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Differences in Knowledge of Female Athlete Triad and Relative Energy Deficiency in Sport in Female Cross-Country Athletes

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Background: The female athlete triad (Triad) and relative energy deficiency in sport (REDs) describe potential health and performance consequences of low energy availability.

Objective: We surveyed female cross-country athletes to assess differences in educational impact scores (EIS; knowledge score × confidence score factor) of Triad and REDs. Associations between EIS and participant characteristics (eg, mileage [current and peak], years of running experience, age, bone stress injury history, division level participation, academic area of study, Triad or REDs diagnoses, and Triad or REDs education) were explored.

Main Outcome Measure(s): An evidence-based online survey was developed and administered via Qualtrics to female collegiate cross-country athletes (n = 275; age = 20 ± 1 years).

Results: A weak correlation existed between peak career mileage and EIS (r = 0.195; P = .010). Educational impact scores significantly differed in athletes with a related academic area of study versus those without (21.91 ± 5.16 and 16.11 ± 5.54, respectively). Educational impact scores significantly differed in athletes with Triad and REDs diagnoses (21.69 ± 5.85 and 22.58 ± 6.82, respectively) versus those without (16.80 ± 6.54 and 17.20 ± 6.34, respectively). Educational impact scores were higher in those who had received Triad education versus those who had not (21.03 ± 6.86 and 18.12 ± 6.82, respectively). A significant interaction between peak career mileage and Triad diagnosis was found (P = .005).

Conclusions: Significant education-based and diagnosis differences suggest that Triad diagnoses correlate with peak career mileage. These findings support the facilitation of education to improve not only the treatment but also the prevention of Triad and REDs.

Key Words: REDs, education, running

Key Points

- A weak but significant correlation existed between peak career mileage and educational impact scores of female athlete triad and relative energy deficiency in sport in female collegiate cross-country athletes.
- Educational impact scores were significantly higher in female cross-country athletes with a related academic area of study who attended National Collegiate Athletic Association Division I institutions, had a history of female athlete triad and relative energy deficiency in sport diagnoses, and received education training on female athlete triad.
- Female athlete triad diagnosis is correlated with peak career mileage.

The female athlete triad (Triad) and relative energy deficiency in sport (REDs) are conditions that outline the potential health and performance consequences of low energy availability (LEA).[1,2] The American College of Sports Medicine proposed Triad in 1992, with the most current consensus statement from 2014 defining a relationship between LEA (with or without an eating disorder), low bone mineral density, and menstrual dysfunction.[3] Female athletes often present with 1 or more components of Triad or somewhere along the spectrum of energy availability (EA), menstrual status, and bone health.[3] In 2014, the International Olympic Committee (IOC) updated their 2005 Triad consensus statement, broadening the concept of LEA in athletes to include men and multiple health (ie, menstrual function, bone health, endocrine, metabolic, hematological, growth and development, psychological, cardiovascular, gastrointestinal, and immunological) and performance (ie, increased injury risk, decreased training response, impaired judgement, decreased coordination, decreased concentration, irritability, depression, decreased glycogen stores, decreased muscle strength, and decreased endurance performance) consequences associated with energy deficiency.[2,4] They named this syndrome RED-S (recently updated to REDs in their newest consensus statement).[5] The consensus statement updated the health and performance conceptual models based on emerging REDs research since 2018, with LEA at the center of the model to illustrate its role as the exposure variable.[5] Both Triad and REDs literature often use EA calculations to establish thresholds of low, subclinically low, and adequate EA. Energy availability equals energy intake (EI) minus exercise energy expenditure (EEE), normalized to fat-free mass (FFM).[6] In female athletes, clinical LEA is commonly recognized as <30 kcal/kg FFM/day, while an EA of 30 to 45 kcal/kg FFM/day is considered subclinical LEA.[6]

The prevalence of REDs in female collegiate cross-country athletes is estimated to be 50% to 91%, which may be low considering stigmatization of mental health disorders and fear of being held out of competition.[7–9] Athletes in sports emphasizing leanness, exhibiting increased injury risk, and those training for prolonged exercise bouts, such as cross-country athletes, are at an increased risk for developing Triad and REDs.[1]

The primary recommendation from the American College of Sports Medicine and the IOC for prevention, management, and treatment of Triad and REDs is the use of educational strategies.[2,3] A recent IOC consensus provided strategies and best practices for primary, secondary, and tertiary prevention of REDs.[10] The goal of primary prevention is to prevent REDs before it occurs, which includes employing strategies such as nutrition education and REDs-related education for athletes and their support staff (ie, coaches, health and performance team members).[10] However, authors of few studies to date have demonstrated the baseline knowledge of athletes and support staff (eg, coaches, athletic trainers [ATs], and registered sports dietitians) regarding Triad and REDs.[11–14] In our 2022 parent study, we developed a survey to assess total knowledge, confidence, and educational impact scores (EISs) of Triad and REDs in collegiate female cross-country athletes and their support staff.[15] Findings illustrated that knowledge of Triad and REDs was significantly lower in collegiate female cross-country athletes than the coaches and ATs of such athletes.[15] Furthermore, most female cross-country athletes indicated that they had not received education on Triad (68%) and REDs (78%), which was like coaches (65% and 70%, respectively), whereas 13% and 40% of ATs had indicated that they had not received education on Triad or REDs, respectively.[15]

More elite athletes are speaking out about their experiences with Triad and REDs, which has popularized the terms in mainstream media.[16] However, little evidence suggests that this has translated into an increase in knowledge of LEA and its related conditions. It is important to investigate and address the lack of proper knowledge of Triad and REDs among all sporting communities, especially those participating in female endurance events (eg, cross-country, cycling, endurance running), as they exhibit increased risk. Subsequently, in this study, we explored characteristics of female cross-country athletes since they are a highly susceptible population in the development of Triad and REDs.[2,7,11,17] Examining differences in female cross-country athletes' characteristics will provide further insight into the translation research gaps and risk of Triad and REDs development as well as identify sport-specific risk factors to assist in the screening, management, and treatment of Triad and REDs.

The primary aim of the current study is to examine the influence of characteristic differences (eg, peak career mileage, total years of running experience, current mileage, history of bone stress injury [BSI], division level participation, academic area of study, Triad diagnosis, and REDs diagnosis) on EISs of Triad and REDs. These differences will help us establish meaningful relationships between characteristics of female cross-country athletes and knowledge of Triad and REDs.

METHODS

Study Design

A cross-sectional study design was used to examine factors that influenced knowledge, confidence, and educational impact related to Triad and REDs.

Participants

Participants were collegiate female cross-country athletes. Participants were recruited from collegiate women's cross-country teams via email to coaches and ATs, accessed through publicly available university team webpages. We directly invited 440 schools in the National Collegiate Athletic Association (NCAA) or National Association of Intercollegiate Athletics (NAIA) to participate. Coaches and ATs were asked to distribute the link to the online survey to their female cross-country athletes. Online flyers and social media were also used to enhance recruitment, which lasted 44 days. Each volunteer was asked to complete an online survey via Qualtrics, and the survey was available for 57 days during the spring 2020 season. Online informed consent was obtained from all participants. The Syracuse University Institutional Review Board approved this study.

Inclusion and Exclusion Criteria

To be included, volunteers had to be 18 years or older and self-identify as a current female cross-country athlete. Those who did not meet these 2 criteria were excluded.

Survey Development

The evidence-based survey was multifaceted and aimed to assess factors (eg, participant characteristics) that influenced knowledge, confidence, and EISs of Triad and REDs in collegiate female cross-country athletes. A previous survey designed to characterize Triad knowledge and tested for content validity, instrument reliability, and concurrent validity was adapted to the current study survey.[18] The current instrument expanded items to include questions specific to the emerging topic of REDs. The entire adapted survey was reviewed by 3 content experts: (1) a medical doctor in sports medicine and endocrinology, (2) a certified sports dietitian in clinical athlete care, and (3) a doctoral-level researcher in female physiology and nutrition education. Test-retest reliability was performed via internal consistency (Cronbach α) with 4 noncollegiate female cross-country athletes and 2 noncollegiate coaches of female cross-country athletes. Though the sample on which we based reliability was small, the original survey was tested for reliability among 12 collegiate coaches.[18] The scored knowledge portion of the survey, tested for reliability, was the same across populations. The 38-item survey was administered to reliability participants twice within 48 hours at least 6 hours apart. Reliability participants were asked not to conduct any educational searches on Triad and REDs between survey responses. The Cronbach score ($\alpha = 0.799$) indicated acceptable reliability. However, the item with the weakest reliability correlation (a multiple choice regarding the definition of REDs) was removed, which improved the reliability of the survey to excellent with high internal consistency ($\alpha = 0.914$). Therefore, the final 37-item knowledge portion of the survey was used for data collection.

Scoring Protocols

The 2022 parent study by Lodge et al outlines the development and scoring protocol for the 3 calculated scores: knowledge, confidence, and educational impact.[15] Brief explanations on how the scores were calculated are provided here (for more information, see the Supplemental Table, available online at https://dx.doi.org/10.4085/1062-6050-0608.22.S1). The EIS is a composite score of knowledge and confidence scores. The total knowledge score is a sum of all 37 knowledge items, where 1 point is added for each correct answer, 1 point is subtracted for each incorrect correct answer, and 0 points are added for selections of *I don't know*. The total confidence score was the sum of all 37 confidence items. Participants were asked to select a confidence level on a scale of 0 points (*no confidence*) to 4 points (*completely sure*).

The total EIS is the product of the knowledge score and confidence factor. The confidence factor is calculated as the quotient of the confidence score divided by 4. For example, a confidence score of 4 equals a confidence factor of 1, and a confidence score of 1 equals a confidence factor of 0.25. Thus, the possible EIS for each item ranges from +1 point (for the correct answer and high confidence) to −1 point (for an incorrect answer and high confidence). Educational impact scores were reduced when respondents had less confidence in their answers.

Please refer to the parent study (Lodge et al) for more information on the survey items assessing knowledge, confidence, and the EIS of Triad and REDs.[15]

Outcome Measures

Participant characteristics included the following survey items, which were supplementary to our understanding and not included in the scoring calculations: mileage (current and peak), total years of running experience, age, history of BSI, division level participation, academic area of study (eg, exercise science, kinesiology, biology, physiology, premedical studies, nutrition, dietetics, health studies, athletic training, physical therapy, chiropractic, and nursing), Triad and REDs diagnoses, and Triad and REDs educational training.

Mileage is a good proxy for EEE in cross-country athletes. Peak and current mileage data were collected, as both could affect EEE and subsequent LEA development. As running is a high LEA-risk sport, total years of running experience was collected. History of BSI was collected because BSI is a known consequence of LEA. Division level participation was assessed to elucidate any global differences, which may represent a difference in resources and funding. Academic area of study was queried, as some may have more knowledge of these topics based on formal education training. Self-reported Triad and REDs diagnoses were collected to determine if any participant had been formally diagnosed by a physician. Female athlete triad and REDs training was collected to assess if previous education training had been effective at improving knowledge of Triad and REDs compared with participants who did not receive training.

Statistical Analysis

Incomplete survey items were excluded from data analysis. All variables were tested for normality using the Kolmogorov-Smirnov test. Educational impact scores, assessed by categorical variables (eg, division level participation, academic area of study, Triad and REDs diagnoses), were analyzed using an independent samples *t* test. Data for continuous variables were analyzed using Pearson correlations and Spearman correlations.

Table 1. Descriptive Participant Characteristics[a]

	Collegiate Female Cross-Country Athletes (n = 175)
Age, y	20 ± 1.0
Total years of running experience, y	8.95 ± 4.0
Years at present institution, y	3.25 ± 1.9
Current running mileage, miles/week	41.54 ± 15.3
Peak career mileage, miles/week	56.11 ± 12.9
Lifetime bone stress injury diagnoses	1.22 ± 1.8
Female, %	100
NCAA DI, %	55
NCAA DII, %	16
NCAA DIII, %	23
NAIA, %	5
Race, % White	91
Related academic area of study, %	15
Mean knowledge score	25.00 ± 5.27
Mean confidence score	95.42 ± 28.83
Mean educational impact score	18.81 ± 7.05

Abbreviations: DI, Division I; DII, Division II; DIII, Division III; NAIA, National Association of Intercollegiate Athletics; NCAA, National Collegiate Athletic Association.

[a] Descriptive and frequency indicate the averages (mean ± SD) for continuous variables and the frequency (%) for categorical variables among each population group. Related academic areas of study include degrees related to health and performance, such as exercise science, kinesiology, biology, physiology, premedical studies, nutrition, dietetics, health studies, athletic training, physical therapy, chiropractic, and nursing.

Pearson bivariate correlations were performed between the EIS and the variables peak career mileage and total years of running experience, as these variables were normally distributed. Spearman correlations were performed between the EIS and the variables current mileage and BSI history, as they were not normally distributed. The univariate general linear model (GLM) was used to assess the EIS in a multivariate approach, examining interactions between significant associations revealed in univariate analyses. Effect sizes were calculated based on Cohen *d* and Hedges g.[19,20] A significance level was set at $P \leq .05$ a priori. All data were presented as means ± SD. SPSS (version 28; SPSS Inc) was used for data analysis.

RESULTS

Participant Characteristics

Two hundred twenty-five collegiate female cross-country athletes accessed the survey and consented to participate. Fifty respondents did not complete the scored portion of the survey pertaining to knowledge and confidence items. The survey completion rate was 78%. Therefore, a total of 175 collegiate female cross-country athletes were included in data analysis. Participant characteristics are shown in Table 1.

Assessment of Knowledge, Confidence, and Impact Scores

Peak Career Mileage. A weak, significant correlation existed between the EIS and peak career mileage ($r = 0.195$, $P = .010$; Table 2; Figure 1). No significant correlations were found between the EIS and the following

Table 2. Relationship Between Knowledge Scores and Educational Impact Scores Compared With Peak Career Mileage and Total Years of Running Experience[a]

	Female Cross-Country Athletes (n)	Knowledge Score (*P* Value)	Educational Impact Score (*P* Value)
Peak career mileage, miles/week	175	.173[b] (.022)	.195[c] (.010)
Total years of running experience, y	175	.055 (.470)	.084 (.270)

[a] Pearson bivariate correlations indicate significant correlations between female cross-country athletes' peak career mileage and knowledge scores and between female cross-country athletes' peak career mileage and educational impact scores.
[b] $P < .01$ significance.
[c] $P < .05$ significance.

variables assessed: current running mileage, BSI history, and total years of running experience (Tables 2 and 3).

Division Level Participation. Educational impact scores of Division I (DI) female cross-country athletes (19.98 ± 7.05) significantly differed from non-DI athletes (17.36 ± 6.82; $P = .014$; Table 4). A small to medium main effect ($d = 0.377$) existed, which demonstrates that DI participants scored an average of 2.6 points (95% CI = 0.53, 4.71) higher than non-DI participants.

Academic Area of Study. Female cross-country athletes with a related academic area of study had a higher EIS (21.91 ± 5.16) than those with unrelated academic areas of study (16.11 ± 5.54; $P < .0001$; $d = 1.078$; Table 4). Student-athletes with a related academic area of study scored 5.8 points (95% CI = 3.04, 8.56) higher than student-athletes with an unrelated academic area of study.

Triad and REDs Diagnoses. Educational impact scores were significantly higher in female cross-country athletes with a Triad diagnosis (21.69 ± 5.85) or REDs diagnosis (22.58 ± 6.82) than female cross-country athletes without a Triad (16.80 ± 6.54) or REDs diagnosis (17.20 ± 6.34; $P < .000001$; Table 4). A large main effect ($d = -0.787$) existed, such that participants with a Triad diagnosis scored an average 5.0 points (95% CI = −6.85, −2.93) higher than those without a Triad diagnosis. Similarly, those with a REDs diagnosis scored an average 5.4 points (95% CI = −7.58, −3.17) higher than participants without a REDs diagnosis (g = −0.822).

Triad and REDs Training. Educational impact scores significantly differed between those who received some form of Triad training (21.03 ± 6.86) versus those who did not (18.12 ± 6.82; $P = .014$; g = 0.425). Athletes with Triad training scored approximately 3.0 points (95% CI = −0.60, 5.23) higher than those without. However, the EIS did not significantly differ between those who had or had not received REDs training ($P = .087$).

Interaction Effects. No significant interaction existed between peak career mileage and division level participation in female cross-country athletes ($P > .05$; Tables 5 and 6; Figure 2). Therefore, the interaction of division level participation and peak career mileage was explored to uncover which variable was driving the significant differences in EISs. The significant difference in EISs of DI participants compared with non-DI participants was no longer significant after controlling for peak career mileage. The univariate GLM illustrates a borderline significant main effect of mileage ($P = .087$; Tables 5 and 6; Figure 2). Furthermore, a significant interaction existed between peak career mileage and Triad diagnosis in female cross-country athletes ($F_{1,156} = 8.309$, $P = .005$, $\eta^2 = 0.052$, 95% CI = 0.068, 0.362; Tables 5 and 6; Figure 3), with a significant main effect of Triad diagnosis ($P < .001$) and peak career

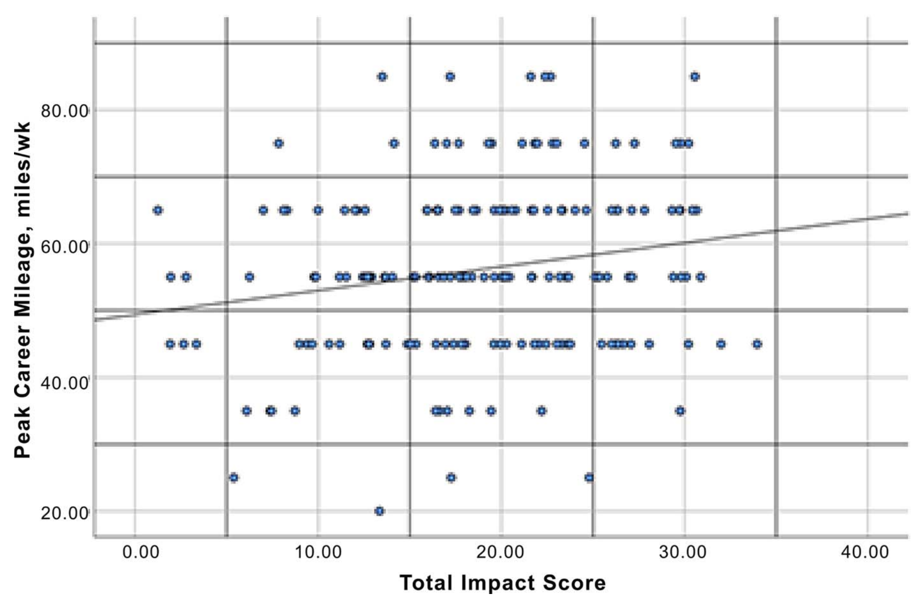

Figure 1. Educational impact scores versus peak career mileage in female cross-country athletes. A Pearson bivariate indicated that peak career mileage (miles/week) was significantly correlated with total impact scores in female cross-country athletes ($r = 0.195$; [a] $P = .010$).

Table 3. **Relationship Between Knowledge Scores and Educational Impact Scores Compared With Current Mileage, Total Bone Stress Injury (BSI), and Number of BSIs[a]**

	Female Cross-Country Athletes (n)	Knowledge Score (*P* Value)	Educational Impact Score (*P* Value)
Current running mileage, miles/week	175	.115 (.129)	.125 (.100)
Lifetime BSI diagnoses	171	.077 (.315)	.074 (.336)
No. BSIs	86	.077 (.482)	.104 (.339)

[a] Spearman bivariate correlations indicate nonsignificant correlations between female cross-country athletes' current mileage, lifetime BSI diagnoses, and number of BSIs compared with knowledge scores. Nonsignificant correlations are illustrated between female cross-country athletes' current mileage, lifetime BSI diagnoses, and number of BSIs compared with educational impact scores. Note: Total BSI includes all participants self-reporting BSI diagnoses; the number of BSIs includes participants who have experienced 1 or more BSI.

mileage ($P < .05$; Tables 5 and 6). Therefore, in this interaction, the effect of Triad diagnosis depended on peak career mileage (Figure 3).

DISCUSSION

In this present study, we examined the role of female cross-country athletes' characteristics on EISs of Triad and REDs. Those who self-reported higher peak career mileage, a related academic area of study, NCAA DI participation, positive Triad and REDs diagnoses, and Triad training demonstrated a higher EIS.

Student-athletes often rely on education programs provided by their athletic department or their formal education through their academic program of study. Availability of education programs provided or mandated by athletic departments at the collegiate level is limited, which leads to a lack of Triad and REDs education for student-athletes. Female cross-country athletes with Triad and REDs diagnoses demonstrated higher knowledge and EISs than those without. A potential contributing factor to the significant differences in diagnostic groups is that receiving a diagnosis of Triad, REDs, or both likely increased that athlete's awareness, education, or resources as part of their treatment from a care team.[11,21,22] A multidisciplinary care team is essential to the treatment of Triad and REDs and should minimally consist of a sports medicine physician, registered dietitian, sports physiologist, and mental health specialist, given the myriad of LEA-associated health consequences.[2]

A positive correlation existed between peak career mileage and the EIS. Higher mileage is more likely to cause an inherent increase in EEE, causing a greater risk of LEA and BSI.[6,23,24] Low energy availability can be caused by decreased EI, increased EEE, or both.[6] The primary issue for athletes is maintaining sufficient EI to support their increased EEE, contributing to LEA.[23] Female cross-country athletes should maintain an EA $\geq$ 45 kcal/kg FFM/day through conscious effort to consume food throughout the day, therefore reducing periods of LEA despite high training volume or rigorous competition schedules.[23]

Table 4. **Relationship Between Knowledge Scores, Confidence Scores, and Educational Impact Scores Compared With Division Participation, Related Academic Area of Study, Female Athlete Triad (Triad) Diagnosis, and Relative Energy Deficiency in Sport (REDs) Diagnosis[a]**

	Female Cross-Country Athletes (n)	Knowledge Score (*P* Value)	Confidence Score (*P* Value)	Educational Impact Score (*P* Value)
Division I participants	97	26.03 ± 5.33	98.56 ± 28.47	19.98 ± 7.05
Non-Division I participants	78	23.73 ± 4.93[b] (*P* = .004)	91.53 ± 28.97 (*P* = .109)	17.35 ± 6.82[c] (*P* = .014, Cohen *d* = 0.377)
Related academic area of study (eg, exercise science, kinesiology, nutrition)	27	26.60 ± 4.00	108.19 ± 19.44	21.91 ± 5.16
Unrelated academic area of study (eg, business, marketing, communications)	35	22.70 ± 5.42[c] (*P* = .02)	87.77 ± 23.27[b] (*P* = .001)	16.11 ± 5.54[c] (*P* = .000088, Cohen *d* = 1.078)
Positive Triad diagnosis	77	26.52 ± 5.05	107.49 ± 20.97	21.69 ± 5.85
Negative Triad diagnosis	80	23.84 ± 4.92[b] (*P* = .001)	87.61 ± 27.87[b] (*P* = .000001)	16.80 ± 6.54[b] (*P* = .000002, Cohen *d* = −0.787)
Positive REDs diagnosis	52	27.34 ± 5.30	109.15 ± 25.71	22.58 ± 6.82
Negative REDs diagnosis	99	23.91 ± 4.96[b] (*P* = .000125)	89.77 ± 27.03[b] (*P* = .000036)	17.20 ± 6.34[b] (*P* = .000003, Hedges g = −0.822)

[a] Mean ± SDs. An independent samples *t* test indicates significant differences between division participation (Division I participants versus non-Division I participants) and scores (knowledge and impact), related academic area of study and scores (knowledge, confidence, and impact), Triad diagnoses and scores (knowledge, confidence, and impact), and REDs diagnoses and scores (knowledge, confidence, and impact).

[b] $P < .01$ significance.

[c] $P < .05$ significance.

Table 5. Multivariate Analysis of Educational Impact Scores in Female Cross-Country Athletes[a]

	Type II Sum of Squares	df	F	P Value	Partial η^2	Observed Power[b]
Division level participation	4.200	1	0.088	.768	0.001	0.060
Peak career mileage	142.109	1	2.964	.087	0.017	0.402
Peak career mileage × division level participation	0.231	1	0.005	.945	<0.001	0.051
Triad diagnosis	539.312	1	15.114	<.001[c]	0.090	0.971
Peak career mileage	230.270	1	6.453	.012[c]	0.040	0.714
Triad diagnosis × peak career mileage	296.492	1	8.309	.005[c]	0.052	0.817

[a] A univariate general linear model indicates tests of between-subjects effects and significant interaction(s) between the following variables: division level participation and peak career mileage and Triad diagnosis and peak career mileage. Mean ± SDs.
[b] Computed using $\alpha = .05$.
[c] $P < .05$ significance.

Furthermore, significant differences in EISs across division level participation did not remain significant when controlling for peak career mileage. This is likely explained by higher career mileage undertaken by DI participants than non-DI participants.[25] Additionally, a Triad diagnosis in female cross-country athletes correlated with peak career mileage, confirming that higher peak career mileage puts athletes at greater risk for LEA and its consequences.[26]

Authors of other studies who have assessed knowledge have illustrated a lack of knowledge of Triad and REDs among ATs and coaches.[12,14,15,27–30] In 2006, 64% of DI collegiate coaches reported not having heard of Triad, and 43% were unable to correctly identify the 3 components of Triad.[29] In 2022, 29% of collegiate cross-country coaches had not heard of Triad, and only 52.4% could accurately identify the 3 Triad components.[31] In a study of collegiate ATs, 98.61% had heard of Triad, and 32.98% had heard of REDs.[12] However, only 13.33% of ATs correctly identified energy imbalance or energy deficiency as a component of Triad.[12] Authors of fewer studies have examined the role of education on knowledge of Triad and REDs in participants.[30] Authors of confirmatory studies should seek to assess participant characteristics as it relates to knowledge of LEA conditions.

Education programs are necessary to increase Triad and REDs knowledge and to properly identify, treat, and prevent LEA conditions.[7,19,20] Authors of previous studies have illustrated the effectiveness of early intervention in other sports medicine cases.[26–28] Coaches and ATs often serve as the primary point of contact for athletes in training and are responsible for the care of injury, illness, examination, and education.[25] Therefore, Triad and REDs education initiatives targeting coaches and ATs are important.[25,32] Our findings also suggest that athlete education programs should be implemented early in their sporting career, as those with a related academic area of study or those who had been diagnosed with Triad demonstrated a higher EIS.

Limitations

Strengths of this study include the incorporation of Triad and REDs survey items, as both terms are underpinned by LEA and discussed in the sports community. Collegiate female cross-country athletes' participant characteristics were explored, which allowed us to assess differences in knowledge, confidence, and EISs within our population. The use of an EIS provides further insight into knowledge translation. Nonetheless, limitations to the study exist. Authors of no studies to date have established reference values for effective knowledge or impact score cutoffs. Because causal relationships were not explored in the current study, a randomized, controlled, longitudinal study design would better illuminate EIS differences due to changes in participant characteristics and education practices. Unfortunately, our sample was quite homogenous; 91% of the sample reported their race or ethnicity as White. Despite lack of representation of various racial or ethnic groups, the current sample is fairly representative of the larger population of collegiate cross-country athletes; 73% of NCAA women's cross-country athletes are White.[33] Because of the lack of diversity in the study and therefore inadequate statistical power, the role of race or ethnicity was not explored. Additionally, selection bias may have existed in the respondents; those who chose to participate

Table 6. Multivariate Analysis Parameter Estimates of Educational Impact Scores in Female Cross-Country Athletes[a]

					95% CI	
	B	Standard Error	t	P Value	Lower Bound	Upper Bound
Division level participation (= DI)	1.503	5.078	0.296	.768	6.058	21.005
Peak career mileage	0.75	0.073	1.032	.303	−0.069	0.220
Peak career mileage × division level participation (= DI)	0.006	0.091	1.032	.945	−0.174	0.187
Triad diagnosis (= positive)	−16.746	4.307	−3.888	<.001[b]	−25.256	−8.236
Peak career mileage	−0.013	0.053	−0.242	.809	−0.117	0.091
Triad diagnosis (= positive) × peak career mileage	0.215	0.075	2.883	.005[b]	0.068	0.362

Abbreviation: DI, Division I.
[a] A univariate general linear model indicates parameter estimates and significant interaction(s) between the following variables: division level participation (= DI) and peak career mileage and Triad diagnosis (= positive) and peak career mileage. Mean ± SDs.
[b] $P < .05$ significance.

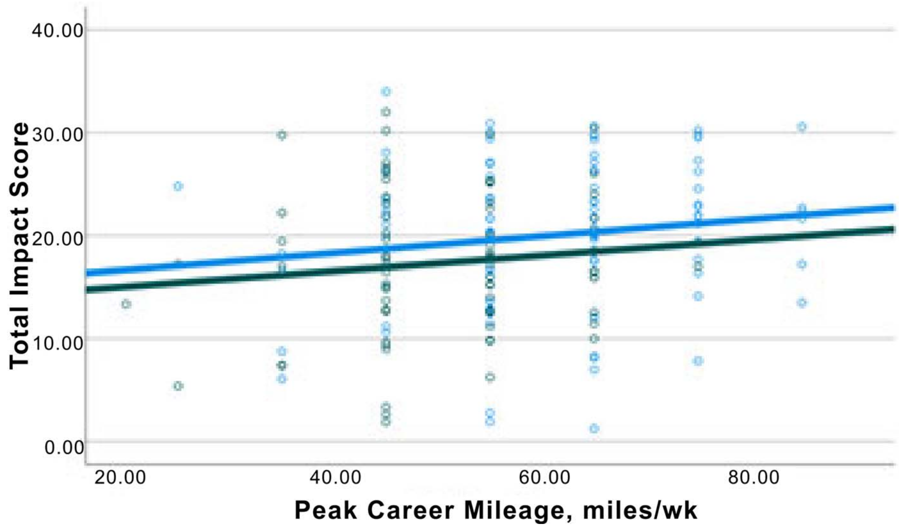

Figure 2. Interaction plot for peak career mileage (miles/week) and division level participation (Division I [DI] participants versus non-DI participants).

in the study may have a higher interest in and more existing knowledge of Triad and REDs than nonrespondents. This study is also not generalizable to all collegiate athletes because of its focus on collegiate female cross-country athletes, a high-risk population for Triad and REDs.

Future Directions

It is necessary to discern additional associations and potential reasons for significant differences in knowledge and EISs among female cross-country athletes. These relationships should be further explored in longitudinal studies. Education programs should be developed and evaluated to ensure that they effectively increase knowledge of Triad and REDs. Education programs and resources have proven effective in other sports medicine areas (eg, concussions) to increase awareness, knowledge, and treatment of athletes.[34] These can serve as models for Triad and REDs education interventions.

CONCLUSIONS

In the current study, we examined the knowledge and knowledge confidence of Triad and REDs, via EISs, in female cross-country athletes. Female cross-country athletes with the following characteristics exhibited significantly higher EISs: related academic area of study, attendance at an NCAA DI institution, history of Triad and REDs diagnoses, and previous education training on Triad. In the present study, we established a significant interaction of peak career mileage and Triad diagnosis, revealing the importance of timing of educational programming. Female cross-country athletes with a history of Triad or REDs diagnoses are likely to have higher EISs, as they gain knowledge from their care team. As such, education programs should begin before the development of higher risk stratification (eg, serious eating disorders or other serious medical conditions related to LEA) of Triad and REDs.[35] Policy changes should be considered at an institutional level to improve the care of athletes, including but not limited to policies requiring education programs, registered

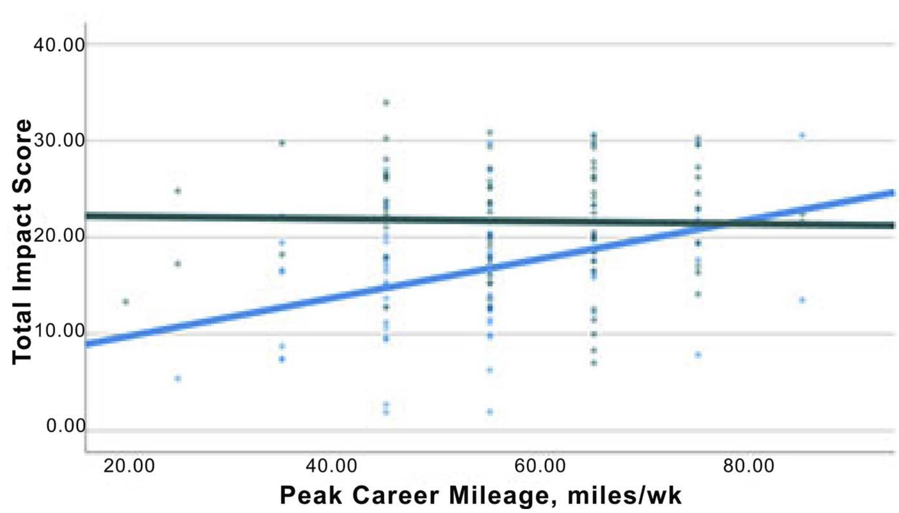

Figure 3. Interaction plot for peak career mileage (miles/week) and Female Athlete Triad (Triad) diagnosis (positive Triad diagnosis versus negative Triad diagnosis).

sports dietitians and mental health specialists on staff in athletic departments, and appropriate referral networks to a specialized multidisciplinary care team.

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SUPPLEMENTAL MATERIAL

Supplemental Table. Scoring Protocol.

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