

# Knowledge of the Female Athlete Triad and Relative Energy Deficiency in Sport Among Female Cross-Country Athletes and Support Staff

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**Context:** Female endurance athletes exhibit an increased risk of the female athlete triad (Triad) and relative energy deficiency in sport (RED-S). The triad and RED-S are conditions that involve the health and performance consequences of low energy availability. Few authors of studies to date have assessed the knowledge that athletes, coaches, and athletic trainers (ATs) have regarding the Triad or RED-S. Proper education has been shown to be effective in increasing knowledge of sports medicine concerns for athletes, yet no known continuing education programs for the Triad or RED-S exist at collegiate institutions.

**Objective:** To assess the knowledge, confidence, and educational impact of identifying, screening, treating, and preventing the Triad or RED-S.

**Design:** Cross-sectional study.

**Setting:** An evidence-based online survey was developed and administered via Qualtrics.

**Patients or Other Participants:** Female collegiate cross-country athletes ( $n = 275$ , age =  $20 \pm 1$  years), collegiate cross-country coaches ( $n = 55$ , age =  $34 \pm 9$  years), and ATs working with cross-country teams ( $n = 30$ , age =  $36 \pm 11$  years).

**Main Outcome Measure(s):** Knowledge, confidence, and educational impact scores were assessed among groups using analysis of variance. Independent  $t$  tests were calculated to determine differences in impact scores between people who had or had not received education on the topic.

**Results:** Female cross-country athletes' total knowledge, confidence, and educational impact scores (mean scores =  $25.00 \pm 5.27$ ,  $95.42 \pm 28.83$ , and  $18.81 \pm 7.05$ , respectively) were different from those of coaches (mean scores =  $26.92 \pm 5.02$ ,  $111.35 \pm 24.14$ , and  $22.41 \pm 6.33$ , respectively) and ATs (mean scores =  $28.66 \pm 4.02$ ,  $117.67 \pm 22.53$ , and  $23.93 \pm 5.69$ , respectively;  $P < .05$ ).

**Conclusions:** Knowledge, confidence, and educational impact scores regarding Triad or RED-S were lowest in female cross-country athletes and highest in ATs. These findings support the call for education, which should be regarded as the primary tool for increasing knowledge, to improve the prevention and treatment of the Triad or RED-S.

**Key Words:** education, running athletes

## Key Points

- Female cross-country athletes' total scores (knowledge, confidence, and educational impact) were lower than coaches' and athletic trainers' total scores.
- Coaches' and athletic trainers' knowledge, confidence, and educational impact scores did not differ.
- Education remains paramount in addressing the gaps in knowledge translation, improving prevention and treatment methods of the female athlete triad and relative energy deficiency in sport, and enacting meaningful policy changes to protect athletes.

Female cross-country athletes reported the highest occurrence of stress fractures across all National Collegiate Athletic Association (NCAA)–sanctioned sports.<sup>1</sup> The authors of a 2017 study<sup>2</sup> observed an incidence of 1.35 stress fractures per female cross-country team per year. In the presence of the female athlete triad (Triad) and relative energy deficiency in sport (RED-S), the likelihood of bone stress injury (BSI), including stress fracture, increases.<sup>2</sup> The Triad and RED-S illustrate the health and performance consequences of low energy availability (LEA) among athletes. In a prospective study<sup>1</sup> of exercising girls and women, the BSI incidence was 11%, with the highest occurrence in distance runners. The presence of 1 Triad factor increased the BSI incidence to 15% to 21% in participants, 2 factors increased the BSI incidence to 21%

to 30%, and 3 factors increased the BSI incidence to 29% to 50%.<sup>1</sup>

Research<sup>3–14</sup> has supported the role of education in ensuring proper prevention and intervention for managing these conditions. Knowledge is necessary to identify, treat, and prevent the Triad or RED-S to reduce the BSI risk and the myriad of health- and performance-related consequences.<sup>7,15,16</sup> Few investigators have demonstrated the effect of education on subsequent knowledge of the Triad and RED-S in participants. Assessments illustrated a lack of Triad knowledge among athletic trainers (ATs)<sup>11,17</sup> and an even greater lack among coaches.<sup>15,17–19</sup> Athletic trainers are certified health care professionals, often serving as the first point of contact in the management of athletes, such as primary care, injury and illness prevention, clinical examination, and wellness education, among other func-

tions. However, few authors have studied athletes' knowledge of the Triad and RED-S. Therefore, it is important to evaluate the knowledge of athletes and support staff in order to direct education efforts appropriately.

Since the expansion of the Triad to RED-S in 2014, the knowledge of both conditions has not been addressed in 1 study design. Furthermore, no authors have assessed knowledge, confidence, and education pertaining to the Triad and RED-S in athletes and support staff simultaneously. Therefore, the purpose of our study was to determine the knowledge, confidence, and educational impact of the Triad and RED-S among 3 populations: collegiate female cross-country athletes, collegiate cross-country coaches, and ATs working with collegiate cross-country teams. An additional goal was to assess the education of participants to better understand and inform the next steps in education, institutional practices, and research.

## METHODS

### Study Design

A cross-sectional study design was used to examine knowledge, confidence, and educational impact related to the Triad and RED-S.

### Participants

Participants were collegiate female cross-country athletes, collegiate cross-country coaches, and ATs working with collegiate cross-country teams. Participants were recruited from collegiate women's cross-country teams via emails to coaches and ATs, accessed through university team websites. We directly invited 440 schools in the National Collegiate Athletic Association or National Association of Intercollegiate Athletics 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 person was asked to complete an online survey via Qualtrics, and the survey was available for 57 days. 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 of age or older and self-identified as a current collegiate female cross-country athlete, collegiate cross-country coach, or AT working with collegiate cross-country teams. Volunteers who did not self-identify as 1 of the 3 categories were excluded.

### Survey Development

The online survey (see Supplemental Appendix, available online at <http://dx.doi.org/10.4085/1062-6050-0175.21.S1>) was multifaceted. It was designed to assess Triad and RED-S knowledge, confidence regarding the level of knowledge, and other participant characteristics, including education. We adapted the items from a previous survey designed to characterize Triad knowledge and tested for content validity, instrument reliability, and concurrent

validity.<sup>20</sup> We expanded the original instrument to include questions specific to RED-S. The scoring protocol was based on the prior survey. Three scores were calculated: knowledge, confidence, and impact. Detailed explanations on how the scores were calculated are provided in the next section. The entire 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. These experts reviewed the original survey and suggested changes to better assess knowledge of both the Triad and RED-S, participant characteristics, and education related to the Triad and RED-S. After content validation, we evaluated test-retest reliability via internal consistency (Cronbach  $\alpha$ ) 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.<sup>20</sup> We tried to recruit ATs for reliability testing, but the response rate was low, as this was at the start of the COVID-19 pandemic. 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 to not conduct any educational searches on the Triad and RED-S between administrations. The Cronbach score ( $\alpha = 0.799$ ) indicated acceptable reliability. After we removed the item with the weakest reliability correlation (a multiple-choice question asking about the definition of RED-S), the Cronbach score increased ( $\alpha = 0.914$ ), indicating excellent reliability with high internal consistency. The final 37-item survey was used for data collection.

### Scoring (Knowledge, Confidence, Educational Impact)

Based on the prior survey, we calculated 3 scores for items 16 through 52b: knowledge, confidence, and educational impact. The remaining survey data were supplemental and not included in the scoring calculations.

The total knowledge score was determined by adding 1 point for each correct answer and subtracting 1 point for each incorrect answer to the 37 knowledge items (items 16–52). An answer of *I don't know* was scored as 0. For “choose all that apply” questions, 1 point was awarded if all correct subanswers were selected; if not, a partial point was awarded. Thus, the total possible knowledge score ranged from +37 (highest score) to –37 (lowest score).

The total confidence score was determined by summing the answers to the 37 confidence items (16b–52b). Participants selected a confidence level from a scale of 0 (*no confidence*) to 4 (*completely sure*) for each knowledge item. Therefore, the total possible confidence score ranged from 0 (lowest score) to +148 (highest score). We calculated a confidence factor 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. The sum of the confidence factors was used to determine impact.

The impact score model was adapted from the scoring reported earlier, in which a factored, composite score of

**Table 1. Scoring Method Sample<sup>a</sup>**

Participant	Question: "The main cause of Relative Energy Deficiency in Sport (RED-S) is ○ Eating disorder(s) ○ Amenorrhea ○ Low energy availability ○ Anemia"	Score (Range)			
		Knowledge Score	Confidence Score	Confidence Factor	Impact Score <sup>b</sup>
A	Selected: <i>Low energy availability</i>	+1	2	0.5	+0.5
B	Selected: <i>Low energy availability</i>	+1	0	0	0
C	Selected: <i>Amenorrhea</i>	-1	4	1	-1

<sup>a</sup> Example of the scoring method for an individual question on the female athlete triad (Triad) and RED-S survey. The confidence scores correspond to the following confidence factors: confidence score of 4 = confidence factor of 1 point, confidence score of 3 = confidence factor of 0.75 points, confidence score of 2 = confidence factor of 0.5 points, confidence score of 1 = confidence factor of 0.25 points, and confidence score of 0 = confidence factor of 0 points.

<sup>b</sup> [Knowledge score] × [confidence factor] (×1 to +1).

impact was reported.<sup>20</sup> The knowledge and confidence scores were combined to create a total impact score (items 16–52b). The total impact score was the product of the knowledge score and confidence factor (see Table 1). Thus, the possible impact score for each item ranged from -1 to +1. The total possible impact score ranged from +37 (highest score) to -37 (lowest score). One point was given for the correct answer and high confidence, and 1 point was subtracted for an incorrect answer and high confidence. The score for each item was reduced when the respondent had less confidence in the answer.

Creating a factored composite score allows for greater understanding of the potential dissemination of information. A low level of confidence has been correlated with a lack of application of one's knowledge.<sup>17</sup> For example, the highest impact scores were from participants who selected the correct knowledge answer with high confidence, as they were more likely to disseminate correct information. Lower impact scores were from participants who selected the correct knowledge answer but expressed low confidence, as they were less likely to disseminate information based on that knowledge. An impact score of 0 resulted from an answer of *I don't know* or a confidence level of 0. The lowest impact scores resulted from participants who selected the incorrect knowledge answer with high confidence, as they were more likely to disseminate incorrect information. This outcome was weighted more heavily, as it is potentially dangerous to confidently believe in incorrect information.

Scores are presented for items specific to the Triad and to RED-S to assess any significant differences in knowledge and impact. Scores for the Triad-specific items (n = 2) and RED-S-specific items (n = 3) were presented as percentages to permit direct comparisons. The range of Triad-specific knowledge and impact scores was -2 to +2. The range of RED-S-specific knowledge and impact scores was -3 to +3.

Each group was asked if their current institution provided educational training on the Triad or RED-S and the types of education they took part in at least once a year related to the Triad or RED-S, including the education provided by their institution. In addition, female cross-country athletes were asked if their athletic departments or coaching staff had a policy specifying what to do if an athlete suspects she or a teammate might be suffering from the Triad or RED-S.

## Statistical Analyses

Before performing statistical hypothesis tests, we evaluated all variables for nonnormality using the Shapiro-Wilk and Kolmogorov-Smirnov tests. Participant characteristics were analyzed with descriptive statistics. All scores among groups were analyzed by computing a 1-way analysis of variance; a Tukey post hoc analysis was conducted in the presence of a significant main effect. Paired-samples *t* tests were calculated to assess differences in Triad- and RED-S-specific knowledge. Independent *t* tests were performed to assess differences in impact scores among individuals who had or had not received education on the Triad and RED-S from their athletic department. Education on the Triad and RED-S was assessed using independent *t* tests to examine differences in impact scores in individuals who had or had not received education. Incomplete survey responses were excluded from data analysis. The significance level was set a priori at  $P \leq .05$ . All data were presented as mean ± SD. We used SPSS (version 1.0.0.1461; IBM Corp) for data analysis.

## RESULTS

### Participant Characteristics

A total of 341 respondents accessed the survey and consented to participate. Eighty-one respondents did not complete the survey (50 collegiate female cross-country athletes, 21 collegiate cross-country coaches, and 10 ATs working with collegiate cross-country teams). Thus, a total of 260 complete surveys were included in data analysis: 175 collegiate female cross-country athletes, 55 collegiate cross-country coaches, and 30 ATs. Participant characteristics are shown in Table 2.

### Assessment of Knowledge, Confidence, and Impact

Scores for each group are provided in Table 3. Female cross-country athletes had lower scores for knowledge ( $P = .047$ ), confidence ( $P = .001$ ), and impact ( $P = .05$ ) than coaches. Female cross-country athletes had lower scores for knowledge ( $P = .001$ ), confidence ( $P < .001$ ), and impact ( $P = .001$ ) than ATs. No differences were seen in scores between coaches and ATs.

Triad-specific knowledge ( $P = .002$ ) and impact ( $P = .0004$ ) and RED-S-specific knowledge ( $P = .02$ ) and impact ( $P = .002$ ) were lower in female cross-country athletes than in ATs. Only the Triad-specific impact score

**Table 2. Participants' Characteristics<sup>a</sup>**

Characteristic	Collegiate Female Cross-Country Team		
	Athletes (n = 175)	Coaches (n = 55)	Athletic Trainers (n = 30)
	Mean ± SD		
Age, y	20 ± 1.0	36 ± 11.0	34 ± 9.0
Total years of experience	8.95 ± 4.0	11.80 ± 7.8	11.6 ± 7.4
Years at present institution	3.25 ± 1.9	8.36 ± 6.9	8.40 ± 7.8
Current mileage, mi/wk	41.54 ± 15.3	NA	NA
Peak career mileage, mi/wk	56.11 ± 12.9	71.27 ± 22.8	NA
Lifetime bone stress injury diagnoses	1.22 ± 1.8	1.37 ± 3.2	0.15 ± 0.8
	%		
Females	100	47	90
National Collegiate Athletic Association Division			
I	55	55	45
II	16	7	21
III	23	25	28
National Association of Intercollegiate Athletics	5	13	10
Race, White	91	91	97
Related academic area of study <sup>a</sup>	15	15	100

Abbreviation: NA, not available.

<sup>a</sup> *Related academic area of study* includes 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.

was lower in female cross-country athletes than in coaches ( $P = .018$ ). Specific knowledge of RED-S was higher than Triad-specific knowledge in female cross-country athletes ( $P < .001$ ). No difference was present between Triad and RED-S knowledge scores among coaches or ATs.

### Characterization of Education

Most female cross-country athletes indicated they had not received education on the Triad (68%) and RED-S (78%; Figure 1 and Figure 2), similar to coaches (65% and 70%, respectively). Athletic trainers who noted they had not received education on Triad and RED-S accounted for 13% and 40%, respectively (Figure 1 and Figure 2). Across groups, 69% of female cross-country athletes, 52% of

coaches, and 51% of ATs reported not receiving education on Triad and RED-S from their athletic departments.

Female cross-country athletes who had received Triad education had higher impact scores ( $21.03 \pm 6.86$ ) than those who did not receive such education ( $18.12 \pm 6.82$ ;  $P = .014$ ; Figure 1). However, impact scores did not differ in cross-country athletes who had or had not received RED-S education. Impact scores were higher in coaches who had received Triad education ( $25.10 \pm 4.50$ ) versus coaches who had not ( $20.10 \pm 6.75$ ;  $P = .021$ ; Figure 1). In addition, impact scores were higher in coaches who had received RED-S education ( $25.81 \pm 4.41$ ) versus those who did not ( $21.06 \pm 6.52$ ;  $P = .009$ ; Figure 2). Among ATs, impact scores were not different based on Triad or RED-S education. Furthermore, impact scores did not differ

**Table 3. Participants' Knowledge, Confidence, and Impact Scores<sup>a</sup>**

Variable	Collegiate Female Cross-Country Team, Mean ± SD		
	Athletes (n = 175)	Coaches (n = 55)	Athletic Trainers (n = 30)
	%		
Triad-specific knowledge	57.48 ± 28.7	66.70 ± 30.25	77.14 ± 22.0 <sup>b,c</sup>
Triad-specific impact	58.45 ± 21.65	68.06 ± 26.24 <sup>b,c</sup>	75.68 ± 21.03 <sup>b,c</sup>
RED-S-specific knowledge	70.52 ± 17.58 <sup>d</sup>	70.93 ± 17.85	79.80 ± 17.43 <sup>b,c</sup>
RED-S-specific impact	61.41 ± 12.72	63.93 ± 15.07	70.66 ± 14.15 <sup>b,c</sup>
	Total Score		
Knowledge	25.00 ± 5.27	26.92 ± 5.02 <sup>b,c</sup>	28.66 ± 4.02 <sup>b,c</sup>
Confidence	95.42 ± 28.83	111.35 ± 24.14 <sup>b,c</sup>	117.67 ± 22.53 <sup>b,c</sup>
Impact	18.81 ± 7.05	22.41 ± 6.33 <sup>b,c</sup>	23.93 ± 5.69 <sup>b,c</sup>

Abbreviations: Triad, female athlete triad; RED-S, relative energy deficiency in sport.

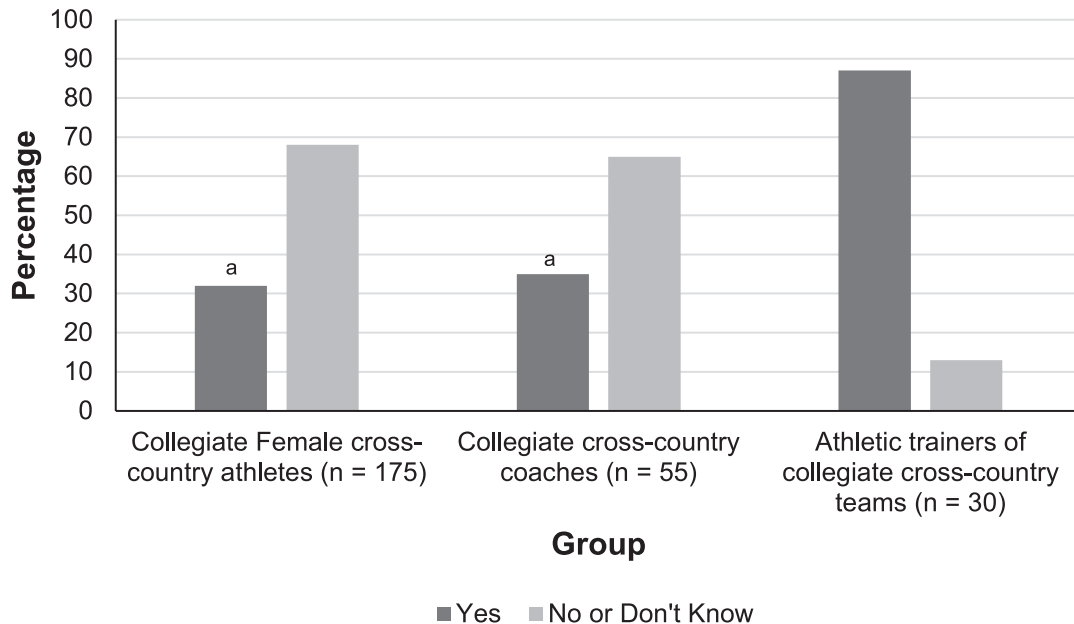
<sup>a</sup> A 1-way analysis of variance indicated differences among groups for Triad-specific knowledge, Triad-specific impact, RED-S-specific knowledge, RED-S-specific impact, total knowledge score, total confidence score, and total impact score. Paired-samples *t* tests demonstrated differences among groups for Triad-specific scores and RED-S-specific scores.

<sup>b</sup> Significant at  $P < .05$ .

<sup>c</sup> Versus collegiate female cross-country athletes.

<sup>d</sup> Versus Triad-specific knowledge.





**Figure 1. Training about the female athlete triad received by group. Assessment of impact scores via independent-samples *t* tests. <sup>a</sup> Significant at  $P < .05$  versus participants who did not receive training.**

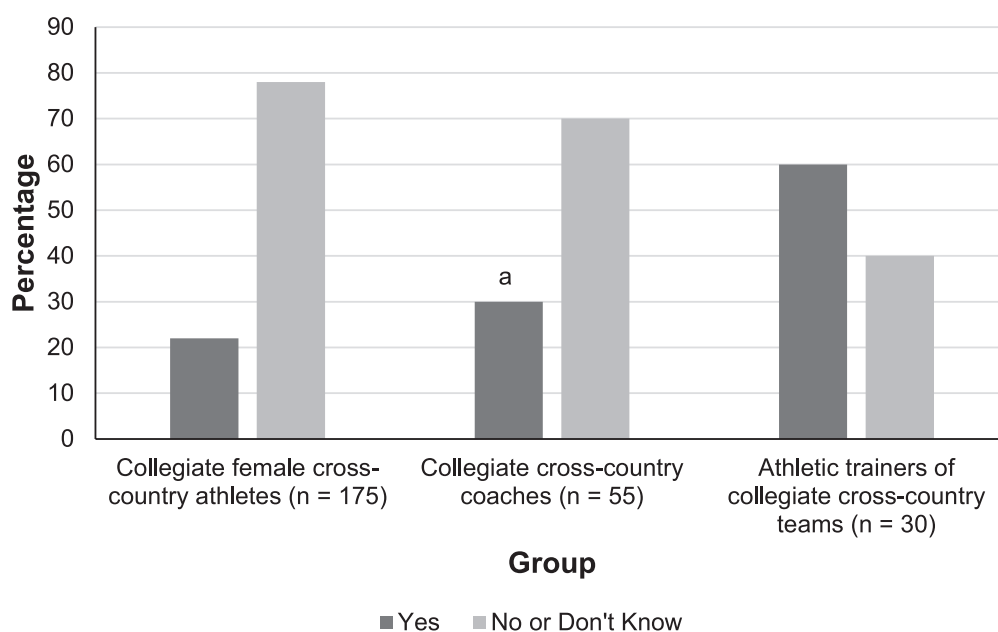
among groups who had or had not received education on Triad or RED-S provided by the athletic department.

A total of 84% of female cross-country athletes, 89% of coaches, and 71% of ATs reported receiving no training from their current institution on the Triad or RED-S. Female cross-country athletes engaged in online searches of information as a primary educational source on the Triad or RED-S. Coaches described reading textbooks related to coaching, physiology, and nutrition, and ATs consulted professionals, such as physicians and dietitians, as primary educational sources. Policies provided by athletic department or coaching staff regarding Triad or RED-S concerns

were identified by 4% and 7% of collegiate female cross-country athletes, respectively.

## DISCUSSION

Using a cross-sectional study design, we examined the knowledge, confidence, and impact of the Triad and RED-S in collegiate female cross-country athletes, coaches, and ATs. The athletes' scores were lower than those of the coaches and ATs for knowledge, confidence, and impact. No difference existed between the scores of coaches versus ATs for knowledge, confidence, impact, or Triad- and RED-S-specific knowledge and impact. Triad- and RED-



**Figure 2. Training about relative energy deficiency in sport (RED-S) by group. Assessment of impact scores via independent-samples *t* tests. <sup>a</sup> Significant at  $P < .01$  versus participants who did not receive training.**

S-specific knowledge and impact were less in athletes than in ATs. On Triad-specific impact, the athletes scored lower than coaches. Thus, coaches and ATs can help increase Triad or RED-S knowledge and confidence in female cross-country athletes. Coaches and ATs are more likely to belong to professional groups and attend professional conferences, where their education about the Triad and RED-S may be enhanced. Student-athletes often rely on the education provided by their athletic departments or their formal education. Due to the lack of mandated education at the athletic department level, student-athletes are at the greatest risk for lack of knowledge, as supported by the lower scores in cross-country athletes than in the other groups.

We assumed that participants would score higher on the Triad-specific questions than on RED-S-specific questions because the development and research of the former, proposed in 1992, is more robust than that of the latter, proposed in 2014. However, female cross-country athletes scored higher on RED-S-specific knowledge versus Triad-specific knowledge ( $P < .05$ ), and no difference was observed between Triad- and RED-S-specific impact scores. The RED-S-specific knowledge scores may have been higher due to the wording of the items, the newer term being more familiar to a younger population, or a shift in terminology about LEA in the sports community. These relationships should be further assessed with a greater number of questions specific to the Triad and RED-S to explore the differences in knowledge and impact across conditions.

Currently, educational programs on the Triad and RED-S are limited. We found that most participants across all population groups had not received continuing education from their athletic departments on the Triad and RED-S. Impact scores of female cross-country athletes and coaches who had received Triad education were higher than for those who had not. Overall, respondents were more likely to receive education on the Triad than on RED-S. They were also less confident in their RED-S knowledge, given the lack of differences in impact scores despite a difference in knowledge scores. Because RED-S is the more inclusive model concerned with identifying several other consequences related to LEA, Triad-only education is likely to overlook the additional potential health and performance consequences outlined by RED-S.

Future educational efforts should focus on both the Triad and RED-S, emphasizing the importance of related symptoms and consequences. To address disparities in knowledge and provide quality treatment for athletes, policies should be implemented at the collegiate institutional and team levels to mandate education. Educational programs should be developed and tested with the aim of increasing knowledge and impact in collegiate athletes, coaches, and health care team members. Programs such as concussion education have proven effective in increasing awareness, knowledge, and treatment among athletes and support staff members.<sup>18</sup> Established programs should be considered when developing and testing Triad and RED-S education. Future authors should explore the most effective and efficacious method of delivery (eg, in-person seminar, online program), frequency (eg, weekly, monthly, annually), and time of training (eg, synchronous versus asynchronous). Overall, educational training and resources should

focus on increasing knowledge of and confidence in the knowledge of the Triad and RED-S as well as the modality that most effectively maintains the highest degree of knowledge posttraining.

In cross-sectional studies, researchers have examined awareness or knowledge of the Triad, RED-S, or both in athletes,<sup>19</sup> high school coaches,<sup>15</sup> and ATs.<sup>10</sup> Tosi et al<sup>19</sup> found that 29% of adolescent and young adult runners had heard of the Triad, and 84% were categorized as having “low knowledge” of it, though “low knowledge” was not explicitly defined.<sup>19</sup> In an investigation<sup>15</sup> of 123 high school coaches, only 24% had heard of the Triad, and even fewer, 14%, were able to correctly identify all components. In addition, more than 85% of coaches said they would not know how to recognize or intervene if signs and symptoms of the Triad were present.<sup>15</sup> In a 2018 study, Kroshus et al<sup>10</sup> reported that 99% of collegiate AT respondents to an online survey had heard of the Triad, and 33% had heard of RED-S. However, only 13.33% correctly identified energy imbalance or energy deficiency as a component of the Triad.

These results, combined with ours, underscore the importance of expanding the framework of the Triad to RED-S because of coaches' and ATs' lack of knowledge of RED-S compared with the Triad, which was already low.<sup>10,15,19</sup> Kroshus et al<sup>10</sup> demonstrated a greater inability of ATs to identify energy deficiency as a component of the Triad, which is at the center of the RED-S model leading to several other health and performance consequences not specifically outlined in the Triad. Both the Triad and RED-S concepts should be included in a comprehensive approach to screening and treatment of and education about these conditions in athletes. Triad and RED-S education for all members of the athletic community (eg, athletes, coaches, ATs, sport physicians) is essential for proper recognition, screening, referral, and treatment of clinical cases of the Triad and RED-S.

Our collegiate female cross-country athletes indicated a lack of policies from their institutions, coaching staff, or both. Policies may include instructional information on the referral, treatment, and management of athletes with the Triad and RED-S. The lack of policies from collegiate institutions or coaching staff provides an opportunity to improve the quality and standard of care for athletes, especially when an athlete may be experiencing the Triad or RED-S. Inclusive policies and protocols to screen and treat athletes, particularly after a diagnosis of menstrual irregularity, BSI, or both, should be established by collegiate institutions. The Triad Coalition and International Olympic Committee developed the Triad Coalition Cumulative Risk Assessment Score and RED-S Clinical Assessment Tool, respectively, to stratify athletes in categories of low, moderate, or high risk.<sup>16</sup> In both models, athletes at low risk may be cleared for sport participation, whereas high-risk athletes may not.<sup>16</sup> Collegiate institutions are uniquely positioned to establish and enforce formal policies and protocols such as these to evaluate and screen athletes presenting with the Triad and RED-S components.

## Limitations

Strengths of this study are the multiple population groups and inclusion of the more robust RED-S entity in our

knowledge testing, as this newer term is gaining popularity in the sports community. Collegiate female cross-country athletes, coaches, and ATs were surveyed, which allowed us to assess scores within and between groups. Calculation of an impact score provides further insight into the potential dissemination of information, which is important in understanding knowledge translation about the Triad and RED-S among athletes and support staff. Despite our novel findings, limitations of the study did exist. No established reference values were available for total knowledge, confidence, or impact scores to classify respondents into high or low categories. Our reliability participant sample was small and did not include ATs. The cross-sectional design did not allow us to adequately explore causal relationships. Thus, a longitudinal study design may provide insight into significant changes in scores due to educational practices. Additional limitations include selection bias. Those who chose to participate may have been more interested in and had more existing knowledge of the Triad and RED-S than nonrespondents. As a result, our findings are likely to overestimate these scores in our target populations, which did not represent the average of all collegiate athletes and staff. Female coaches accounted for 47% of our coach sample (head and assistant coaches), whereas a report<sup>21</sup> of Division I institutions indicated that only 17% of head cross-country coaches were female. Extrapolation of these results to other sporting populations should be carefully considered.

### Future Directions

More research is required to establish reference values for these scores and discern additional associations and potential reasons for differences. Other sporting populations should be evaluated on their knowledge of and confidence in their knowledge of the Triad and RED-S. It is likely that sporting populations with less risk of developing the Triad and RED-S would score lower on the Triad and RED-S survey. In this event, education should address sport-specific contexts to best educate, treat, and prevent the Triad and RED-S in each population.

The role of registered sports dietitians and mental health specialists on staff should be further explored at collegiate institutions. These medical professionals could assist in the screening, recognition, treatment, and prevention of the Triad and RED-S, and coaches and ATs could refer patients to these medical professionals more effectively.

### CONCLUSIONS

We examined the knowledge, confidence, and impact of Triad and RED-S among collegiate female cross-country athletes, coaches, and ATs. The athletes' total scores for knowledge, confidence, and impact were lower than those of the coaches and ATs. Total scores for knowledge, confidence, and impact were not different between coaches and ATs. In addition, athletes and coaches who received education on the Triad as well as coaches who received education on RED-S had higher impact scores than those who did not receive such education. Education remains chiefly important in increasing knowledge to improve the identification, treatment, and prevention of the Triad and RED-S. Future research is necessary to determine effective methods of education among various populations.

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