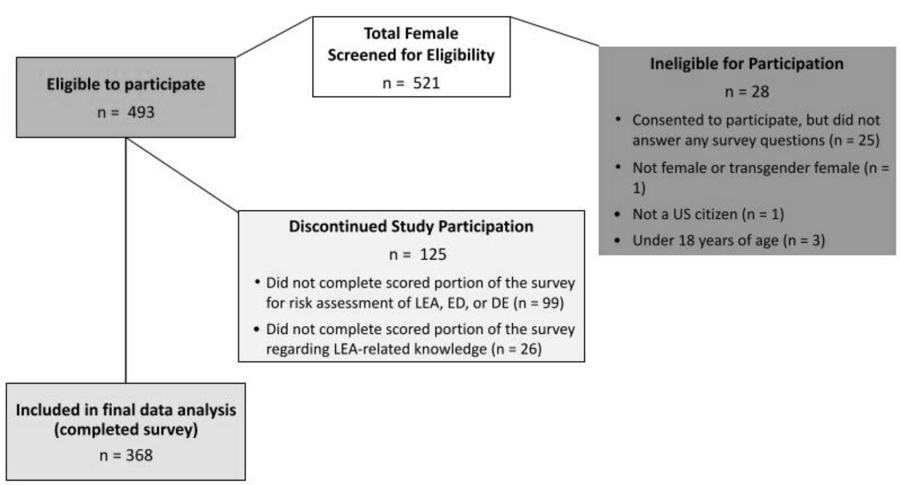

Figure 1. USATF LEA-KQ cohort summary

DOI: 10.53646/e3rijh65
PUBLISHED ONLINE: SEPTEMBER 3, 2025

Table 1. Categorical participant demographics

Characteristic	*Total Sample n (% of valid sample)*
Sex	
Female	365 (99.2%)
Non-binary	3 (0.8%)
Age Group	
18-28	195 (53.0%)
29-39	127 (34.5%)
40+	33 (9.0%)
Competition Level	
College	68 (18.5%)
Recreational	170 (46.3%)
Sub-elite/Elite	108 (29.4%)
Professional	17 (4.6%)
High School	4 (1.1%)
Primary Event	
Throws	5 (1.4%)
Jumps	2 (0.5%)
Sprints	4 (1.1%)
Middle Distance	24 (6.5%)
Middle Distance/Distance	48 (13.1%)
Distance	102 (27.8%)
Half/Full Marathon	174 (47.4%)
Multis/Combination	8 (2.2%)
Ethnicity/Racial Identity	
Caucasian	325 (88.8%)
African American	10 (2.7%)
Asian or Asian American	11 (3.0%)
Mixed Race	4 (1.1%)
Hispanic or Latino	11 (3.0%)
Indian American	1 (0.3%)
Arab	1 (0.3%)
Prefer Not to Answer	3 (0.8%)
Hormonal Birth Control Use	
Yes	157 (42.7%)
No	211 (57.3%)
Academic Area of Study	
Unrelated	197 (55.8%)
Related	156 (44.2%)
Triad Awareness	
Yes	304 (84.0%)
No/I Don't Know	58 (16.0%)
REDs Awareness	
Yes	319 (88.1%)
No/I Don't Know	43 (11.9%)

Percentages refer to frequency within column total for valid cases. Triad, Female Athlete Triad; REDs, Relative Energy Deficiency in Sport. Examples of related academic area of study include exercise science, kinesiology, biology, physiology, pre-medical studies, nutrition/dietetics, athletic training, physical therapy

Table 2. Breakdown of survey responses of the outpatient knee arthroscopy patient cohort stratified by gender

Measure	*Sample (mean ± SD)*
Age (years)	29.03 ± 8.19
Years in Primary Event	12.63 ± 7.00
Years in Competition Level	6.51 ± 6.10
BMI (kg/m²)	21.33 ± 2.75
BSI Number	1.08 ± 1.63
High-risk BSI Number	0.16 ± 0.49
Average Training Hours	10.47 ± 4.86
Peak Training Hours	13.17 ± 6.22
Average Weekly Mileage (mi/wk)	47.33 ± 19.04
Peak Weekly Mileage (mi/wk)	58.54 ± 21.26

BMI, body mass index; BSI, bone stress injury; mi/wk, miles per week

LEA and ED/DE risk

Of the total population, 49% of all participants demonstrated a high risk of LEA on the LEAF-Q (defined as a total LEAF-Q score ≥ 8), 35% were at risk of subclinical DE (defined as a total FAST score between 74-94), and 12% were at risk of clinical ED via the FAST (defined as total FAST score > 94). Furthermore, 22% had a high risk of ED via the EDE-Q (defined as global EDE-Q score ≥ 2.3) (Figure 2).

There was a significant difference between age groups based on LEAF-Q scores (F(2, 355) = 5.126, p = 0.006, η = 0.028), with 18-28 year olds having a LEAF-Q score 1.45 points higher than 29-39 year olds. There were no significant differences in LEAF-Q scores between the 40+ year old age group and 18-28 or 29-39 year old age groups, as well as no significant differences in FAST or EDE-Q scores based on age group.

LEA Knowledge

Eighty-four percent of the sample reported having heard of the Triad and 88% reported having heard of REDs. The mean LEA-KQ score of the total population was 24.57 ± 4.26 (range: 9.20-32.67). There was no significant differences in LEA-KQ scores between athletes with low LEA risk (24.88 ± 3.98) compared to athletes at high LEA risk (24.26 ± 4.53) ([F (1, 366) = 1.931, p = 0.165, η = 0.005]; Table 3). Based on EDE-Q, mean LEA-KQ scores were not significantly different based on low EDE-Q risk (24.50 ± 4.40) and high EDE-Q risk (24.84 ± 3.75) ([F (1, 366) = 0.416, p = 0.519, η = 0.001; Table 3).

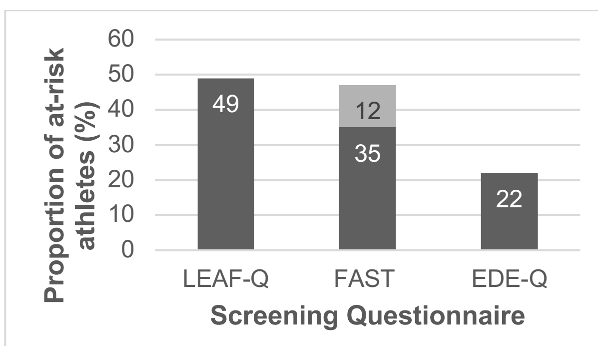

Figure 2. Risk of LEA and ED/DE in United States Track and Field athletes

Athletes at low risk for DE, based on FAST scores, had a mean LEA-KQ score of 25.13 ± 3.88, whereas athletes with subclinical DE risk and clinical ED risk had mean LEA-KQ scores of 24.16 ± 4.57 and 23.40 ± 4.59, respectively (Table 3). There

DOI: 10.53646/e3rijh65
PUBLISHED ONLINE: SEPTEMBER 3, 2025

was a significant difference in mean LEA-KQ scores in athletes at risk for DE (based on the FAST) [$F(2, 365) = 4.078$, $p = 0.018$, $\eta = 0.022$] (Table 3). Athletes with clinical ED risk scored significantly lower (1.73 points) on the LEA-KQ compared to those with low risk ($p = 0.034$). There were no differences in LEA-KQ scores in athletes with low risk vs. subclinical DE risk ($p = 0.108$) and subclinical DE risk and clinical ED risk ($p = 0.546$).

Awareness of Triad and REDs

There was a statistically significant association between Triad awareness and REDs awareness, $\chi^2(1) = 51.52$, $p<0.001$, Φ^2 effect size = 0.144, indicating a large effect. There was a statistically significant difference in LEA-KQ scores based on Triad awareness ($t(72.65) = -7.32$, $p < 0.001$, $d = 1.048$) and REDs awareness ($t(51.5) = (-6.020$, $p < 0.001$, $d = 1.063$, indicating a large difference in scores in athletes who were aware of the Triad or REDs, compared to athletes who were not aware of these conditions, respectively (Table 4).

Association Between LEA-KQ and LEAF-Q

The mean LEA-KQ score was 24.79 ± 4.00 and the mean LEAF-Q score was 8.01 ± 4.05, while covariates of BSI and peak training mileage had means of 0.65 ± 0.76 BSIs and 58.48 ± 20.90 miles per week, respectively. There was no significant association between LEA knowledge and LEAF-Q scores, $r(344) = -0.021$, $p = 0.703$. Pearson's partial correlation demonstrated that the strength of this linear relationship was slightly stronger when controlling for BSI and peak training mileage, however the association remained non-significant, $r_{partial}(342) = -0.034$, $p = 0.534$. The association between LEA-KQ and LEAF-Q scores remained non-significant at each age group level: 18-28 years old, 19-29 years old, and 40+ years old ($p > 0.05$; Table 5).

Association Between LEA-KQ and FAST

The association between LEA-KQ (mean score: 24.83 ± 4.02) and FAST scores (mean score: 72.28 ± 16.17) was assessed, with covariates of BSI (0.67 ± 0.80 BSIs) and peak training mileage (58.14 ± 20.66 miles per week). LEA-KQ and FAST scores were not significantly correlated ($r(347) = -0.091$, $p = 0.088$) and remained non-significant after controlling for BSI and peak training mileage, $r_{partial}(345) = -0.105$, $p = 0.051$. Sub-analyses by age group did not illustrate any significant association between LEA-KQ and FAST in 18-28 year olds, 19-29 year olds, and 40+ years ($p > 0.05$; Table 5).

Association Between LEA-KQ and EDE-Q

The mean LEA-KQ score was 24.83 ± 4.02 and the mean EDE-Q score on the EDE-Q was 1.35 ± 1.23, with covariates of BSI (0.67 ± 0.80 BSIs) and peak training mileage (58.14 ± 20.66 miles per week). There was no significant correlation between LEA-KQ and EDE-Q scores, $r(347) = 0.000$, $p = 0.999$ and remained non-significant when controlling for BSI and peak training mileage, $r_{partial}(345) = -0.004$, $p = 0.934$. Further sub-analyses demonstrate no association between LEA-KQ and EDE-Q by age group ($p > 0.05$; Table 5).

Table 3. LEA-KQ scores based on low- vs. high-risk for LEA, DE, and ED

Measure	LEA low risk *via LEAF-Q*	LEA high risk *via LEAF-Q*	DE low risk *via FAST*	Subclinical DE risk *via FAST*	Clinical ED risk *via FAST*	ED low risk *via EDE-Q*	ED high risk *via EDE-Q*
LEA-KQ score	24.88 ± 3.98	24.26 ± 4.53	25.13 ± 3.88	24.16 ± 4.57	23.40 ± 4.59*	24.50 ± 4.40	24.84 ± 3.75

*Low Energy Availability Knowledge Questionnaire (LEA-KQ); low energy availability (LEA) risk was assessed via Low Energy Availability in Females Questionnaire (LEAF-Q), disordered eating (DE) risk was assessed Female Athlete Screening Tool (FAST) for subclinical DE and clinical eating disorder (ED), ED risk was assessed via Eating Disorder Examination Questionnaire (EDE-Q). *p < 0.05.*

Table 4. LEA-KQ scores based on triad and REDs awareness

	N	*LEA-KQ score (mean ± SD)*	*p-value*	*d*	*95% CI*
Triad Awareness					
No/Don't know	58	21.26 ± 4.52			
Yes	304	25.32 ± 3.74	< 0.001**	1.048	[-5.16, -2.97]
REDs Awareness					
No/Don't know	43	20.91 ± 4.38			
Yes	319	25.14 ± 3.92	< 0.001**	1.063	[-5.64, -2.82]

Table 5. Association between LEA risk and knowledge based on age group

	Mean scores	***N***	***r***	*p-value*
LEAF-Q				
18 – 28	8.57 ± 3.99	179	-0.008	0.915
29 – 39	7.26 ± 4.03	121	-0.078	0.400
40+	8.00 ± 3.82	33	0.067	0.719
All	8.01 ± 4.05	346	-0.034	0.534
FAST				
18 – 28	72.55 ± 16.56	182	-0.089	0.236
29 – 39	71.48 ± 14.87	120	-0.118	0.204
40+	77.27 ± 18.27	33	-0.176	0.345
All	72.28 ± 16.17	349	-0.105	0.051
EDE-Q				
18 – 28	1.36 ± 1.25	182	0.031	0.679
29 – 39	1.30 ± 1.14	121	-0.021	0.819
40+	1.67 ± 1.43	33	-0.160	0.389
All	1.35 ± 1.23	349	-0.004	0.934

DISCUSSION

The present study investigated the strength of the associations between LEA knowledge and LEA and ED/DE risk. There were no significant associations between LEA-KQ and LEAF-Q, FAST, or EDE-Q. It is important to note that when controlling for BSI and peak weekly mileage, the association between scores LEA-KQ and LEAF-Q and EDE-Q scores remained non-significant, indicating that BSI and peak weekly mileage do not appear to influence the association between LEA knowledge and LEA and ED risk. Contrary to current literature in this area and our hypotheses, these findings indicate that LEA knowledge and LEA risk and ED/DE risk are not significantly related in this sample of athletes.

Awareness of Triad and REDs

In the current sample, Triad and REDs awareness (84% and 88%, respectively) were significantly associated with each other and higher than previously reported by athletes (29% Triad), coaches (24-58% and 54%, respectively), athletic trainers (99% and 33%, respectively).[27-30] To the authors' knowledge, this is the first time that a greater proportion of participants have reported having heard of REDs, compared to the Triad.[26] However, studies have not traditionally assessed Triad and REDs in one study design. As the average

DOI: 10.53646/e3rijh65
Published online: September 3, 2025

age of athletes in the sample is 29.03 ± 8.19 years, there may be an age effect. REDs was introduced in the literature in 2014, and Triad has been a topic of interest since 1992, as such younger athletes may be more likely to have been introduced to the syndrome of REDs, while older athletes may be more likely to recognize the Triad.[31-32] Despite a higher proportion of participants reporting having heard of REDs, both Triad and REDs awareness were significantly associated with each other. The present sample of female track and field athletes who were aware of the Triad and REDs scored significantly higher on the LEA-KQ compared to athletes who were not aware of these conditions, which is similar to findings in collegiate female cross-country athletes from Lodge et al. (2022).[26] Future education efforts should focus the vast array of health and performance consequences associated with all LEA-related conditions.

Association between LEA knowledge and LEA and ED/DE risk

Similar to findings from Pai et al. (2024) in which sports nutrition knowledge did not vary in female team sport athletes at risk for LEA compared to female athletes not at risk for LEA, the present study did not find an association between LEA knowledge and risk of LEA or ED/DE.[8] Magee et al. (2023) also demonstrated no significant relationship between sports nutrition knowledge and risk of LEA or ED in young male and female athletes.[11] The non-association observed between knowledge and risk may be due to a lack of accurate sports nutrition information, leading to overall poorer sports nutrition and LEA knowledge scores in female athletes.[16] Furthermore, there may be additional factors, apart from knowledge alone, such as financial restrictions, poor access to food options, and lack of time or resources, limiting an athlete's ability to fuel adequately.[16]

Contrary to our findings, Jagim et al. (2021) found a positive association between sports nutrition knowledge and perceived needs for absolute protein, carbohydrate, and energy intake in female athletes and Burger et al. (2024) found that female athletes with higher nutrition knowledge were more likely to be at risk for LEA.[9-10] It is possible that female athletes who intentionally restrict their energy intake may exhibit greater nutrition knowledge because of increased time spent exploring how to manipulate their body weight and shape.[9,16] Misguided intentions to achieve a discipline-specific physique to optimize performance is a common risk factor in the development of LEA and ED/DE in female track and field athletes.[33] As such, education remains a priority to address poor knowledge of sports nutrition and LEA-related conditions and misconceptions regarding body composition and potentially reduce the risk of LEA-related conditions in female athletes.[5,12]

Furthermore, a majority of studies have assessed sports nutrition knowledge using the Abridged Nutrition for Sport Knowledge Questionnaire (A-NSKQ), which includes questions related to general and sport nutrition knowledge, food choices, hydration, and supplementation.[34] In contrast the present study utilized a questionnaire (LEA-KQ) specifically designed to assess theoretical and practical understanding of LEA and related conditions, with questions related to health and performance outcomes, signs and symptoms, and risk factors. Prevention strategies for LEA ought to address sports nutrition and REDs-related education, as such sports nutrition and LEA-related knowledge should be characterized and explored in the literature.

Limitations

In this study, a cross-sectional, survey-based design was utilized, which may have led to some limitations. While it can be seen as a strength of the study that the sample population includes exclusively United States athletes; on the other hand, this may limit the generalizability to athletes outside of the United States. The current sample was predominantly Caucasian (88.8%), which may further limit the generalizability of the findings to other ethnicities or racial identities. Causal relationships cannot be drawn based on our findings due to the cross-sectional study design and further research is needed to explore the directionality of this relationship. As such, a longitudinal and/or intervention-based study design would provide further insight into changes in knowledge and risk scores due to education programs. Due to the survey-based nature of this study, it is possible participants opting in exhibited selection bias, such that individuals who chose to participate may have a greater interest in and more existing knowledge of LEA than non-respondents. Selection bias could result in an overestimation of LEA and ED/DE risk, but it is also possible participants under-reported on screening questionnaires due to fear of being held out of sport, unwillingness to acknowledge maladaptive

DOI: 10.53646/e3rijh65
Published online: September 3, 2025

behaviors, and/or social desirability bias. Although the LEAF-Q is widely used to identify risk of LEA in female athletes, it may not be as precise or reliable in athletes over the age of 40 due to potential differences in hormonal profiles, bone density, or other age-related factors. Despite this, we did not exclude athletes > 40 years of age; and sub-analyses based on age group did not impact the overall findings observed in the total population. Finally, it is important to note that the LEA-KQ was developed prior to the 2023 consensus statement on REDs and therefore does not reflect updates in the health and performance conceptual models.[1]

Future Directions

In light of the current and previous findings examining the strength of the associations between LEA knowledge and LEA and ED/DE risk, it is important to continue to explore athletes' knowledge of LEA and ED/DE and the implications it has on their health and performance. Current literature highlights a need to establish intervention strategies, including education programs, to improve LEA and ED/DE risk. Despite LEA and ED/DE risk being high, few education programs exist and those that do have primarily demonstrated an improvement knowledge, not yet LEA/REDs risk.[7,35] Moving forward, it is important to consider timing of prevention efforts in order to provide education prior to the development of LEA/REDs and ED/DE. Few studies to have examined the role of sports nutrition education on LEA/REDs risk and dietary behavior change. Day et al. (2016) provided six, 30-minute nutrition education sessions which resulted in a summed improvement of nutrition knowledge, but no increase in dietary energy intake.[35] Fahrenholtz et al. (2023) assessed a 16-week nutrition intervention program of online sports nutrition lectures and individualized nutrition counseling for female athletes at risk of REDs which improved sports nutrition knowledge but not dietary behaviors.[7] Future interventions should focus more on positive changes in dietary behavior, such as opportunities to practice dietary skills and addressing other barriers to implementing changes in dietary energy intake. More research on intervention-based strategies is warranted to not only improve sports nutrition or LEA knowledge but also LEA/REDs risk and other pathological eating behaviors.

CONCLUSION

In our sample of United States female track and field athletes, there was no significant association between LEA knowledge and risk of LEA and ED/DE, despite previous research studies illustrating a relationship between sports nutrition knowledge and LEA risk.[7,9,10,12,13] It is necessary to further explore the relationship between sports nutrition and LEA-related knowledge and LEA and ED/DE risk in order to better understand the direction and cause of these relationships, as well as the associated risk factors. Education may be a valuable method of improving sports nutrition and LEA-related knowledge, but whether improved knowledge translates to positive dietary behaviors and reduced risk of LEA and ED/DE is yet to be determined and more research is needed. Better understanding the relationship between LEA knowledge and risk will assist in the development of effective education programs to address adequate fueling in female athletes to prevent against the negative health and performance consequences of LEA.

Conflict of Interest Statement

The authors declare no conflicts of interest with the contents of this study.

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DOI: 10.53646/e3rijh65
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DOI: 10.53646/e3rijh65
PUBLISHED ONLINE: SEPTEMBER 3, 2025